

**Co-evolution of Information Processing Technology and Use:
Interaction Between the Life Insurance and Tabulating Industries**

WP#3575-93

Jo Anne Yates

Revised October 1993

**Co-evolution of Information Processing Technology and Use:
Interaction between the Life Insurance and Tabulating Industries**

JoAnne Yates
Sloan School of Management
MIT E52-545
50 Memorial Drive
Cambridge, MA 02139
(617) 253-7157
jyates@sloan.mit.edu

Sloan School Working Paper #3575-93
Center for Coordination Science Working Paper #145

October 1993

Accepted for publication in *Business History Review*

ACKNOWLEDGMENTS

I am very grateful to Martin Campbell-Kelly, Alfred D. Chandler, Jr., Glenn Porter, Philip Scranton, Eric von Hippel and two anonymous reviewers of the *Business History Review* for comments on earlier versions of this paper. I appreciate the able assistance of Daniel May and the library staff at the Metropolitan Life Archives, and of Michael Nash, Margery McNinch, and the staff of the Hagley Museum and Library. This research has been generously supported by the Center for Coordination Science, by the MIT Sloan School of Management, and by the Hagley Museum and Library.

Co-evolution of Information Processing Technology and Use: Interaction between the Life Insurance and Tabulating Industries

In 1890, at the invitation of inventor Herman Hollerith, 25 members of the Actuarial Society of America attended a demonstration of a new type of information-handling equipment: the punched-card tabulator. According to a news account of the meeting, the life insurance actuaries attended because "Any labor-saving device that can be used in the preparation of tabular statements is of interest to actuaries."¹ Their interest was justified by the magnitude of the information-handling tasks faced by their life insurance firms. The largest firms already had millions of policies, leading to many times that number of statistical analyses and transactions involving those policies. This meeting between Hollerith and the actuaries marked the beginning of what was to be a decades-long interaction between two industries: the punched-card tabulating industry and the life insurance industry.²

The tabulating industry, embryonic at the time of this meeting, would be dominated in the U.S. by two firms: the firm founded by Hollerith became the core of IBM; that founded by Hollerith's main rival, James Powers, became part of Remington Rand. These two firms would become major players in the early commercial computer industry midway through the twentieth century. Although historians studying forerunners of the computer have often mentioned Hollerith's tabulating equipment, especially in the context of his Census work,³ the industry it spawned has only recently received the closer attention it deserves for its role in establishing and developing the data processing market that computers would later inherit. Recent treatments have begun to explore business use of tabulating equipment before World War II, as well as the function of the business market in the growth of the tabulating equipment industry in the U.S. and Britain.⁴ The present study moves the analysis down into a single industry, life insurance, and looks at both the shaping influence of tabulating machinery on insurance firms' business processes and the role that insurance as a user industry has played in shaping the development of tabulating technology.

The life insurance industry, the second industry represented in the 1890 meeting noted above, is particularly interesting for these purposes because of its information-intensive nature.⁵

For such an industry, information technology is essentially its production technology--the technology by which it produces the information and documents that are its only products. During the first half of the twentieth century, tabulating equipment became an increasingly central part of the life insurance business, transforming its processes and paving the way for later computerization. The insurance firms initially adopted basic tabulating systems to mechanize existing and primarily manual processes of sorting, counting, and adding data; as the capabilities of the technology evolved, leading firms developed new ways of using it to integrate data processing with the production of documents. At the same time, as an early and major customer of the tabulating industry, the insurance industry influenced inventions and commercial developments in tabulating technology in directions that allowed that evolving use just described. In recent years researchers in management of innovation and economic history have highlighted the role of users in shaping technical innovations.⁶ This study of the life insurance industry as it interacted with the tabulating industry reveals an array of specific strategies and mechanisms--ranging from the market, on the one hand, to direct user invention and development, on the other--by which leading insurance firms and industry groups shaped tabulating technology and the tabulating industry.

Of course, life insurance was not the only industry using and influencing tabulating technology. In Hollerith's early developments, the U.S. Census and the railroads played a major role. Later, accounting uses spanning industries also had an interest in numerical printing abilities, and utilities, like life insurance, desired alphabetical printing capabilities. Other industries, such as banking and state governments, also were large users. The Hughesian technological system⁷ (with its social and organizational as well as technical elements) of tabulating technology would include these other major user industries, and study of them would surely highlight other influences. But focusing on the perspective of one major user industry from Hollerith's early days of commercialization on to the verge of the computer age allows us to understand the interaction between user-influenced technological innovation and the new uses allowed by the evolving technology. Moreover, the study views the tabulating industry primarily as it interacts with the life insurance industry, and thus provides only a circumscribed Chandlerian picture of competitive

developments within the tabulating industry.⁸ The primary purpose of this account is to illuminate the co-evolution of tabulating technology and its use within life insurance, and the co-evolution of the tabulating industry with the life insurance industry.⁹

After briefly describing some of the salient features of the U.S. life insurance business and its information needs, I will describe the origin and nature of tabulating technology. The rest of the paper is divided into three major phases: the period of insurance's initial adoption of tabulating technology, up to 1910; the next decade's push to acquire printing capabilities; and the evolution and incorporation of alphabetical tabulating capabilities in the 1920s and early 1930s.

The American Life Insurance Industry

Although life insurance was well established in England in the early nineteenth century, the American life insurance industry only took off in the 1840s.¹⁰ Initially, what came to be called **ordinary insurance**, in which policies were written for relatively large amounts and premiums were generally paid yearly, by mail or in person at the insurance office, was the focus of the industry. In the 1850s, the British insurance industry introduced **industrial insurance**, which offered small policies on the lives of industrial workers and their families, with very small premiums collected weekly at the worker's home by sales agents assigned to a particular geographical area or debit. In the late years of the nineteenth century the American insurance industry followed the British lead in establishing industrial insurance. While both segments of the industry were based on the same actuarial principles, the operating aspects of the two segments differed significantly. Industrial insurance involved many more transactions for much smaller amounts (e.g., a dime a week), making it inherently more costly to provide and thus more expensive (per dollar of insurance) to the buyer. From the beginning, controlling costs was, therefore, especially important for the largest providers of industrial insurance such as Metropolitan Life Insurance Company and Prudential Insurance Company in the U.S. and the Prudential Assurance Company in Britain (unrelated to the American firm). These lead users, in von Hippel's terms and in accordance with his theory, were to play major roles in the user-driven technological

innovation that is a key part of the reciprocal interaction discussed in this paper.¹¹

By the turn of the twentieth century life insurance had become very big business in the U.S., with the largest firms handling policies valued at over \$1 billion, having assets over \$250 million, and receiving over \$30 million in premium income each year. All were regulated by the states, but not by the federal government). The five largest firms included three that handled only ordinary insurance (New York Life Insurance Company, Mutual Life Insurance Company, and Equitable Life Assurance Society) along with the two industrial insurance companies already mentioned (Metropolitan and Prudential), which also handled ordinary insurance. Many insurance firms, including Metropolitan and Prudential, were (or became by early in the century) mutual companies in which any profits were redistributed among policyholders.¹²

Thus most large insurance companies, unlike railroads and manufacturing firms, were not driven to adopt new methods of management and supporting techniques and technologies of information by crises of profitability, per se.¹³ Nevertheless, the firms felt the need to keep costs down in order to fulfill their public service mandate, to keep regulators satisfied, and to remain price competitive so they could continue to grow. Competition was still stiff for market share (generally expressed in terms of value of insurance in force), if not for profit, and firms were acutely aware of competitive rankings.¹⁴ Cost containment was particularly important for the growth of industrial insurance, where costs of doing business were higher and the incomes of those insured much lower. State legislation, combined with market trends, enabled the two biggest industrial insurance firms, which ranked fourth and fifth in 1900, to move ahead of the three leading ordinary insurance firms, taking over first and second places by 1915.¹⁵

Information Processing Needs of Life Insurance

Turn-of-the-century life insurance firms had to manage a variety of different types and forms of information for many policies (the largest firms handled tens of thousands of ordinary insurance policies or several millions of industrial policies). While a complete catalog would be far too long to include here, a review of the most basic processes illustrates the nature of the industry.

For the ordinary insurance policy-holder, firms received and processed applications and their supporting documents, prepared and transmitted a written policy, issued notices of premium payments due at regular intervals, processed and sent receipts for premium payments, monitored missed payments to reduce lapses, responded to inquiries, received and processed claims, and issued payments on claims. For agents and district offices, they maintained accurate records of policies serviced (by agent and by district), responded to inquiries about policies, figured commissions, distributed pay, and maintained employment records. In industrial insurance, while firms did not mail out premium notices, they maintained the necessary records to guide agents in weekly collections of small payments from policyholders, provided some form of receipt for payments, handled remittance of collections to the firm, credited payments to the policyholder's account, and monitored missed payments, which could occur 52 times a year rather than once, to try to prevent policy lapses. For actuarial purposes, they maintained information about the person insured by each policy (e.g., age, health, occupation), supported the extraction of data on a variety of these dimensions, calculated many statistics based on the data, and developed or modified products based on them. To meet varying regulatory requirements of the various states, they computed and reported a variety of statistics on policies (e.g., value of policies and reserve requirements by state) and on the firm's financial transactions (including its investments). For internal management purposes they maintained a cost accounting system, personnel records, sales records, financial accounts, agency accounts, and so on.¹⁶

Even this superficial listing (which omits many factors such as loans on policies, changes to existing policies, and distributions to policy-holders in mutualized firms) is enough to make clear the magnitude of the information handling required. It also suggests what one speaker at an insurance convention called "the outstanding characteristic of the life insurance office; that is, the repetition of the same data and same transactions in the various records and statistics. From the very moment a policy is issued this repetition stays with it until the ultimate termination of the policy."¹⁷ This characteristic was combined with the high level of accuracy necessary to give individuals good service over the long lifetime of the policy--a much higher level of accuracy than

was required in Census statistics, for example, and an active lifetime of records that could easily exceed half a century. It is also evident from the above listing that many types and enormous numbers of documents were generated to handle this business. Some, such as the records of policies serviced by a particular agent, were solely for internal use, while others, such as the policies, premium notices, and receipts, served as the link between the insurance firm and the customer. All of these characteristics influenced company decisions about tabulating technology, as well as the industry's overall approach to information technology.

The Origin and Nature of Punched-card Tabulating Technology

Tabulating technology was initially developed by Herman Hollerith to speed up processing of data collected in the 1890 U.S. Census. Hollerith saw the potential for commercial customers early, and made a few limited contacts with prospects such as railroads and insurance firms. Only after he lost the business of the U.S. Census around the turn of the century, however, did he focus his attention on developing this market.¹⁸

Tabulating systems, originally so called because they aided in producing tables of census data, included devices for punching, sorting, and counting or adding quantities on cards.¹⁹ Figure 1 illustrates Hollerith's original versions of the three devices; Figure 2 shows later, more characteristic versions. The card punch was initially a pantograph punch with a swinging arm and a perforated metal plate to guide the pin into predetermined positions; later this version was replaced by a key-operated device. The initial census system used cards divided into irregular fields with customized letter or number codes in each punching position. In the 1890s, working with his first commercial customer, the New York Central Railroad, Hollerith developed a more standardized format with multiple columns each having digits from 0 to 9. A group of columns, or a field, represented a number of more than one decimal digit. From the early twentieth century to the late 1920s, 45-column cards were standard (see Figure 3).

Hollerith's original electro-mechanical tabulator (the *tabulator* designation was attached to the counting device itself as well as to the entire system) was a hand-fed press attached to counter

wheels. Using pins and tiny cups of mercury to complete circuits, this device simply counted cards with particular holes or combinations of holes punched. In his work for the Census and for the New York Central Railroad in the 1890s, Hollerith developed accumulators for adding totals in predefined fields, rather than simply counting cards. This increase in functionality greatly increased the potential uses of the equipment. During the processing of the 1900 Census he introduced tabulators that automatically fed the cards, thus improving the speed of the tabulating process.

At the time of the 1890 Census, sorting occurred as a quasi-manual by-product of counting. A primitive sorting box was attached to the tabulator. At the same time that the operator used the press to read some pre-set field on the card during the counting operation, holes punched in another pre-set field on the card also activated one of two dozen lids on the sorting box via an electrical connection; that lid flew open, and the operator placed the card into the box and closed the lid. This sorting prepared cards for the next tabulating run. Using the sorting box clearly slowed down the speed at which cards could be run through the tabulator, forming a "reverse salient" in the terminology of Thomas P. Hughes.²⁰ In fact, it was so slow that users often sorted cards using a knitting needle pushed through a specified hole. At the beginning of the twentieth century, Hollerith introduced a separate sorting machine to sort cards into 11 groups by the value (0 to 9 or no punch), in a given column.

Insurance and Tabulating before 1910

It was possible to handle the information tasks required by large insurance firms with few mechanical aids, as Campbell-Kelly's description of the clerical methods used by the British Prudential from the 1870s well into the twentieth century demonstrates.²¹ In American firms, he notes by contrast, an initial wave of office technology had been adopted by 1910, giving them an array of mechanical and electrical devices to aid in handling information: adding and calculating machines, dictaphones, photostats, typewriters, telephones, and duplicators. Punched card tabulating systems had appeared in a few insurance firms by 1910, with significant implications for their internal business methods. The life insurance industry was among the earliest commercial users of this technology. In this early period, a few insurance firms used these systems to help deal

with their growing information processing needs by speeding up various sorting, counting, and adding processes. Yet even during this early period, the life insurance industry made known the inadequacies of tabulating technology for its purposes, with insurance firms and associations wielding their inventive resources and market power in ways that initiated on-going patterns of interaction between the insurance industry and the tabulating industry.

The life insurance industry was one of the very first private industries to show interest in Hollerith's system. That interest began with the Actuarial Society demonstration described at the beginning of this paper. At that meeting the Prudential, which, with over one million insurance policies,²² was second only to Metropolitan Life in number of policies handled, announced plans to try the system. (The decision to try it was made easier by the fact that from the very start, Hollerith and his successors always rented rather than sold equipment to commercial customers.) Within a year Hollerith installed a tabulating system for the Prudential, presumably including the slow sorting box which had not yet been replaced by a separate sorter.

The Prudential's actuary, John K. Gore, evidently found the sorting method a significant drawback and was not willing to wait for Hollerith to address this problem. Surprisingly, he had or could acquire in his own family the inventive and mechanical skills necessary to address it himself. In 1895, Gore installed at Prudential a key-operated card punch and electro-mechanical sorter of his own invention and his brother-in-law's construction.²³ His sorting device (see Figure 4), which used a radial configuration quite different from Hollerith's contemporary or future designs, sorted specially designed cards (different in size and shape from those used by Hollerith) at a rate of 250 cards per minute, much faster than Hollerith's sorting box. His system lacked, however, any form of tabulator, thus requiring some other manual or mechanized process for counting cards or adding quantities. Apparently Gore felt that sorting was more important (or more of a bottleneck) than counting in handling the firm's voluminous industrial insurance records.

Presumably Hollerith learned about Gore's device right away, since he had installed his own equipment there in 1891, made several trips back to get it working, and, at some point, removed it.²⁴ He did not, however, immediately respond to this challenge. In the time leading up

to the 1900 Census he developed an automatic card feeding system and the accumulating or adding function for the tabulator, as well as a new, key-operated card punch, speeding up those two aspects of the system. At this point, in Census tabulation (as well as in the manual punched card sorting and counting systems used by many insurance companies), knitting needles passed through holes in the cards were the most common sorting method, suggesting that the sorting boxes were too slow and probably incompatible with the automatic card feeder.²⁵

By 1901, however, pressure had mounted on Hollerith, both from Census work and from the insurance companies, to address this remaining bottleneck or reverse salient in the system. Considerable correspondence between Hollerith and various insurance company actuaries and executives in 1900 and 1901, both about their own firms' needs and about a multi-company mortality study to be undertaken by the Actuarial Society of America (ASA) in 1902, demonstrates that Hollerith was highly aware of this potential market and the shortcomings of his system for that market.²⁶ In a 1901 letter from Gore to Hollerith concerning which system--Gore's or Hollerith's--would be adopted by the ASA for use in its mortality study, Gore stated his view of the relationship between the two systems: "I have always had an idea that a combination of your system and my own would produce maximum results as to speed. In sorting vast numbers of cards, even including the counting, my system is much quicker than yours. When, however, by sorting, the numbers of cards in the various groups are reduced to the hundreds your system is the quicker."²⁷ Of course, incompatibility of card shape and design precluded such a combination. Unfortunately for Hollerith, his late-1901 introduction of an electro-mechanical sorter for his own system²⁸ came too late to gain him the contract for the Actuarial Society study. By then, the ASA committee had decided to use Gore's machine for the 1902 mortality study, even though its smaller card size required a reduction in the amount of data to be collected.²⁹

Hollerith's new sorting device quickly became a key part of his system. It started out sorting at 250 cards per minute, the same rate as the Gore sorter, and subsequent improvements made it even faster.³⁰ Soon the Gore sorter was clearly unable to keep up. The 1902 study was the first and last multi-company insurance study to use Gore's system, and Gore apparently never

considered marketing his device to other insurance firms. By the 1910s, the Prudential had begun exploring alternatives to the Gore sorter, though the inertia of what is now referred to as an "installed base," combined with one developmental dead end,³¹ meant that it was not until the 1930s that the Prudential completely abandoned the Gore equipment in favor of an extensive IBM set-up.³² While Gore's invention was soon outmoded, however, it should be viewed not just as a technological curiosity; rather, it was the first of several instances in which lead-user life insurance firms with incentive to innovate put efforts into in-house development of punch-card technology to better meet their needs than equipment available from external vendors (of which Hollerith was, at this time, the only one), thereby exerting market pressure on the tabulating industry to respond to the unmet needs.

In the final years of the nineteenth century and the opening decade of the twentieth century, other insurance companies were also beginning to experiment with mechanized sorting and tabulation. Initially these firms, like the Prudential, experienced the shortcomings of Hollerith's early equipment for their purposes, though they did not typically follow the Prudential's path of in-house invention. In the years preceding the turn of the century, several moderate-sized insurance firms contracted with the service arm of Library Bureau, a library and office supply firm that was licensed to use Hollerith equipment in providing services to firms, to undertake studies for them.³³ In a 1901 letter to Hollerith, a Travellers Insurance Company actuary described his firm's 1896 experience--and problems--contracting with the Library Bureau to compile one year's accident statistics:

As I stated before, the original difficulty seemed to be that the sub-divisions of our cards were so numerous that the time required to wire or set up a machine for the work was so great as to take away all advantage gained in the rapid tabulation after it was once set up.³⁴

At this point, any change in the columns to be counted or added required time-consuming rewiring. But the experience was not entirely useless:

We found, however, that the punch card served our purpose very much better than the written card previously used. We have therefore since that time used your punches in preparing the cards and have done our tabulating by means of knitting needles and comptometers. . . . The results have been so satisfactory that we shall continue to use the punch.

Apparently Travellers was not alone in this strategy, since Hollerith's correspondence with representatives of insurance companies reveals that several expressed interest in the card punches but not in other parts of the system.³⁵ At this time, Hollerith's Census business interfered with his ability to respond to these firms' needs and to work with them as he had done with the New York Central Railroad: "I have at present appointments with several insurance actuaries, to which I have not been able to give attention on account of my rush here in Washington."³⁶ This lack of time for the life insurance industry was also clearly a factor in his failure to convince the ASA to use his equipment in its 1902 mortality study.³⁷

By 1905, having lost the U.S. Census business, at least for the present, Hollerith turned to the commercial market in earnest. By the end of the first decade of the new century, evidence suggests that both the equipment and insurance companies' perceptions of it had changed. The sorter had been added to Hollerith's line and improvements were already being introduced to speed it up. Moreover, a plugboard system had replaced the time-consuming rewiring system complained of by the Travellers' actuary, speeding up changeovers. By 1910, a New York Life actuary, apparently reflecting the view of many life insurance actuaries, noted that while Hollerith's system had been around for 20 years, recently Hollerith had finally developed and adapted his machines to a point that they were suitable for insurance use.³⁸ By then, New York Life and many more insurance companies were adopting Hollerith machinery, primarily for actuarial and occasionally for broader insurance purposes.

In 1909 New York Life, which was then the second largest insurance firm in terms of

value of insurance in force (but not in terms of number of policies in force, since it sold ordinary but not industrial insurance), converted from a manual card system for mortality studies to a Hollerith system.³⁹ According to Arthur Hunter, the actuary who reported the change in the Transactions of the Actuarial Society of America (TASA), the reasons for the conversion were clear:

While there is considerable expense involved in making a change from written to punched cards, the cost of installing the new system should be offset by the saving in clerk hire in from three to five years. In addition to the saving in money the saving in time and facility for making investigations in greater detail have induced many companies to look with favor on the new system.⁴⁰

The Hollerith equipment was viewed as speeding up existing processes for in-house mortality investigations, allowing more extensive analysis in the same time period, and reducing labor costs. In order to assure accuracy, New York Life adopted a system by which two 45-column cards were independently punched for each policy, on different colors of card stock, then superimposed and held up to the light to be visually checked for errors. While the extra card punching took time, Hunter made a virtue out of necessity, arguing that "This constitutes one of the greatest advantages of the perforated card over the written card" (p. 265), since it resulted in two complete sets of cards, one of which could be kept in numerical order and one in mortality investigation order, thus saving time in updating cards (the former set could be used as an index to the latter) and in conducting further investigations as desired. Even with this duplication of effort, the system was expected to save time and money.

Perhaps the clearest signal of the change in attitude towards Hollerith tabulators in the life insurance industry was the adoption of Hollerith equipment for the 1910 Joint Medico-Actuarial Mortality Study, a multi-company study similar to that of 1902. In describing how the Actuarial Society was adapting New York Life's new Hollerith methods to the upcoming multi-company study, Hunter noted that by this time, "the use of perforated cards is so well known that a lengthy explanation is not necessary."⁴¹ While insurance firms submitted their data for the 1902 study

written on tabular forms to be converted to punched form, many of them submitted data on Hollerith punched cards in 1910. The Committee in charge of the 1910 study created a set of codes for standard 45-column Hollerith cards, because "There were so many companies who desired to use the Hollerith machines in supplying the data for the Committee." As in New York Life's internal system, firms supplying data in card form would punch two sets of cards to check for accuracy, but after verification would submit only one set to the Committee, retaining the other for further study of their own statistics. This Medico-Actuarial study was significant both in revealing the extent to which Hollerith tabulating equipment had become accepted in actuarial departments of life insurance firms and in serving as the means for introducing the machinery into other firms or segments of firms.⁴²

By this time, Hollerith machines were also beginning to be used for broader insurance purposes in a few firms. Henry N. Kaufman, an assistant actuary from Phoenix Mutual Life Insurance Co. of Hartford, a moderate-sized firm, described his firm's fairly complicated system of Hollerith cards, which included a new business card (recording the details of new policies), a deferred premium card (to "provide a method of obtaining the totals of the gross and net deferred premiums"), and several other cards with specific purposes.⁴³ Each card was designed differently, with appropriate labels printed over each set of columns and some with designated sections for handwritten entries. The labelling and use of combination cards with handwritten and punched data allowed the cards to be used to look up information on a specific card, just as the older, non-punched records would have been used. Kaufman stated that each card must be punched in duplicate for verification; like Hunter, he argued that duplicate typing was the most economical way of ensuring accuracy and that it provided cards that could often be of use when kept in a different order from the originals.

The actuarial mortality studies described previously used Hollerith equipment primarily to sort large numbers of policy cards into categories and to count the number of cards in each category; the resulting tally was then entered onto a tabular schedule by the machine operator. Valuation of all policies in force for regulatory bodies, another actuarial application, involved

summing only one field, the one with the monetary value of the insurance policy. More general applications of Hollerith equipment to standard insurance processes such as that of Phoenix Mutual, which held great potential for improving the efficiency of normal operations, but which also involved a wider range of needs, exposed some of the weaknesses of the equipment of that era. For example, several of the cards had different or additional fields with quantities that needed to be summed (e.g., loan amounts as well as policy value). The tabulating device "must be ordered especially to meet the requirements of each particular office" and "It is necessary therefore to carefully ascertain in advance what fields are desired to be added, because when once such fields are established they cannot be changed."⁴⁴ Thus the tabulating machines themselves were not very flexible at this stage. (Within two years, an exchange of memoranda within the Tabulating Machine Company reveals, it became clear to the makers of Hollerith equipment that it was desirable to build in flexibility by having all equipment configured to allow accumulation on any column.⁴⁵)

Card capacity was also a constraint. As Kaufman explained, "It is necessary of course to have a number of different cards, as all the information cannot be punched on one card; and furthermore, it will facilitate matters if one card is not used for too many purposes, especially as the punching of the cards is a very small matter."⁴⁶ Moreover, the cards used in the system described by Kaufman, like those used in actuarial studies, for the most part simply translated non-punched-card records to punched cards, and in some cases even created new, intermediate steps not necessary before.

Perhaps most significantly, these broader uses highlighted the lack of any printing capability in the system. During the period up to 1910, tabulating technology functioned essentially as a large and fast sorting, counting, and adding machine in the life insurance industry. An operator had to stand by the tabulator to record the number displayed on the dial each time it reached a total, another opportunity for inefficiency and inaccuracy. Any use that involved recording some quantity from each card, rather than just counting or aggregating large groups of cards, received only limited aid from the Hollerith equipment of this era. By contrast, adding and

calculating machines of this period, although they could not sort, could list as well as add items, thus allowing visual verification for accuracy. Bookkeeping machines used with pre-printed forms created permanent records as they listed, added, and subtracted. Clearly, insurance companies would be able to use the tabulating equipment for more and different types of processes if it had printing capability to list information it read from cards and to print totals.

In this first period, then, the insurance industry, as represented by the Actuarial Society and by individual firms, recognized both the potential and the shortcomings of Hollerith's technology for facilitating information handling. Early in the relationship, the insurance industry made its desires known through several mechanisms: the Prudential's invention of an alternative sorting technology in-house, the Actuarial Society's choice of Gore's over Hollerith's equipment for the multi-company mortality study of 1902, and the correspondence of actuaries from various companies with Hollerith. By 1910, Hollerith's Tabulating Machine Company (TMC), at this point still the sole provider of such equipment to commercial customers, had broadened its insurance market by responding to some of the industry's initial needs. The 1911 annual report of TMC listed the largest three ordinary insurance companies as well as several smaller firms as customers. Nevertheless, it had yet to win the business of the two largest industrial insurance firms. Prudential still used its Gore machines, while Metropolitan Life, which had tried out Hollerith machines during its participation in the 1910 Medico-Actuarial Mortality Investigation, found them useful for this work, but "not applicable to the general work of the [Actuarial] division," work for which they continued to use hand-sorted cards or bound registers.⁴⁷ Yet TMC was still a small, inventor-dominated firm struggling with product development, a firm that had not yet established the solid base of production, management, and marketing capabilities necessary, according to Chandler, to establish a real first-mover advantage in its new industry.⁴⁸ Indeed, marketing still seemed secondary at this stage, since the early publicity Hollerith received combined with the great need for better methods of handling large quantities of data and TMC's weaknesses in manufacturing and management had created a backlog of unfilled orders in 1907 that was not eliminated until 1909.⁴⁹

The still-significant shortcomings of the technology for insurance purposes needed to be addressed before broader insurance use would become common. The next phase of the relationship between insurance firms and the tabulating industry centered on the tabulating industry's development of printing capability, on the one hand, and insurance firms' initial attempts to integrate tabulating data with creating internal documents needed for operations, on the other.

The Push Toward Printing

In 1911, Hollerith's TMC joined in a merger of four makers of business machinery for measurement and information handling; thus it became a component (within a few years, the central component) of the Computing-Tabulating-Recording Company (C-T-R), and Hollerith's own role became that of advisor. In 1914 Thomas J. Watson took over as general manager (soon to become president) of C-T-R, and in 1924 would change the firm's name to IBM. Under his leadership the firm began to invest in marketing as well as production and management. Development of tabulator technology, however, was still critical to expanding and dominating the market for tabulating equipment, and the next major stage of tabulator development, the addition of printing capability, came not from Hollerith and his successors, but from newly emerging external competition. The life insurance industry encouraged the push towards printing by supporting Hollerith's two competitors: J. Royden Peirce and James Powers. Almost a decade later, when Peirce had demonstrated that his talents were in invention, not in development or production, C-T-R would hire Peirce and buy his patents to use against Powers' Accounting Machine Company; that firm, which became a division of Remington Rand in 1927, would remain C-T-R's only real challenger for the life insurance business and the market as a whole.⁵⁰ In the 1910s, the life insurance industry encouraged the development of printing capability in tabulating equipment through both Peirce and Powers.

J. Royden Peirce was an inventor who designed a few innovative, customized sets of punched-card equipment for life insurance companies. He apparently first came to Hollerith's attention as a potential competitive threat in 1912, when a report on Peirce's machinery to the

President's Commission on Economy and Efficiency (PCEE) and a prospectus for a Peirce company were forwarded to Hollerith.⁵¹ According to the prospectus, Peirce Patents Company had been formed to manufacture his "entirely new system of perforated cards in conjunction with automatic selective machinery and adding machinery." The PCEE report noted that the adding machine portion of this system (based on expired adding machine patents) accumulated totals, then, in a subsequent step, printed them out by categories on a paper tape. In this system, the device for perforating the cards also typed at the top of the card the numbers corresponding to the punched holes, making it easy for a person (as well as the other machines in the system) to read the card.

This 1912 report did not suggest that Peirce was working with life insurance firms at that time, and other evidence makes it clear that he was, in fact, working with electric utilities to develop punch-card equipment specialized to that industry's needs.⁵² By 1914, however, insurance company interest in his devices had focused much of his attention on the life insurance industry. In that year, a paper presented at the Actuarial Society of America described a Peirce installation being used by Mutual Benefit Life Insurance Company, a moderately large company that had shown early interest in the Hollerith tabulator.⁵³ By then, Peirce was also under contract to develop an installation for the largest U.S. insurance firm in terms of both value of insurance in force and number of policies, Metropolitan Life, which retained Peirce "to adapt his devices to the special requirements of the Actuarial Division."⁵⁴

By 1914, Hollerith's successors were also aware of the threat from Peirce. Gershom Smith, then general manager of TMC (still a separate operating company within C-T-R, though it would soon become a division of C-T-R), warned newcomer Watson of the insurance industry's defection, writing that "there seems considerable to be feared from [the] Royden Peirce machine in connection with life insurance companies and the Powers Printing Tabulator in connection with other insurance companies."⁵⁵ He proceeded to cite rental fees and card sales for this segment of the market, which added up to almost \$140,000 a year, nearly 15% of TMC's total 1913 revenues of roughly \$950,000.⁵⁶

The 1914 description of Mutual Benefit's Peirce system⁵⁷ suggests the directions of development being supported by the life insurance industry at this early stage. The Peirce system used only four possible hole positions, of which one, two, or three were punched in specified combinations to indicate the numbers from one through nine (see Figure 5). This system allowed two rows of coding per card, thus potentially doubling the capacity of a Hollerith card (although Mutual Benefit chose to increase the amount of punched data only slightly, to 50 columns, while using the remaining space for additional handwritten data). Another advantage of the Peirce machinery was that the punching machines simultaneously punched the desired hole(s) in a column and typed the corresponding number along the top of the card, thus promoting more accurate punching and allowing users of the cards to read the figures punched. Most importantly, the custom-made tabulator could print out or list on plain paper or forms the designated data from each card, providing printed totals as needed. This printing feature was cited by the Metropolitan as the major innovation to be realized in the Peirce system it was having built:

The tabulating machine tabulates the number of policies, amount of insurance, annual premium, premium payable,--either annually, semi-annually or quarterly,--and deferred premium, according to the various subdivisions into which they are sorted; prints the detail of the classifications, as well as the totals, all the while recording restorations in red ink and cancellations in black ink. When the cards for one group are tabulated, the machine records the totals before proceeding to tabulate the next group.⁵⁸

The promised ability to list details from each card as it passed through the tabulator (a capability apparently added to Peirce's system after 1912) and to print out totals and subtotals as it went, rather than having the machine stop after each set of cards and wait for operators to copy down the numbers in the registers, would obviously improve efficiency and remove an opportunity for human error in transcription of totals. It would also allow many internal reports (e.g., lists of policy numbers and policy amounts by location, with total amounts in each category), to be created directly from cards (Figure 6).

Peirce's strengths were more in conceptualizing than in building machinery, and this

system, ordered in June of 1913 to be delivered within six to nine months, was still not even approaching completion sixteen months later.⁵⁹ The promised equipment was apparently completed in 1916, with its key device, the listing-adding machine, costing double the price originally set.⁶⁰ While the final product of this first Peirce contract never lived up to all of Peirce's claims, it must have performed well enough to seem highly promising in comparison to the non-printing Hollerith machines of this period. In early 1918 Metropolitan Life's Vice President wrote to the head of the British Prudential Assurance Company, "Our experience convinces us that the Peirce machines are so superior to the Powers and Hollerith machines that they will eventually supplant both the latter, though now we are using all three."⁶¹ Like the Prudential's earlier investment in Gore's development, Metropolitan Life's investment in Peirce's on-site development reflected the strong incentive of a lead user to innovate. The fact that they continued to use a few Hollerith and Powers machines as well suggests a pragmatic desire to benefit from commercial equipment as they waited, without getting too heavily invested in either available system. Moreover, around this time, the Prudential also contracted with Peirce for a successor to the Gore sorters.⁶² In retrospect it is clear that Peirce, who lacked the business ability to develop his inventions, was never a serious challenger to C-T-R's insurance market; nevertheless, at this time and into the next phase of the relationship between insurance users and the tabulating industry, he continued to divert some life insurance business from C-T-R and to require attention from Hollerith's successors.⁶³

James Powers posed a more serious threat to the Hollerith machine's market as a whole and to its insurance market, specifically. Powers was essentially put in business by the U.S. Census Bureau, which hired him as an alternative to Hollerith.⁶⁴ By 1911 he had formed his own firm, Powers Accounting Machine Corporation, which eventually became a division of Remington-Rand. The Powers Printing Tabulator (Figure 7), cited as a threat to the insurance market in Gershom Smith's 1914 letter, used cards compatible with those used in Hollerith equipment (since it was developed within the Census Department, at a time when some Hollerith equipment was also still in use) but sensed the holes purely mechanically rather than electrically.⁶⁵

Like the promised Peirce machine, it could list selected data from each card run through it and print totals.⁶⁶ When used with appropriately designed forms, it could generate usable records and reports directly from the cards. For example, cards could be sorted by district and then agent, and, with pre-printed forms in the printing section of the tabulator, could be used to create lists of all the policies serviced by a specific agent.⁶⁷ Previously such a listing would have been prepared by hand or typewriter from the sorted cards. While the Powers Printing Tabulator did not offer all of the advantages promised by Peirce, the machines existed in working models by 1913 and were readily available for rental by commercial customers by 1915, unlike the Peirce machines, which were forever promised but always delayed.⁶⁸ A few medium-size life insurance firms, such as the Travellers Insurance Company and the Phoenix Insurance Company, quickly adopted Powers equipment to gain printing capability.⁶⁹ The card compatibility and rental basis of the business made this switch easy for them.

While the largest American life insurance firms were initially more interested in the Peirce equipment, the largest British life insurance company, the venerable Prudential Assurance Company, was showing great interest in the Powers printing tabulator. Like the rest of the British insurance industry, the Prudential had dragged its heels in introducing office technology of any sort; by the second decade of the century, however, it showed interest in punched-card tabulating.⁷⁰ The 1911 Approved Societies Act had legislated a health insurance system for the working class in England, and the industrial assurance companies were asked to administer it. Prudential actuary Joseph Burn decided to use this new project, which was entirely independent of the Prudential's regular insurance business, as an opportunity to test the new technology. He set up a battery of Powers machines to handle this project.

Burn was so enthusiastic about the results that by 1917 he wrote to his firm's American counterpart, Metropolitan Life, noting that the Powers machines, although they needed many further improvements, "are much better than Hollerith" machines and suggesting that Metropolitan Life join Prudential in an attempt to "control and if possible manufacture" the Powers machine or some other alternative to the Hollerith machine, such as the Peirce, in order to insure their own

supplies at reasonable prices while also making a good investment.⁷¹ Metropolitan Life showed no interest in this proposal; its executive stated that the Peirce equipment was superior to that of both Hollerith and Powers, as noted above, and that Metropolitan Life preferred to remain the sole beneficiary of Peirce's development efforts sponsored by the company. Meanwhile, the Prudential proceeded to assure its supply and to give itself some influence over further developments (as the next section will demonstrate) by buying the British Powers agency in 1919.⁷²

C-T-R's failure to win the two largest American industrial insurance companies (Metropolitan Life and the Prudential) and its British affiliate's failure to win the largest British industrial insurance company (Prudential), along with defections among smaller insurance companies and other businesses, such as public utilities,⁷³ clearly threatened its business. At a time when C-T-R under Thomas Watson was investing in marketing, management, and manufacturing facilities to a much greater extent than Powers, C-T-R was still struggling with a challenge from the financially weaker but technically superior (in capabilities offered, though not in reliability) Powers. Shortly after recognizing the dual threat posed by Powers and Peirce, Watson had established an 'experimental' or research and development department to enable C-T-R to better respond to technical challenges.⁷⁴ Drawing on the capabilities of this new experimental department, in 1917 C-T-R introduced an innovation in key punching that benefitted life insurance companies: the verifier.⁷⁵ This device allowed the firms to check the accuracy of punched cards using a second operator, but without producing a second set of cards and without requiring manual comparison of the two cards by holding them up to the light. The new process saved time and cards, though at the sacrifice of the extra set of cards some companies had seen as advantages in the earlier period. While the verifier gave the Hollerith line an advantage on one dimension, it clearly was not enough to offset the advantage of the printing tabulator.⁷⁶ Only C-T-R's introduction of a printing tabulator of its own at the beginning of the 1920s prevented continued erosion of its life insurance business.⁷⁷

When it finally became available, C-T-R's printing tabulator added another useful patented feature: automatic control.⁷⁸ The device that provided this control determined when a designated

field changed value and triggered the tabulator to provide a total; it rendered unnecessary the stop cards previously manually inserted to stop the tabulation. In an early 1920s comparison of Hollerith and Powers printing tabulators for use in handling actuarial work for Metropolitan Life's industrial insurance (although that firm continued to work with Peirce, as the next section will show, it also rented some equipment from the two commercial vendors), the analyst noted that "We use the Hollerith Printer Tabulator machines exclusively for all Classification work, the reason for this is, that 'Stop', 'Space' and 'Total' cards are not required in the Hollerith Tabulators."⁷⁹ Not only did this feature save time, the report pointed out, but it improved accuracy, since on tabulators without automatic control, "If the 'Space' card is not in place, the machine will total, but the wrong total will be produced." The combination of automatic control with printing capability, as well as the greater reliability of Hollerith equipment, moved some life insurance firms from Powers back to Hollerith equipment. Both Phoenix and the Travellers had switched to Hollerith equipment by 1924, and the actuary of the Travellers noted, "We did use Powers tabulating machines, until the Hollerith Automatic Control Printer came out, after which we shifted principally to that."⁸⁰ Again, the switch was eased by compatible cards and the fact that the equipment was rented.

The author of a paper presented at the Life Office Management Association (LOMA; an industry association that facilitated the sharing of information on methods and technologies used in managing life insurance firms) around 1926 summarized the impact of printing capability on insurance practices as follows:

Because the original Hollerith tabulator was a non-listing machine, the punched cards were seldom used for direct preparation of records and their use was more or less limited to the various analysis work.

This condition was changed when the Powers, and a few years later the Hollerith printing tabulator, made their appearance on the market. These tabulators opened a new field for the use of punch cards.

The practice of tabulating original records directly from punch cards is gradually

becoming more common and is taking the place of former analysis of records after they were made by hand.⁸¹

Thus the printing tabulator made insurance processes more efficient (as well as more accurate) by allowing firms to eliminate steps from the old manual methods and, with the aid of pre-printed forms that identified the numbers printed in specified locations, to create reports and records directly from cards. Still, the printing tabulator only sorted, tabulated, and printed **numbers**, thus limiting the types of documents it could create. This limitation would soon be addressed.

Acquiring Alphabetical Capabilities

The next key phase in the relationship between tabulating technology and the life insurance industry was the evolution of alphabetical capabilities in the mid-1920s. Alphabetical tabulating allowed names as well as numbers to be printed, thus providing more useful listings and reports for internal use and opening the way for the direct generation of policyholder documents from punched cards. As in the case of printing capability, the life insurance industry did not wait passively until C-T-R brought this innovation to market; rather, it encouraged the development in a variety of ways, once again working through C-T-R's rivals in the tabulator business, Peirce and Powers. This was to be the last major challenge to C-T-R's (soon IBM's) domination of the American tabulator market.

A brief look at some common types of internal and external documents requiring alphabetical information and how they were generated in the first two decades of the century demonstrates why insurance firms sought alphabetical capability. The weekly payments of industrial insurance were collected by agents who went door to door, based on manually created and updated bound registers and frequently retyped lists by policy-holder name of all active policies in an agent's assigned area or debit. The yearly or quarterly premiums of ordinary insurance, and the monthly premiums of a growing category of intermediate insurance required sending out first a notice of premium due and then a receipt for payments rendered. Such external documents required names and addresses, as well as numerical information such as the amount of

the premium and the value of the policy. This addressing was accomplished by typewriter until the second decade of the twentieth century, when most life insurance firms adopted addressing machines such as the Addressograph.⁸² Addressing machines used embossed metal plates or fiber stencils to record and print information used repeatedly. Such devices avoided repeated manual typing of the same information (which introduced multiple chances for error) and allowed rapid processing of notices. Still, a plate had to be created for each policy holder and the bulky sets of plates had to be maintained, updated when policyholders moved or changed their policies, sorted, and kept consistent with the punched cards used for other purposes, requiring a significant staff and introducing some (if fewer than the old system) opportunities for error. Creating both debit lists for internal use and premium notices and receipts for external use directly from punched cards would certainly reduce transcription errors and potentially simplify and speed up insurance business processes.

As early as 1913, well before Powers or Hollerith and his successors are known to have expressed interest in this idea, Peirce seems to have envisioned an alphabetical tabulator for producing policyholder documents. Confidential drawings for Metropolitan Life, many dated as early as May 20, 1913, show Peirce's vision of a system that would use punched holes to encode the name and address of the insured, along with the relevant numerical information (Figure 8).⁸³ By 1916 Peirce had submitted to Metropolitan Life a formal proposal to construct a set of customized punched-card machinery designed to prepare and address premium notices, receipts, and stubs that would be mailed to policyholders and to prepare various internal records, including a register of policies issued and an agent's list of notices.⁸⁴ The perforating machine, which resembled a typewriter (Figure 9), was to punch numbers and letters onto cards, while simultaneously typing the corresponding letters and numbers along the top of the card. The promised system also included a listing machine and a machine for duplicating certain information needed by the Actuarial Department onto another card. Peirce's proposal laid out his vision for transforming the Metropolitan's document creation processes through this system:

By means of these machines all hand work in connection with the recording, notice

sending and preparation of data for the Actuary's Office is entirely done away with.[...]

I would point out, finally, what a great step in advance of anything which has heretofore been done in this line, these perforated card machines are. Once the primary card has been made[,] all the reports and notices from the beginning of the policy's career to its end will be made by machinery. From the production of the card to the final reports in the Actuarial Division is one continuous automatic mechanical cycle.

By 1918, when this proposal had been converted into a contract, the plans had become even more ambitious, including sixteen different, customized devices, all variations on the machines described in the original proposal. The names of just a few indicate how the proposed system had been expanded and specialized: notice and receipt machine, audit report tabulator, commission tabulator, state report tabulator. It is unclear whether this increased specialization was driven primarily by Peirce, by Metropolitan Life, or by the interaction of both. Around that time, Peirce also entered into two other major contracts for alphabetical punch-card systems for life insurance, one with the Insurance Division of the United States Veterans Bureau and one with the (American) Prudential Insurance Company.⁸⁵ In fact, in 1919 Peirce approached Metropolitan Life with a proposal to renegotiate its contract to share the development costs and the resulting developments with these two and potentially more organizations. As it had done with the British Prudential's proposal, however, Metropolitan Life turned down the opportunity, preferring to bear all of the costs and all of the rewards of Peirce's customized developments by itself.

In the mid-1920s, some members of Metropolitan Life's Home Office Study Committee challenged the firm's strategy with regard to Peirce, initiating studies with Powers and Hollerith equipment and pointing out the endless delays as well as many disadvantages Peirce's nonstandard and highly customized equipment, even if finally delivered, would have for the firm.⁸⁶ In particular, they noted its inflexibility to any changes in insurance products or in the nature of the data and documents needed. In response to the anti-Peirce faction's observation that Powers equipment could be made to serve the firm's needs with only minor modifications, Actuary J.D.

Craig, one of Peirce's supporters in the firm, revealed an ideological motive for the long pursuit of the chimerical Peirce system:

Our fundamental proposition is that the Metropolitan is big enough, and its work important enough, so that we do not have to fit our system to existing machines; that time is not imperative; that the Metropolitan, rather than propose a plan to fit existing machines, can demand that machines be built to fit its system.⁸⁷

This ideological component to the debate may help explain why support for Peirce continued so long. Metropolitan Life continued to hold Peirce to his contracts and to renew these contracts, until at least 1926.

Peirce's vision of a system fully integrating all stages of information handling and document production was ahead of his mechanical and business abilities, and none of the three contracts he made for insurance tabulating systems was to be satisfactorily completed nor the machinery put into complete operation. In fact, a thorough "Study of the Peirce Machines" conducted by the Metropolitan in 1926, after the firm had paid over \$1 million for Peirce's development efforts, makes the following assessment:

In reviewing the other installations of Peirce machines one is impressed with the fact that in every case the installation has been practically a development and that a great deal of time has been consumed before machines have been delivered. On delivery considerable time has elapsed before the equipment is ready to use. In no one instance has there been a complete installation of equipment.⁸⁸

Thus these attempts by Metropolitan Life and the Prudential to fund customized development by Peirce, while consistent, at least initially, with the incentives for a lead user, were not very successful.

Meanwhile, the Powers camp was again taking the lead from C-T-R in the practical realization of a simpler and more flexible version of alphabetical tabulating than the highly customized and integrated installations envisioned by Peirce. Beginning in 1915, even before it bought the British rights to produce and market Powers machines, the British Prudential Assurance

had started working with the British Powers agency, the Accounting and Tabulating Machine Company (or 'Acc and Tab,' as it was known) to develop an alphabetical tabulator.⁸⁹ The impetus for this undertaking came from the Prudential manager in charge of its Powers machine installation, who saw how valuable this capability could be for the insurance company. A mid-1930s retrospective Prudential account stated its goal as follows: "This development came about by the express desire of the Prudential Assurance Company, in order that the name of the assured might be printed mechanically in the Industrial Branch records."⁹⁰ The Prudential initially sponsored and, after buying the Powers agency in Britain, funded and oversaw most of the development, by 1920, of an alphabetical attachment to the regular Powers tabulator.⁹¹ According to Campbell-Kelly, Prudential actuary Burn had a comprehensive and ambitious vision of reconfiguring his own company's processes around tabulating equipment:

Joseph Burn saw this development as one which was crucial to his long-term plans to decentralize and reduce the cost of insurance policy administration. It would be a costly development, but one with vast potential for the Prudential business, allowing the complete accounting operation to be done by one system, and thus enabling them to dispense with their batteries of Addressograph and bookkeeping machines.⁹²

Dispensing with the Addressograph machines was still decades away, since both greater card capacity and the ability to print material from a single card onto multiple lines were still needed to allow the printing of addresses. Yet by 1923, the Prudential was using this system to generate various lists and registers demanded in its industrial insurance business (Figure 10).⁹³ Since at this time the firm had 24 million industrial policies (as compared to 1 million ordinary policies), this use had vast potential for savings, helping to reduce the always troublesome expense ratio of industrial insurance.

Interestingly, Prudential did not follow Metropolitan Life's policy of attempting to retain all costs and benefits of development itself. As Campbell-Kelly explains it, "Since it was unlikely that Powers would undertake this development of its own volition, the plan was for the Prudential to

do the development, and recoup the cost by supplying machines to other insurance companies."⁹⁴ The Prudential did not view this purchase as a mechanism for acquiring competitive advantage over other British insurance firms; in fact, Burn actively helped the Acc and Tab market the equipment to other insurance companies. Until after World War II, the Acc and Tab continued to function as a well-funded subsidiary of the Prudential with royalty agreements with Powers in the U.S., a situation that allowed it to avoid the financial crises that weakened the latter firm and to compete on much more even terms with the British Hollerith agency than Powers did with C-T-R.

After the Prudential sponsored the development of alphabetical capabilities in the British Powers affiliate, Metropolitan Life began to add its weight to similar developments in Powers, although the exact sequence of events is now obscure. Sometime before the beginning of 1924 AMC had apparently developed a machine with limited alphabetical capability, allowing only 13 of the 26 letters to be used.⁹⁵ It could not, however, have printed policyholder names with so few letters. In late 1923, a committee of Metropolitan Life executives had visited the British Prudential's offices and seen their full-alphabet tabulators, which they noted as first of "the more important additions and improvements that have been made by the British Powers Company" and clearly superior to the 13-letter tabulators of the American Powers organization.⁹⁶ Their report also outlined in great detail Prudential's application of this machinery in its industrial insurance operations. At this time, although Peirce continued to work for Metropolitan Life on contract, Metropolitan Life's Home Office Study Committee had also begun working with Powers and IBM to develop ways of modifying their equipment to mechanize more of the insurance firm's operating processes.⁹⁷ For these developmental efforts, however, Metropolitan Life provided very little monetary support, since the two vendors were competing to acquire all of this huge firm's business.

One intermediate outcome of this effort is commemorated in a framed sample listing--including names as well as numerical information--of Metropolitan Life industrial insurance policies, shown in Figure 11.⁹⁸ This document claims to be a "Sheet Run on the First Alphabetic Tabulator in the United States," which was "Constructed by the Powers Accounting Machine

Company for the Home Office Study Committee of the Metropolitan Life Insurance Company,"Text on the commemorative listing makes clear the potential application the Committee had in mind: "The machine will now produce life and lapse register sheets from punched cards showing all the details necessary for Home Office and District Office purposes as well as subtotals for each class of transaction and a grand total for the week's business." In the process of working with Powers AMC in developing this alphabetical tabulator, according to the Committee's logs, one Metropolitan Life employee devised several mechanical changes to the equipment that the insurance firm wanted to patent, to "furnish us protection against undue charges for the Powers machines, should we come to a final arrangement."⁹⁹ This protection was never to be needed as Metropolitan Life ultimately followed a different path. Nevertheless, this sequence of interactions indicates that the largest American life insurance firm had begun to shift away from its early and expensive strategy of solely funding Peirce's developments and was now also working closely with the more viable Powers organization and even, Home Office Study Committee logs reveal, with IBM itself in its attempt to acquire the technological improvements it wanted for handling its voluminous industrial insurance business.

How, then, was C-T-R (which became IBM in 1924) responding to the alphabetical tabulator challenge from Powers, so soon after it had finally introduced its first numerical printing tabulator? In 1922, as an initial step towards addressing this threat, C-T-R bought Peirce's main engineering shop (though not the shop he had set up within Metropolitan Life for his contract work) and the rights to his patents, including some alphabetical patents, and hired Peirce himself to help the firm develop its own alphabetical tabulating machine.¹⁰⁰ The essential incompatibility of Peirce's system with the Hollerith machinery, along with Peirce's continued work on contract for Metropolitan Life, may help account for the long lag before IBM introduced its own alphabetical tabulator in 1931.¹⁰¹ Meanwhile, however, in the late 1920s IBM addressed another drawback of tabulating equipment for insurance work (as well as for some other uses), a limitation that would be exacerbated by alphabetical capability: card capacity. Encoding a name required a field of about 15 to 18 of the 45 columns on a standard card of the era, restricting the number of columns

available for numerical fields and often requiring multiple cards for even the most basic data on a single policy. In 1928 IBM introduced the 80-column card that remained its standard into the early computer era (Figure 12).¹⁰² This new card, when used in conjunction with the alphabetical tabulator IBM introduced three years later, had room for a substantial alphabetical field as well as the numerical fields. Moreover, IBM's machinery could be modified to use both the new 80-column cards and the old 45-column cards, thus offering a new advantage without making the insurance firms' existing cards obsolete.¹⁰³ Interestingly, the slotted holes of the IBM 80-column card were patented and also could not be used with the mechanical hole-sensing system of the Powers tabulators; thus, in order to compete, Remington Rand introduced a 90-column card that used a method of compression similar to that used in the original Peirce equipment (two rows of short columns per card, with multiple holes in the same column punched to represent characters).¹⁰⁴ These changes ended the compatibility between the two vendors that had allowed easy switching.

Once again, IBM overcame a Powers technical advantage with a delayed but superior product. While Powers had mounted a serious technical challenge, it lacked the solid financial footing necessary to overcome IBM's advantages in the other capabilities. For example, in a meeting between the president of Powers and the head of Metropolitan Life's Home Office Study Committee to discuss their joint development efforts, the former noted that his firm's financial problems limited the extent of its experimentation without compensation.¹⁰⁵ This financial weakness in Powers was almost certainly a factor in AMC's failure to overtake IBM's first mover advantage, in spite of Powers' technological lead in the mid-1920s. In 1927, Powers merged with several other office machine companies into Remington Rand, shoring up its financial situation; however, it was never the central component of that larger firm as TMC had been in C-T-R.

IBM had responded to the pressure of the life insurance industry (and of others such as utilities and accounting applications cutting across industries) towards printing and alphabetical capacity, and many American life insurance firms seem to have standardized on IBM equipment by the early 1930s (e.g., the Equitable, Travellers Insurance Company, Phoenix Insurance Company,

the Prudential). This shift in momentum towards IBM was not restricted to the life insurance industry; by the 1930s IBM had established an eight-to-one advantage over Remington Rand's Powers Division in the tabulating market.¹⁰⁶ By 1940, even the Metropolitan had fully abandoned its experimentation with Peirce and Powers equipment, and introduced a large, 300-piece IBM installation.¹⁰⁷

Peirce's overly ambitious vision of an integrated tabulating system to handle all tasks from initial creation of cards through final documents remained out of reach. Nevertheless, by the end of the tabulator era specific tasks such as premium billing had been automated in some companies. Responding to customer needs, IBM and Remington Rand continued to introduce technical improvements to facilitate such tasks: in 1929, Remington Rand introduced an attachment allowing the use of continuous forms; in 1934, IBM introduced its automatic carriage, allowing continuous multi-part carbon paper forms; in 1935, it introduced "Machines designed for issuing utility bills to customers or premium notices to insurance policyholders," although these apparently required multiple cards to produce multiple-line addresses; in 1941, it introduced a tabulator that allowed three-line addressing from a single card; in 1948 it introduced high speed machines with a tape-controlled automatic carriage for more flexible use of forms.¹⁰⁸ Life insurance companies gradually reconfigured their processes to take advantage of the capabilities they had sought. In a 1938 LOMA study of how member life insurance companies were handling premium billing routines for ordinary insurance, only 2 out of the 95 companies making up the stratified sample were using the tabulator to imprint "identifying data" onto forms, while 79 used Addressographs and 14 used typewriters.¹⁰⁹ By the early 1950s, the LOMA publications were describing an increasing number of such applications.¹¹⁰

Conclusion

As a large and highly information-intensive industry, life insurance was one of the major commercial industries using tabulating technology in the first half of the twentieth century.¹¹¹ But the insurance industry was not simply a passive, if eager, recipient of this technology. Its leading

firms and its industry organizations played an active role in encouraging technical and market developments they saw as desirable. Beginning with Gore's design and development of his own sorting machine in the 1890s, the industry--especially the largest industrial life insurance firms with the greatest need for aid in handling ever-growing amounts of information--used its leverage to encourage certain types of developments in the technology. These developments in turn allowed firms to use tabulating systems in an increasing number of ways.

In the early years of tabulator development, the industry was most interested in the rapid and multi-dimensional sorting of data required for actuarial work. Specific firms exerted pressure towards this end via Gore's construction of an alternative sorting device for the Prudential as well as the complaints of firms such as the Travellers, which had contracted for Library Bureau Hollerith services. The industry as a whole communicated its needs to Hollerith through the Actuarial Society's correspondence with him and its ultimate choice of the Gore sorter for the 1902 multi-company mortality study. It signalled approval for his subsequent developments by changing its policy and adopting Hollerith technology for the 1910 study, thereby providing many of the society's members with their first substantive exposure to the technology. The influence of the life insurance industry, among other early user industries, helped shape the configuration of the tabulating equipment Hollerith developed for the commercial market after he lost the census market.

In the decades following 1910, the life insurance industry exerted its influence towards a new goal. While tabulating continued to be important to actuarial calculations, its potential uses in many other phases of the business soon became evident, making new capabilities desirable. With the industry's heavy dependence on documents--both internal records such as agents' lists and external transactional documents such as policyholder bills and receipts--it supported and encouraged developments that broadened the uses of tabulating to integrate data manipulation with document production, including first the printing tabulator and later the alphabetical tabulator. Many companies (e.g. Travellers, Phoenix, and Mutual Benefit) made their needs known by straightforward market choices, adopting the first printing tabulators developed by Powers and

Peirce, and returning to the Hollerith/IBM fold when it introduced its own printing tabulator, which offered additional features and better reliability. Metropolitan Life and the American and British Prudentials--the largest insurance companies on each side of the Atlantic, by both number and value of policies--deliberately invested in innovation in tabulating technology. As lead users, in Von Hippel's terminology, these three firms had the greatest incentives to seek more efficient and accurate ways of handling the data and document processing associated with the increasing number of policies. The British Prudential bought the British Powers agency, giving it direct influence over the evolution of the technology as well as protecting the firm from exorbitant prices or restricted supply brought on by the Acc and Tab's relationship to Powers in America.¹¹² Metropolitan Life initially contracted with Peirce to develop customized proprietary technology to support its processes, then, as delays mounted, it sought competitive developments from Powers and IBM, as well. The American Prudential also contracted with Peirce for custom equipment.

While all of these mechanisms encouraged the evolution of printing capabilities, different approaches had different effects on the specific life insurance firms adopting them. The British Prudential's approach of buying and working with the British Powers organization (the Acc and Tab) while allowing it to continue competing in the British market seems to have been a reasonably successful intervention from Prudential's point of view. Rather than trying to gain competitive advantage in the British insurance market through the exclusive use of this technology, Burn helped market it to his colleagues in competing firms, preaching the importance of modern office technology. His investment seems to have been successful financially and strategically, for the Acc and Tab and for the Prudential, which only sold this subsidiary when Burn retired after World War II.¹¹³

The attempts to develop proprietary technology for exclusive use of the developer had less successful results. Gore's development of his sorter for the American Prudential initially gave that firm a headstart in mechanized information processing, but later functioned to lock it into an incompatible system as the commercial vendors improved the capabilities of tabulating technology far beyond those offered by the Gore machine. That firm's contract with Peirce in 1918 indicates

that by that time it recognized the need to acquire new equipment, but its decision to contract for Peirce's custom-developed equipment was an unfortunate variation on its previous mistake. That contract, which was never completed, delayed its ultimate adoption of modern tabulating equipment on a large scale until almost 1940. Metropolitan Life had similar problems with Peirce, investing a great deal of money and time for a highly customized but inflexible proprietary system that was never successfully completed. In her study of the British capital equipment industry, MacLeod found that "For the individual user-firm, exclusive reliance on the inventions of its own machine shop was a high-risk strategy. . . .if pursued dogmatically, it could lead to expensive mistakes, technological dead-ends, inefficient and even obsolete machinery."¹¹⁴ Such a strategy was inherently even more risky when the user firm was innovating (or overseeing innovation) in an area requiring fundamentally different skills, as was the case with life insurance firms innovating in machine technology. Furthermore, Metropolitan Life's ideological predisposition towards special-purpose machines designed around its processes at one point in time built inflexibility into the system it was attempting to develop. One of the advantages of the commercial devices that emerged over time was the fact that they could be reconfigured as well as combined with other devices, creating a much more flexible system.

Whatever their effect on individual insurance firms, these actions by the largest firms, along with the market-mediated shifts of the smaller firms and the role of industry associations, certainly influenced technological developments in directions that the life insurance industry as a whole saw as desirable. The added printing and alphabetical capabilities allowed increasing integration of clerical steps, reducing the repetition so characteristic of the insurance business and eliminating many opportunities for transcription errors.

Focusing for a moment on the tabulating industry itself, we see that Hollerith's TMC and successors C-T-R and IBM under Thomas J. Watson ultimately established and built on a first mover advantage to become the clear leader in the tabulating industry. Only two challenges to IBM's dominance were mounted, both based on technical improvements (real or promised) that expanded the equipment's capabilities. These challenges were both encouraged by the insurance

industry. As Campbell-Kelly has pointed out, the rental nature of the tabulating equipment industry creates pressure on vendors to delay new introductions to avoid making existing equipment obsolete.¹¹⁵ The competition from Powers in particular pushed the industry leader to continue to innovate, and to work more closely with major user industries such as life insurance. In spite of its repeated technical innovations, Powers lacked the Chandlerian investment in marketing, manufacturing, and management to challenge IBM successfully. The monetary and managerial problems Powers faced until it became part of Remington Rand continually undercut its challenge, and its position as a single and non-dominant division of the new combination with inadequate managerial focus never allowed it to catch up. Moreover, the post-1928 card incompatibility forced by IBM's patent on the rectangular holes of the 80-column card made it more difficult for it to capture existing IBM business.

The on-going interaction between the life insurance and tabulating industries shaped both industries in significant ways, setting the stage for continued interaction between the two industries during the transition to computers beginning at mid-century. The relationship between the two industries also reflects the co-evolution of tabulating technology development and use over time. By looking at both sets of developments together we can appreciate the nature of the relationship and the dynamic process by which it unfolded, each served as a shaping context for the other.

¹ The New York Tribune, April 25, 1890, as quoted by Geoffrey D. Austrian, Herman Hollerith: Forgotten Giant of Information Processing (New York: Columbia University Press, 1982), p. 83.

² While I will refer to both tabulating and the life insurance industry as industries, they are both clearly parts of larger industries. James W. Cortada, in Before the Computer: IBM, NCR, Burroughs, & Remington Rand & the Industry They Created, 1865-1956 (Princeton, NJ: Princeton University Press, 1993), sets the tabulating business within the office machinery industry, and that industry definition could be broadened further to include the office appliance and office supply businesses. Indeed, Cortada argues that all the forms of office and data-handling equipment evolved in interaction with the information needs of businesses in general, and I have made a similar argument with regard to earlier office techniques and technologies in JoAnne Yates, Control through Communication: The Rise of System in American Management (Baltimore: Johns Hopkins University Press, 1989). Nevertheless, here I am making a much narrower and specific argument, and for these purposes the tabulating business itself was fairly well defined with a limited set of vendors, as will become evident in this paper. Thus it is useful to discuss it as an industry by itself. Similarly, while life insurance is clearly part of a larger insurance industry, it functioned quite separately during this period, for regulatory and other reasons; even its trade associations were usually solely for life insurance. Other types of insurance adopted and used tabulating technology, as well, but at a somewhat slower rate and somewhat less extensively because they lacked the immense numbers of policies common in life insurance and had more variation in the policies themselves. Thus I have chosen to limit my user industry analysis to life insurance, and unless otherwise stated, references to insurance should be taken to mean life insurance.

³ See, for example, Herman H. Goldstine, The Computer from Pascal to von Neumann (Princeton, NJ: Princeton University Press, 1972). On the other hand, there is no treatment of tabulating equipment in, for example, Michael R. Williams, A History of Computing Technology (Englewood Cliffs, N.J.: Prentice-Hall, 1985).

⁴ Austrian, Herman Hollerith; James R. Beniger, The Control Revolution: Technological and Economic Origins of the Information Society (Cambridge, MA: Harvard University Press, 1986); Arthur L. Norberg, "High Technology Calculation in the Early 20th Century: Punched Card Machinery in Business and Government," Technology and Culture 31 (1990), 753-779; Martin Campbell-Kelly "Punched-Card Machinery," in William Aspray, ed., Computing before Computers (Ames, Iowa, 1990); and Cortada, Before the Computer.

⁵ In one of the few studies recognizing the non-mechanical roots of information technology, Campbell-Kelly has studied the emergence of manual methods of large scale data processing in a British insurance firm during the Victorian era. He notes that "the insurance business is perhaps the purest example of an 'information-based' industry - that is, an industry whose sole activity consists of gathering, processing, and distributing information." Martin Campbell-Kelly, "Large-Scale Data Processing in the Prudential, 1850-1930," Accounting, Business and Financial History 2 (2), 118.

⁶ In the management of innovation literature, Eric von Hippel, in The Sources of Innovation (NY: Oxford University Press, 1988) and other work has highlighted the role of lead users in innovation. In economic history, Ross Thomson has studied the "learning by selling" process by which users influence ongoing technological innovation ["Learning by Selling and Invention: The Case of the Sewing Machine," Journal of Economic History 47 (June 1987): 433-45; The Path to Mechanized Shoe Production in the United States (Chapel Hill, NC: North Carolina University Press, 1989)]; Christine MacLeod has examined the innovation and diffusion practices of machine makers and machine users, finding that users played a more important role in innovation and makers in diffusion ["Strategies for Innovation: The Diffusion of New Technology in Nineteenth Century British Industry," Economic History Review 45:2 (1992), pp. 285-307]; and Janet T. Knodler has examined user-initiated joint consumer-producer efforts in the U.S. to innovate in steel products ["Market Structure, Industrial Research and Consumers of Innovation: Forging Backward Linkages to Research in the Turn-of-the-Century U.S. Steel Industry," forthcoming in

Business History Review]. Of course, studies of the social construction of technology have also shifted focus from the individual inventor to the broader social system influencing innovation, in which users may be considered one of the relevant social groups [e.g., Wiebe E. Bijker, "The Social Construction of Bakelite: Toward a Theory of Invention," in Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch, The Social Construction of Technological Systems (Cambridge, MA: MIT Press, 1987), pp. 159-187].

⁷ As defined in Thomas P. Hughes, "The Evolution of Large Technological Systems," in Wiebe E. Bijker, Thomas P. Hughes, and Trevor Pinch, The Social Construction of Technological Systems (Cambridge, MA: MIT Press, 1987), pp. 51-82.

⁸ Alfred D. Chandler, Jr., Scale and Scope: The Dynamics of Industrial Capitalism (Cambridge, MA: The Belknap Press of Harvard University Press: 1990). This study does not, for example, go into more involved competitive developments in the European market, which generally had little direct effect on the American market, except for one brief foray into Great Britain to deal with a significant technical innovation that occurred in conjunction with a British life insurance firm.

⁹ I do not use *co-evolution* in the same biological sense invoked by Edward W. Constant ("On the Diversity and Co-evolution of Technological Multiples: Steam Turbines and Pelton Water Wheels," Social Studies of Science 8 (May 1978), 183-210); rather, I use it to denote the contemporaneous and interacting developments of a technology and its use, and of the vendor and user industries. In particular, many of the developments are the conscious actions and reactions of managers, inventors, or other individuals or groups involved. Since writing this paper, I have discovered a group of researchers in technology and innovation management who have recently introduced what seems to be a similar use of the term. See, for example, Lori Rosenkopf and Michael L. Tushman, "The Co-Evolution of Technology and Organization," and Joel A.C. Baum and Jitendra V. Singh, "Organization-Environment Coevolution," both forthcoming in J.A.C. Baum and J. V. Singh (eds.) Evolutionary Dynamics of Organizations (NY: Oxford University Press).

¹⁰ Viviana A. Rotman Zelizer, Morals and Markets: The Development of Life Insurance in the

United States (New York: Columbia University Press, 1979). The background information on the life insurance industry in this paragraph and the next comes from this source and from Morton Keller, The Life Insurance Enterprise, 1885-1910: A Study in the Limits of Corporate Power (Cambridge, MA: The Belknap Press of Harvard University Press, 1963).

¹¹ The largest industrial insurance firms fit both characteristics of lead users defined in The Sources of Innovation (p. 107): 1) they face information handling needs that will be experienced by all life insurance firms (and many other types of firms, as well), but they face them significantly earlier than other firms; and 2) they will benefit significantly by obtaining solutions to those needs. The large number of transactions required by industrial insurance brought on problems of data management much sooner than in ordinary insurance. And, while many of the firms were non-profit mutuals, as discussed later in this section, they all wanted to continue growing. Reducing the information-handling costs of industrial insurance would both expand the total market for such insurance and give a particular company an opportunity to increase market share.

¹² The Armstrong Commission Hearings of 1905, conducted by a joint committee of the New York Legislature, were a watershed event in the history of insurance in America. In the wake of the investigation, which exposed widespread abuses in insurance finance, state regulators passed a series of statutes strictly limiting the investment activities of the firms and mandating stricter controls over products and operations. During this period, many firms also mutualized. [Keller, The Life Insurance Enterprise, pp. 265-292; Douglass C. North, "Life Insurance and Investment Banking at the Time of the Armstrong Investigation of 1905-1906," The Journal of Economic History 14 (Summer 1954), 209-228.

¹³ Yates, Control through Communication; and "Evolving Information Use in Firms, 1850-1920: Ideology and Information Techniques and Technologies," in Information Acumen: the Understanding and Use of Knowledge in Modern Business (forthcoming from Routledge Press). See also Beniger, The Control Revolution

¹⁴ E.g., Marquis James, The Metropolitan Life: A Study in Business Growth (New York: The

Viking Press, 1947), p. 168.

¹⁵ J. Owen Stalson, D.C.S., Marketing Life Insurance: Its History in America (Cambridge, MA: Harvard University Press, 1942), p. 800.

¹⁶ Campbell-Kelly (personal communication, January 1993) notes that British insurance firms did not handle all of these types of information. In Britain, a single annual valuation of policies in force was the major actuarial task, for example, with no need to value and compute reserve requirements for each state as in the U.S. There was little focus on mortality studies, with most British firms continuing to use 19th Century mortality tables well into the 20th Century. Moreover, they did not maintain internal cost accounting systems to monitor costs and to aid in pricing products. While the first of these differences reflects the state-level regulation of U.S. insurance industry, the others reflect the preoccupation with systematization and statistical analysis prevalent in the American business community around the turn of the century (see Yates, Control through Communication, pp. 1-20).

¹⁷ B. F. Dvorak, untitled address to Life Office Management Association, Fort Wayne, Ind. Undated, but with materials from ca. 1926 in Home Office Study Committee, Cabinet 13, Metropolitan Life Insurance Company Archives.

¹⁸ Austrian, Herman Hollerith, p. 238; Norberg, p. 764.

¹⁹ The following description of early Hollerith equipment is based on Campbell-Kelly, "Punched-card Machinery"; Campbell-Kelly, ICL: A Business and Technical History (Oxford: Oxford University Press, 1989); Norberg, "High Technology Calculation"; Charles J. Bashe, Lyle R. Johnson, John H. Palmer, and Emerson W. Pugh, IBM's Early Computers (Cambridge, MA: The MIT Press, 1986); Leon E. Truesdell, The Development of Punch Card Tabulation in the Bureau of the Census: 1890-1940 (U.S. Bureau of Census: Washington, D.C., 1965); and Austrian, Herman Hollerith.

²⁰ Thomas P. Hughes, Networks of Power: Electrification in Western Society, 1880-1930 (Baltimore: The Johns Hopkins University Press, 1983), p. 14.

-
- 21 Campbell-Kelly, "Large-Scale Data Processing in the Prudential."
- 22 Calculated roughly from data in Marquis James, The Metropolitan Life: A Study in Business Growth (New York: The Viking Press, 1947), pp. 94-95.
- 23 Moorhead, Our Yesterdays, p. 338; David Parks Fackler, "Regarding the Mortality Investigation, instituted by the Actuarial Society of America and now in progress," Journal of the Institute of Actuaries 37 (1903), 1-15. Prudential's archives are closed to the public, so I can only speculate about Gore's motives.
- 24 Austrian, Herman Hollerith, p. 82-3.
- 25 Campbell-Kelly, "Punched Card Machinery," p. 133.
- 26 Hollerith corresponded with Louis F. Butler and H. J. Messenger of Travellers Insurance; Emory McClintock of Mutual Life; John Tatlock of the Actuarial Society of America; John B. Lunger, Rufus Weeks, and A. R. Grow of New York Life; and D. H. Wells of Connecticut Mutual Life in the period from December 1900 through May of 1901 (Container #10, Hollerith Collection, Library of Congress).
- 27 23 May 1901, Gore to Hollerith, Library of Congress, Hollerith Collection, Container #10.
- 28 Austrian, p. 177; Campbell-Kelly, 1989, 1990.
- 29 20 May 1901, John Tatlock, Jr., Secretary of the Actuarial Society of America [writing for Mr. McClintock], to Hollerith, and 23 May 1902, Gore to Hollerith, both in Container #10, Hollerith Collection, Library of Congress, .
- 30 Campbell-Kelly, "Punched-Card Machinery," p. 140.
- 31 When the Prudential realized that the Gore sorter could not keep up with subsequent tabulating developments [Earl Chapin May and Will Oursler, The Prudential: A Story of Human Security (Garden City, NY, Doubleday & Company, 1950), p. 308], it contracted with Royden Peirce for an alternative system similar to the one he was developing for Metropolitan Life (discussed in the next section). While the contract stipulated a 1918 installation, the order was not fulfilled until 1925, and even then incompletely, with the machines requiring the full-time efforts of a Peirce

mechanic to keep running ["A Study of the Peirce Machines," pp. 5-6, Peirce Machine Matters, Cabinet 2, Metropolitan Life Archives]. Judging by the Metropolitan's experience with Peirce, catalogued in the same report, the installation was probably not very satisfactory and could not be adapted to changes in the types of policies or data gathered. The Prudential's own accounts of its tabulating experience omit mention of the Peirce machinery [Moorhead, Our Yesterdays, p. 338], reinforcing this supposition.

32 Moorhead, Our Yesterdays, p. 338; May and Oursler, The Prudential, p. 308.

33 Austrian, Herman Hollerith, p. 134.

34 13 Mar. 1901, Louis F. Butler to Hollerith, Container #10, Hollerith Collection, Library of Congress.

35 28 April 1900, Hollerith to John B. Lunger of New York Life, in Container #10, Hollerith Collection, Library of Congress. At this time, card files with tabs, notches, or holes were just coming into use as systems for storage and retrieval of structured data (Yates, "Information Systems for Handling Manufacturing and Marketing Data in American Firms, 1880-1920," Business and Economic History, 2nd ser., 18 (1989), pp. 207-217). Travellers and other firms were simply using the Hollerith punch to create such a system.

36 8 May 1901, Hollerith to H. E. Davidson of the Library Bureau, Container #10, Hollerith Collection, Library of Congress.

37 Hollerith's correspondence with various members of the committee from December 1900 through May of 1901 [with Louis F. Butler and H. J. Messenger of Travellers Insurance; Emory McClintock of Mutual Life, also chair of the committee; John Tatlock of the Actuarial Society of America; John B. Lunger, Rufus Weeks, and A. R. Grow of New York Life; and D. H. Wells of Connecticut Mutual Life--all in Container #10, Hollerith Collection, Library of Congress] makes clear that lack of adequate attention on Hollerith's part affected the decision. Although the sorter must have been under development for the Census at this point, he did not mention it in this correspondence. Hollerith insisted on having as many committee members as possible view the

new accumulating tabulators he had recently installed in the New York Central Railroad, but he was too busy to travel up to New York to demonstrate it himself. This equipment, it turned out, was less relevant to the needs of the mortality study than that used by the Census. Misunderstandings also arose. For example, some committee members questioned whether Hollerith's equipment could count cards with combinations of holes, not single holes, simultaneously. In his correspondence Hollerith stated that it would, but the issue was alluded to later as a decision factor in favor of the Gore equipment [Dec. 31, 1900, Hollerith to D.H. Wells of Connecticut Mutual Life; May 21, 1901, John Tatlock of the American Society of Actuaries to Hollerith--both in Container #10, Hollerith Collection, Library of Congress]. According to Austrian [Herman Hollerith, p. 180], the **sorters** that Hollerith introduced later that year did not sort on combinations, but the **tabulators** allowed tabulation of combinations. This fact was not, apparently, clear to the committee.

³⁸ Arthur Hunter, "Method of Making Mortality Investigations by Means of Perforated Cards, Sorting and Tabulating Machines with Special Reference to the Medico-Actuarial Mortality Investigation," Transactions of the Actuarial Society of America 11 (1909-10), 252-275.

³⁹42. Arthur Hunter, "Note on an Approximate Method of Making Mortality Investigations," Transactions of the Actuarial Society of America 10 (1907-8), p. 361; Hunter, "Method of Making Mortality Investigations." See also New York Life Insurance Co., A Temple of Humanity (New York: 1909). New York Life's rank (in terms of value of insurance in force) is from Stalson, Marketing Life Insurance, p. 800.

⁴⁰ Hunter, "Methods of Making Mortality Investigations, pp. 268-9.

⁴¹ Hunter, "Methods of Making Mortality Investigations," p. 253. The next passage quoted is from pp. 252-3.

⁴² E.g., Metropolitan Life's Ordinary Insurance Section [Metropolitan Life Insurance Company, The Metropolitan Life Insurance Company: Its History, Its Present Position in the Insurance World. Its Home Office Building and Its Work Carried on Therein (New York: The Metropolitan

Life Insurance Company, 1914), p. 70].

⁴³ Henry N. Kaufman "Some Uses for the Hollerith Machines," Transactions of the Actuarial Society of America 11 (1909-10), 276-295; quote is from p. 291. Kaufman's company is not identified in this article, but a Nov. 9, 1911 letter from Kaufman to Herman Hollerith on the latter's retirement (Container #10, Hollerith Collection, Library of Congress) reveals his title and affiliation a year later, which was probably the same. Phoenix was ranked 19th out of 214 firms in 1910 (Stalson, Marketing Life Insurance, pp. 800, 821.

⁴⁴ Kaufman, "Some Uses for the Hollerith Machines," p. 278. While it is generally assumed that machines could always be rewired, the detailed description provided in Kaufman's article on accumulator configuration and attachments makes clear that at this point fields defined for accumulating (as opposed to counting) could not be changed by simple rewiring.

⁴⁵ Nov. 25, 1912, C.L. Hayes to Mr. Braitmayer; Dec. 3, 1912, Braitmayer to Hayes, Container #10, Hollerith Collection, Library of Congress.

⁴⁶ Kaufman, "Some Uses for the Hollerith Machines," p. 279.

⁴⁷ Metropolitan Life, The Metropolitan Life Insurance Company: Its History, Its Present Position in the Insurance World. Its Home Office Building and Its Work Carried on Therein (New York: The Metropolitan Life Insurance Company, 1914), p. 70.

⁴⁸ Chandler, Scale and Scope, pp. 8, 35.

⁴⁹ Austrian, Herman Hollerith, pp. 238-256.

⁵⁰ Bashe et al, IBM's Early Computers, pp. 9-10; Campbell-Kelly, ICL, p. 69.

⁵¹ "Report on the Royden System of Perforated Cards," Mar. 9, 1912, addressed to the President's Commission on Economy and Efficiency, signed by M.O. Chance, F. H. Tonsmeire, and E.H. Maling, located in Container #3, the Hollerith Collection, Library of Congress. Prospectus for a new company, The Royden Company, intended to take over these patents (this attempt probably failed, since I have found no further references to a company of that name, but Peirce Patent Company continued to exist and to manufacture machines), with 24 Sept. 1912 cover

letter from Arthur C. Sherwood to James R. Morse, located in Container #10, Hollerith Collection, Library of Congress.

⁵² W.E. Freeman, "Automatic Mechanical Punching, Counting, Sorting, Tabulating and Printing Machines Adaptable to Various Lines of Accounting and Statistical Work Essential for Public Service Corporations with Particular Reference to Improvements in the Art of Mechanical Accounting," paper presented at the annual convention of the National Electric Light Association, San Francisco, CA, June 7-11, 1915.

⁵³ Percy C. H. Papps, "The Installation of a Perforated Card System with a Description of the Peirce Machines," Transactions of the Actuarial Society of America 15 (1914), 49-61; for Mutual Benefit's earlier interest in tabulating, see Austrian, p. 324. Mutual Benefit ranked 8th in value of insurance in force in 1910 and 1915 (Stalson, Marketing Life Insurance, p. 800).

⁵⁴ The company's public account of when Peirce was retained was contradictory [Louis I. Dublin, A Family of Thirty Million: The Story of the Metropolitan Life Insurance Company (New York: Metropolitan Life Insurance Company, 1943), pp. 253 and 397], suggesting as early as 1907 and as late as 1913, but the absence of anyone from the Metropolitan on the 1912 prospectus's list of individuals who had approved the Peirce system suggests that the latter date is most likely.

⁵⁵ June, 1914 letter quoted in Austrian, pp. 332-3.

⁵⁶ "Tabulating Machine Co. Operating Revenue and Operating and Selling Expense, 1909 to 1913," Container #10, Hollerith Collection, Library of Congress.

⁵⁷ Papps, "The Installation of a Perforated Card System...."

⁵⁸ Metropolitan Life, Its History..., pp. 71-2.

⁵⁹ Series of contractual letters between J. Royden Peirce and J.M. Craig, Actuary for Metropolitan Life, dated May 29 through June 23, 1913. Peirce Machine Matter, Cabinet 2, Metropolitan Life Archives. Commentary by J.D. Craig on Percy C. H. Papps, "The Installation of a Perforated Card System with a Description of the Peirce Machines," Transactions of the Actuarial Society of America 15 (1914), pp. 409-413.

⁶⁰ Undated, unsigned internal report [probably from Mr. Washington] to the Third Vice President [Mr. Henry Bruere]. Context and other references to it make 1916 the likely date. In it, he notes that "Mr. Pierce [sic] is now nearly finished with the work he is doing for the Actuarial Division." He also notes the final cost of the key machine. In Peirce Machine Matter, Cabinet 2, Metropolitan Life Archives.

⁶¹ 12 February 1918, Vice President Hegeman to J. Burn, Actuary of Prudential Assurance Company, Ltd., Peirce Machine Matters, Cabinet 2, Metropolitan Life Archives.

⁶² "A Study of the Peirce Machines," pp. 5-6, Peirce Machine Matters, Cabinet 2, Metropolitan Life Archives.

⁶³ Copies of the report to the President's Commission on Economy and Efficiency and the prospectus for the Royden Company were in Hollerith's papers and stamped "Personal/H.H.," indicating that Hollerith was following Peirce's progress. The letter from Gershom Smith to Thomas J. Watson attests to the concern of Hollerith's successors. Both in Hollerith Collection, Container #10, Library of Congress.

⁶⁴ Austrian, Herman Hollerith, pp. 272-4.

⁶⁵ A certain amount of patent litigation took place between the Hollerith and Powers organizations in the U.S. and in Europe, but ultimately, a cross-licensing arrangement was reached for use of the basic tabulating patents, removing them from the competitive arena. Some later patents that were relevant to the competition will be noted as necessary. (James Connolly, A History of Computing in Europe (NY: IBM World Trade Corporation, 1967), p. 13; Campbell-Kelly, pp. 35, 64, 88-90.)

⁶⁶ Norberg, "High Technology Calculation," p. 765.

⁶⁷ E.g., see samples in Home Office Study Committee, Cabinet 13, Metropolitan Life Archives.

⁶⁸ "Powers Machinery: Origin and Development," The Prudential Bulletin (December, 1934), pp. 2664-5.

⁶⁹ 20 November 1924, [Henry] Bruere, 3rd Vice President, to James D. Craig, Actuary; 22

November 1924, Craig to Bruere; 25 November 1924, Bruere to Craig. All in Home Office Study Committee, Cabinet 13, Metropolitan Archives.

⁷⁰ Martin Campbell-Kelly, "Large-Scale Data Processing in the Prudential," pp. 128-130.

⁷¹ 7 November 1917, J. Burns to Mr. Hegeman, Vice President, Metropolitan Life, Peirce Machine Matters, Cabinet 2, Metropolitan Archives.

⁷² Campbell-Kelly, ICL, pp. 44-45.

⁷³ Freeman, "Automatic Mechanical Punching, Counting, Sorting, Tabulating and Printing Machines [...]."

⁷⁴ Campbell-Kelly, ICL, pp. 35-6.

⁷⁵ Bashe et al., IBM's Early Computers, pp. 7-8.

⁷⁶ An internal comparison of Powers, Hollerith, and Peirce equipment at the Metropolitan in the mid-twenties revealed a clear preference for the verifier over other methods of verifying accuracy, but other issues, including printing and alphabetical printing capability, were more important. Feb. 2, 1926, report to Mr. Dobbins, file copy unsigned, in Home Office Study Committee, Cabinet 13, Metropolitan Life Archives.

⁷⁷ Charles J. Bashe, Lyle R. Johnson, John H. Palmer, and Emerson W. Pugh, IBM's Early Computers (Cambridge, MA: The MIT Press, 1986), p. 9, dates the introduction to 1921, while Campbell-Kelly, "Punched-card Machinery," p. 141, says it was introduced in 1920. Campbell-Kelly speculates that the long delay between the introduction of the Powers printing tabulator in 1915 and the first IBM printing tabulator, the Type I with automatic control, in 1920 reflected not just the first world war and the time required to develop printing and automatic control devices, but also IBM's intentional holding back from the market to delay making its non-printing machines obsolete (Campbell Kelly, ICL, pp. 63-4). George Jordan, in "A Survey of Punched Card Development," (master's thesis, Massachusetts Institute of Technology, 1956), argues that C-T-R continued to produce its standard machinery to fill high war-time demand, then faced a post-war crisis of surplus machinery on its hands. The development of its own printing tabulator responded

to this crisis, again expanding demand.

⁷⁸ Campbell-Kelly, "Punched-Card Machinery," p. 142.

⁷⁹ Undated document from A.C. Carpenter in material from 1923-26, Home Office Study Committee, Cabinet 13, Metropolitan Archives.

⁸⁰ Quoted in 22 November 1924 memo from James D. Craig to Mr. Bruere, Home Office Study Committee, Cabinet 13, Metropolitan Archives.

⁸¹ This document, identified as an address by B.F. Dvorak for the Life Office Management Association, Fort Wayne, Ind., was filed with Metropolitan Life materials from around 1926, Home Office Study Committee, Cabinet 13, Metropolitan Life Archives. An earlier document refers to Dvorak as a Powers representative, but his status at the time of the paper is unclear.

⁸² A 21 December 1925 report on the Addressograph from Mr. Washington to Mr. Dobbins, 4th Vice President of Metropolitan Life, discusses the use of these systems by other insurance firms (Metropolitan Life Archives, Home Office Study Committee, Cabinet 13). He notes that "nearly all of the smaller companies and most of the larger companies use the Addressograph," and he discusses its use by five specific companies, all of which adopted it between 1913 and 1920. See also, for example, Equitable Life Insurance Society, The Home Office of the Equitable: Description of Departments (New York: Equitable Life Assurance Society of the U.S., 1916), pp. 124-5. For a brief history and description of addressing equipment, see William Henry Leffingwell, ed., Office Appliance Manual (National Association of Office Appliance Manufacturers, 1926), pp. 409-450.

⁸³ 20 May, 1913, drawings marked "Confidential" and "Peirce Patents Company," Metropolitan Life Archives, Peirce Machines Matters, Cabinet 2.

⁸⁴ 18 December 1916, J. Royden Peirce to James M. Craig, Actuary, Metropolitan Life, Peirce Machine Matters, Cabinet 2, Metropolitan Life Archives.

⁸⁵ The history of Peirce's other contracts is traced in a 1 March 1926 internal Metropolitan Life report, "A Study of the Peirce Machines", Peirce Machine Study, Cab. 2, Metropolitan Life

Archives. See also 21 January 1919 and 5 February 1919, Peirce to Metropolitan Life, with attached notes from Metropolitan executives, Peirce Machine Matters, Cabinet 2, Metropolitan Life Archives.

⁸⁶ 7 November 1924, unsigned memorandum addressed to Home Office Study Committee, in Home Office Organization Study, Cabinet 13, Metropolitan Life Archives.

⁸⁷ 22 December 1924, J. D. Craig to Mr. Henry Bruere, Third Vice-President and chairman of the Home Office Study Committee, in Home Office Organization Study, Cabinet 13, Metropolitan Life Archives.

⁸⁸ 1 March 1926, "A Study of the Peirce Machines," pp. 58-59, Peirce Machine Study, Cab. 2, Metropolitan Archives.

⁸⁹ Campbell-Kelly, ICL, pp. 43-45.

⁹⁰ "Powers Machinery: I. Origin and Development" (first of a six-part series), The Prudential Bulletin (December, 1934), p. 2665.

⁹¹ Campbell-Kelly, ICL, p. 48.

⁹² Campbell-Kelly, ICL, p. 45.

⁹³ "Report on Perforated Card Systems of English Companies, January 1924" (dated December 13, 1923 at the end of the report itself), item 63.33.3, Cabinet 2, Metropolitan Life Archives.

⁹⁴ Campbell-Kelly, ICL, pp. 45, 51-52.

⁹⁵ "Report on Perforated Card Systems of English Companies, January, 1924," (contrary to the title, the report itself is dated December 13th, 1923; presumably it was written in December, possibly in England, but only typed and delivered on the contingent's return) 63.33.3, Cab. 2, Metropolitan Life Archives. It is unclear whether Powers AMC ever marketed this 13 character version.

⁹⁶ "Report on Perforated Card Systems of English Companies," p. 2. Actually, "full" alphabetic tabulators generally printed 24 letters, using the same character for U and V and the same character for S and 5.

⁹⁷ Home Office Organization Study, 1924, Cabinet 13, Metropolitan Life Archives. See especially entries for June 13-July 12, pp. 52-56. This notebook, assembled by the office of Henry Bruere, 3rd Vice President and chairman of the committee, includes logs of meetings and phone calls as well as copies of memos and reports exchanged. The study was initiated to address a space crisis in the home office. Mechanization of clerical processes was seen as one way to save space.

⁹⁸ April 2, 1925, Metropolitan Life Archives. The date probably refers to the date on which the sample sheet was created, not the date on which this machine was first successfully run. Standard treatments of the history of tabulating equipment date introduction of alphabetical tabulating by Powers to 1924 (Campbell-Kelly, "Punched-Card Machinery," p. 142; Norberg, "Punched Card Machinery in Business and Government," p. 768), and the log of the Home Office Study Committee places the first successful demonstration of the alphabetical attachment on November 19, 1924 (see pp. 66-71).

⁹⁹ June 16-July 12, 1924 (pp. 55-56), Home Office Organization Study, Jan. 1924, Cabinet 13, Metropolitan Life Archives. Later entries in the committee logs indicate that patent issues became more problematic later, as IBM informed Metropolitan Life that their Peirce patents invalidated Powers AMC's patents (July 9, p. 56; Sept. 1-8, p. 61; Dec. 1-31, p. 72). The meeting between Mr. Bruere and Mr. Pritchard of Powers AMC is described in the entry dated Dec. 1-31, p. 72.

¹⁰⁰ Bashe et al, pp. 9-10. For the next several years, Peirce continued to work independently with the Metropolitan, overseeing work in the separate machine shop they had set up for him, at the same time that he worked for IBM on developing alphabetical tabulating. Eventually, IBM took over Peirce's Metropolitan contract, as well as Peirce's contracts with the American Prudential and with the Veterans Bureau.

¹⁰¹ Bashe et al, IBM's Early Computers, p. 10.

¹⁰² Campbell-Kelly, "Punched-Card Machinery," p. 142.

¹⁰³ Connolly, A History of Computing in Europe, p. 25.

¹⁰⁴ Campbell-Kelly, ICL, p. 82.

¹⁰⁵ Log book entry for 1-21 December 1924, p. 72, Home Office Study Committee, January 24, 1924, Cabinet 13, Metropolitan Life archives.

¹⁰⁶ Norberg, "High Technology Calculation," p. 771. This momentum was more a business momentum than a technological momentum, in the sense of Thomas P. Hughes (Networks of Power, pp. 15, 140-174). Both technological approaches to punched-card tabulating, electrical and mechanical, remained available, but IBM dominated the market.

¹⁰⁷ Saul Engelbourg, International Business Machines: A Business History (NY: Arno Press, 1976). pp. 316-7.

¹⁰⁸ Campbell-Kelly, ICL, p. 65; Jordan, "A Survey of Punched Card Development," pp. 31-2, 52; "Parade of the Business Machines," Business Week (October 19, 1935), p. 11 (quote is from this source); "Ways and Means" (an in-house newsletter issued by Metropolitan Life's Standardization Bureau) 4 (August 1948), p. 1.

¹⁰⁹ "Renewal Premium Notices and Receipts and Premium Billing Routines," prepared by L.O.M.A. Staff Office, Report No. 2 of the Office Machinery and Equipment Committee of the Life Office Management Association, September 1, 1938.

¹¹⁰ For example, L.O.M.A. Bulletin 17 (1951) includes three items about conversions of billing operations to punched cards: May 15, p. 25; July 15, p. 40; Nov. 15, pp. 63-64.

¹¹¹ While I have not been able to locate figures reflecting what percentage of the tabulating market the life insurance industry accounted for, it certainly accounted for some of the largest single users of the equipment, including Metropolitan Life. As a possible index to its importance, we can look at the first firms to computerize, all of which were major users of tabulating equipment. After government agencies and universities, insurance was the second commercial customer to have a Univac (the first commercially available large digital computer) installed; the life insurance industry accounted for one quarter of all acquirers of Univacs in 1954, the first year of commercial deliveries, and 1955 (Yates, "From Tabulators to Early Computers in the U.S. Life Insurance

Industry: Co-evolution of Data Processing Technology and its Use," paper delivered at the Society for the History of Computing annual conference, October, 1993. While this figure clearly overstates life insurance's share of the total tabulating market, which included many firms and organizations with much smaller installations which would not have jumped into the computer market right away, it does indicate how significant insurance was among large users of data processing equipment.

112 Campbell-Kelly, ICL, pp. 54-55.

113 Campbell-Kelly, ICL, pp. 129-130.

114 MacLeod, "Strategies for Innovation," p. 301.

115 Campbell-Kelly, ICL, pp. 63-4.