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Mobilizing Venture Capital during the Second Industrial Revolution: Cleveland, Ohio, 1870-1920

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Abstract

During the Second Industrial Revolution of the late nineteenth and early twentieth centuries, Midwestern cities were important centers of innovation. Cleveland, the focus of this study, led in the development of a number of key industries, including electric light and power, steel, petroleum, chemicals, and automobiles, and was a hotbed of high-tech startups, much like Silicon Valley today. In an era when production and invention were increasingly capital-intensive, technologically creative individuals and firms required greater access to funds than ever before. This paper explores how Cleveland's leading inventors and technologically innovative firms obtained financing. We find that formal financial institutions, such as banks and securities markets, were of only limited significance. Instead our research highlights the vital role played by a small number of successful local enterprises that both exemplified the wealth-creation possibilities of the new technologies and served as hubs of overlapping networks of inventors and financiers. We conclude by suggesting that such nodal firms have spawned important clusters of innovative enterprises in other places and times as well.

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Since the early nineteenth century the U.S. economy has benefited from a legal, economic, and cultural environment that strongly encouraged technological innovation. Nonetheless, there has been substantial change over time in the way new technological ideas have been generated and exploited. Although the dominant practice in the early nineteenth century was for inventors to commercialize their ideas themselves, during the middle two quarters of the nineteenth century a growing division of labor emerged between those who invented and those who exploited inventions commercially. Most new developments during this period involved mechanical technologies, and as a consequence the amount of capital and formal education that an inventor needed to set up shop was relatively low. Innovative firms eagerly sought patent rights to cutting-edge technologies, and many creative individuals learned to support themselves as independent inventors by selling their intellectual property in the market. By the end of the century, however, the more science-based technologies associated with the second industrial revolution had significantly raised the capital requirements (both human and physical) for effective invention, and inventors found it increasingly difficult to maintain their independence.[1]

The result was a general tendency for inventors to move inside firms, with some of the most productive taking positions that allowed them to continue to specialize in invention. This development is conventionally associated with large firms' creation of R&D laboratories, but as we show in this article, there is more to the story. Although some productive inventors took employment positions in the research departments of large-scale enterprises, others became principals in start-ups or spin-offs formed to exploit their inventions. These firms were organized with the aim of commercializing a particular line of technology with the inventor's assistance, but typically inventors obtained space and resources to continue their work of technological discovery—facilities that might subsequently evolve into R&D labs.

New firms, we argue, provided much of the technological leadership in second-industrial-revolution industries. This leadership was especially pronounced in the East North Central region of the country. Indeed, the formation of new firms seems to have thrived in areas located, much like Silicon Valley in the late twentieth century, at a significant distance from the nation's main capital markets and established financial institutions. It is thus of particular interest to understand the locational dynamics of this phenomenon—how inventors in such a region were able to attract the attention and resources of those with capital, why investors there were willing to risk funds in such ventures, and what the role of formal financial institutions was in supporting the formation of new firms.

[1] See Lamoreaux and Sokoloff (1999b, 2003, 2005, 2006 forthcoming).

Such questions can often best be answered through detailed local studies that make it possible to track the financial sources tapped by individual inventors and firms. Here we focus our analysis on Cleveland, Ohio, a city that played a leading role in the development of a remarkable number of second-industrial-revolution industries, including electric light and power, steel, petroleum, chemicals, and automobiles. We first provide an overview of Cleveland's industrial and financial development and then place our case study in context by comparing data on inventors in Cleveland with similar information we have collected for a nationwide sample of patentees. As we show, inventors in Cleveland conformed to a larger Midwest pattern during the late nineteenth and early twentieth centuries. Like other inventors in the East North Central region, they seem to have become increasingly associated with new enterprises formed for the purpose of exploiting their inventions.

The national data indicates that even inventors who were later very successful found it difficult early in their careers to make the connections they needed to form such enterprises—that they had to establish themselves (and the worth of their ideas) before financiers were willing to provide the necessary backing. A key problem then is to understand how inventors were able to establish themselves in a context where the cost of engaging in technological discovery was rising steeply. Our research on Cleveland highlights the important role in the training, cultivation, and publicizing of young inventors played by a small number of successful local enterprises that both exemplified the wealth-creation possibilities of new technologies and served as hubs of overlapping networks of inventors and financiers. The heart of our paper focuses on one of the most important of these hubs—the Brush Electric Company. We show how such the Brush Electric Company served multiple functions for the inventors who gathered at its facilities. On the one hand, it fostered technological cross-fertilization and the exchange of ideas about how to solve particularly difficult problems. On the other hand, it was a place where the technological community could pass on—validate—promising ideas and thus perform a useful vetting function for local capitalists. This validation not only opened up sources of venture capital for start-up firms connected to the "hub" or nodal firm, but also plugged these enterprises into the network of formal financial institutions that local capitalists were simultaneously building. In this way, start-ups were able to gain access to commercial credit and also to the possibility of raising additional capital in local equity markets.

Brush was not the only hub enterprise in Cleveland. The last section of the paper broadens the analysis by describing the network that formed around another important Cleveland businesses, the White Sewing Machine Company. Nor was Cleveland the only city that gave rise to such hubs. We conclude by connecting our study with other scholarship emphasizing the vital role that nodal firms have played in spawning clusters of innovative enterprises in different places and times.

The Rise of Cleveland's Manufacturing and Financial Sectors

Located on Lake Erie at the terminus of the Ohio Canal, Cleveland had long been the commercial center of northeastern Ohio. Cleveland's first heavy industrial enterprise, a firm that produced steam furnaces, was founded in the 1830s, and its first iron rolling mills were built in the 1850s, but the city's rise as a manufacturing center was largely a post-Civil War phenomenon (Miller and Wheeler 1990). As late as 1870 Cuyahoga County, where Cleveland is located, ranked number twenty-two in manufacturing output among counties nationwide; by 1920 it had risen to fourth place (over the same period Cleveland's ranking in terms of population rose from 20 to 7). Intriguingly, although the average size of firms in the county rose over the same period, the local economy continued to be characterized by relatively small enterprises (see Table 1). In 1870 the county ranked sixty-sixth among the hundred largest manufacturing counties in terms of the average number of workers employed per establishment. In 1920 its rank on this

Table 1. MANUFACTURING IN CUYAHOGA COUNTY, OHIO, 1860 -1920

Year	Ranking by Average Firm Size out of Top 100 Manufacturing Counties	Manufacturing Output ($000)	Average Number of Workers per Firm	Average Number of Workers per Firm, Top 100 Manufacturing Counties
1850	NA	884	NA	NA
1860	59	6,973	11.5	15.76
1870	66	27,049	8.8	13.79
1880	44	50,910	17.9	18.27
1890	35	116,466	21.5	16.43
1900	20	156,760	23.2	17.33
1910	NA	NA	NA	NA
1920	52	1,158,922	53.5	47.84

Source: U.S. Bureau of the Census, Historical Census Browser. Retrieved 28 July 2006, from the University of Virginia, Geospatial and Statistical Data Center: http://fisher.lib.virginia.edu/collections/stats/histcensus/index.html.

scale was still only fifty-two. Although some Cleveland enterprises grew very large, high rates of formation of new firms kept the average size of firms low.[2]

Many of the new firms founded in Cleveland during the late nineteenth and early twentieth centuries were in industries associated with the second industrial revolution. Cleveland's location gave it convenient access to Lake Superior iron ore, so it is not surprising that iron and steel was the city's leading industry (in terms of value of output) throughout the nineteenth century, falling to second place in 1910 and to third in 1920 (see Table 2). Machine tools was also persistently among the city's top three industries throughout the period 1870 to 1920. By 1910, however, automobiles had become the third largest industry, and it would climb to number one by 1920. During that same decade electrical machinery rose to fourth place, so that the city's top industries by 1920 were automobiles, machine tools, iron and steel, and electrical machinery. Another industry with a major presence in the city and its surrounding areas was chemical products, such as paints and varnishes.[3]

Cleveland's financial sector also grew rapidly over the half-century between 1870 and 1920. In 1870 the city was home to five national banks, most of which were originally founded in the 1840s, and one very substantial savings institution, the Society for Savings (founded in 1849). By 1920 the city was home to thirty-eight banks, savings institutions, and trust companies with total deposits amounting to more than $800 million. More than a dozen national banks were founded during this period, though because of mergers, the net gain in number over the entire period was only two. After the Ohio legislature passed enabling legislation, a dozen trust companies were organized, eleven of which remained active through the period. An 1868 law permitting the formation of building-and-loan and savings-and-loan associations stimulated a rash of entry, but many of these institutions were short-lived.[4]

Since the chartering in 1816 of the Commercial Bank of Lake Erie, the city's leading businessmen had long been active in founding its most important financial institutions, so it is not surprising that industrialists played significant

[2] From 1880 to 1900 the number of firms in Cuyahoga County tripled with little or no change in their average size. During the first decade of the twentieth century, however, the number of firms in the city fell by a third, despite continued growth in employment and output. As a consequence, average firm size nearly doubled. Between 1910 and 1920, however, the number of firms rebounded and the average size of firms did not change. U.S. Bureau of the Census, Historical Census Browser, retrieved 28 July 2006, from the University of Virginia, Geospatial and Statistical Data Center: http://fisher.lib.virginia.edu/collections/stats/histcensus/index.html.

[3] Cleveland was also, of course, the home of Standard Oil, and petroleum refining was the city's third largest manufacturing industry in 1890. As the locus of crude-oil production shifted to other regions, however, the city's refining capacity declined.

[4] "Banks and Savings and Loans," *Encyclopedia of Cleveland History*; "Banks and Finance: The Solid Institutions of a Prosperous City," *Cleveland Plain Dealer*, 14 July 1892, p. 13.

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Table 2. CLEVELAND'S LARGEST INDUSTRIES, 1870-1920

Industry Rank	1870	1880	1890	1900	1910	1920
1	Coal, rectified	Iron and steel	Iron and steel	Iron and steel	Iron and steel, steel works, and rolling mills	Automobiles
2	Iron, forged and rolled	Slaughtering and meatpacking	Foundry and machine-shop products	Foundry and machine-shop products	Foundry and machine-shop products	Foundry and machine tools
3	Flour-mill products	Foundry and machine-shop products	Petroleum Refining	Slaughtering and meatpacking, wholesale	Automobiles	Iron and steel
4	Meat, packed pork	Clothing, men's	Slaughtering and meatpacking, wholesale	Clothing, women's factory product	Slaughtering and meatpacking	Electrical Machinery
5	Iron, castings (not specified)	Liquors, malt	Carpentering	Liquors, malt	Clothing, women's	Clothing, women's

Notes and Sources: U.S. Bureau of the Census, *Census of the United States*, 1920, and U.S. Census Office, *Census of the United States*, 1850-1910. The 1870 data are for Cuyahoga County. All other years are for the city of Cleveland.

roles in organizing and running many of the banks and trust companies formed after 1870.[5] For example, Robert Hanna helped to organize the Ohio National Bank in 1876, eight years after founding the Cleveland Malleable Iron Company. His nephew and partner, Marcus Hanna, organized the Union National Bank in 1884, served as its president for at least a decade, and also subsequently served on the board of the Commercial National Bank, the Guardian Trust Company, and the People's Savings and Loan Association.[6] Similarly, C. A. Grasselli, a leading chemical manufacturer, was founder and president of the city's first trust company, Broadway Savings and Trust (1884), and also its second trust company, Woodland Avenue Savings and Trust (1886).[7] Prominent among the founders of the Cleveland Trust Company (1895) were Fayette Brown, president of the Brown Hoisting Machine Company, and Jacob D. Cox, owner of the Cleveland Twist Drill Company. Brown's son, Harvey H. Brown, who replaced him as president of the Hoisting Company, served on the board of the Bank of Commerce.[8] Many savings institutions also had industrialists among their organizers. For example, the founding board of directors of the Detroit Street Savings and Loan included Theodor Kundtz, an inventor and manufacturer of sewing-machine cabinets and auto bodies, and E. R. Edson, an inventor and manufacturer of machinery for extracting oil and other products from fish.[9]

Undoubtedly the industrialists who founded these banks, trust companies, and savings institutions aimed to benefit their own enterprises, but it seems that they were primarily concerned with increasing their access to working capital. In any event, the institutions they created supported the city's industries mainly by providing firms with short-term commercial credit. Although they sometimes assisted new firms in other ways, for example by handling their bond issues or accepting their securities as collateral for loans to individuals, the extant records suggest that such aid was not central to the financing of new firms.[10]

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[5] *Cleveland Plain Dealer*, 14 July 1892, p. 13.

[6] *Cleveland Plain Dealer*, 14 July 1892, pp. 1, 6, 13; "Eberhard Manufacturing Company," "M. A. Hanna Company," and "Marcus Alonzo Hanna," *Encyclopedia of Cleveland History*; Croly (1965).

[7] "Our Prominent Men: Leading Spirits of the Younger Financial Institutions," *Cleveland Plain Dealer*, 22 March 1887, p. 1. See also 7 July 1892, p. 13.

[8] Minutes of the Board of Directors of the Cleveland Trust Company, 1903-1906, Folder 125, Container 12, Ameritrust Corporation Records, Ms. No. 4750, Western Reserve Historical Society Manuscript Collections.*Cleveland Stock Exchange Handbook*, 1903.

[9] *Cleveland Stock Exchange Handbook*, 1903; Minutes of the Detroit Street Savings & Loan, 1895-1901, Folder 1, Container 1, Ameritrust Corporation Records.

[10] For example, in May of 1904 Cleveland Trust underwrote $15,000 in bonds for the Addresso Printograph Company and $10,000 in bonds for the Brilliant Electric Company. In March of 1905 it underwrote $30,000 in bonds for the Whiting Electric Company. Cleveland Trust regularly underwrote much larger bond issues for more established local enterprises, however. For example, for the Wellman-Seaver-Morgan Company it underwrote $800,000 in bonds in

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Cleveland's equity markets also developed during this period. Daily quotations of government bond prices first appeared in the *Cleveland Plain Dealer* in 1880, and by 1886 the daily lists included prices for the stocks of local banks, street railroad companies, iron mines, and "miscellaneous" securities, including industrials. Moreover, advertisements in the *Plain Dealer* offered shares for sale in companies such as the Cleveland Stock Yard Company, the Brush Electric Company, and Brush Electric Light and Power. The continued growth both of local brokerage houses and of trading in local securities resulted in 1900 in the formal organization of the Cleveland Stock Exchange. Although local brokers led the formation of the exchange, its founding members also included prominent Cleveland industrialists such as Harvey Brown, Jeptha Wade, and Daniel R. Hanna.[11]

As was the case for other exchanges at that time, railroads initially dominated the listings. Compared to the New York Stock Exchange, however, the Cleveland market from the beginning handled the securities of a more diverse set of firms. For example, 52 percent of the firms listed on the New York Stock Exchange in 1900 were railroads, and in 1910 the figure was still 48 percent. By contrast, railroads accounted for only 40 percent of the listings on the Cleveland exchange in 1903, and by 1910 the share had fallen to 15 percent.[12] This decline in the relative position of railroads on the CSE owed mainly to the listing of new banks, trust companies and utilities, including several local electric light companies and nine local telephone companies. Between 1910 and 1914, however, the number of manufacturing firms on the CSE more than doubled. The newly listed manufacturers included some of the most successful of the innovative firms formed over the previous several decades (American Multigraph; the Bishop-Babcock-Becker Company; Brown Hoisting Machine; National Carbon; Wellman-Seaver-Morgan, and the White Company).

The important point to underscore, however, is that these firms did not turn to the CSE to raise capital. Nor did their largest shareholders use the market to increase the liquidity of their investments. Trading in the equities of these manufacturing firms was at best light, and it seems that the listings were mainly

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June 1903, $400,000 in October 1903, and $1,100,000 in October 1905. Reports of the Cleveland Trust Company's Trust Department, 1903-1906, Folder 125, Container 12, Ameritrust Corporation Records.

We have found one example of an institution (the Fairmount Savings Bank) accepting shares of new firms as collateral for loans to individuals. Of the nearly 150 loans approved by the savings bank from July, 1903 to November, 1904 approximately 20 percent were backed by equities. Of these, about 50 percent were issued by small manufacturing enterprises. Journal of the Finance Committee of the Fairmount Savings Bank (1903), Folder 12, Ameritrust Corporation Records.

[11] *Cleveland Plain Dealer*, 5 Oct. 1900, p. 5.

[12] *Cleveland Stock Exchange Handbook*, 1903 and 1910; Cull and Davis (1994), p. 63.

useful to local brokers who from time to time had small lots of these securities to offer the public.[13] Although venture capitalists today often make their profits by taking firms public and then cashing out their investments, that does not seem to have been the practice in the early twentieth century. To the contrary, investors in start-up enterprises appear to have planned to receive their profits over the long run in the form of dividends on their shareholdings.

Cleveland Inventors in National Context

By the late nineteenth century Cleveland was a hotbed of patenting as well as a center of production in second industrial revolution industries. In 1900 it ranked eighth out of all U.S. cities in the total number of patents granted to residents. Moreover, if the calculation is limited to patents deemed by official examiners to have made significant contributions to the industrial art of the period, Cleveland was the fifth most technologically important city in the country (Fogarty, et al. n.d.). The purpose of this section is to set Cleveland's patenting record in the context of changes that were occurring in the organization of inventive activity across the United States. We show that inventors residing in Midwestern cities such as Cleveland were disproportionately likely to become principals in firms formed to exploit their inventions at a time when many productive inventors elsewhere appear to have been taking employment positions in large-scale enterprises.

As we have already suggested, the increase in patenting activity that occurred in the mid-nineteenth century U.S. was associated with a rise in the proportion of inventions attributable to highly productive inventors. Many talented individuals took advantage of the period's vibrant market for technology to specialize in the generation of inventions, financing their creative work by selling off the rights to their patents. By the early twentieth century, however, this "golden era of the independent inventor" was coming to an end, to a large extent, we argue, because the rising amount of capital (both human and physical) required for effective invention was making it increasingly difficult for inventors to survive on their own (Lamoreaux and Sokoloff 2006 forthcoming; Hughes 1989).

This change is visible in the assignment behavior of a nationwide sample of more than five hundred patentees.[14] The sample was generated, first, by drawing three random cross-sectionals from the lists of patents reported in the *Annual Reports of the Commissioner of Patents* for the years 1870-71, 1890-91, and 1910-11, and then, for those patentees whose last names began with "B," collecting data on all patents received by them during the twenty-five years before and

[13] *Cleveland Stock Exchange Handbook*, 1914. Daily trades on the exchange were reported once a week in the Cleveland journal, *Finance*.

[14] For further discussion and analysis of these samples, see Lamoreaux and Sokoloff (1999a, 2003, 2005, and 2006 forthcoming).

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Table 3. CHANGES IN THE DISTRIBUTION OF PATENTS IN THE "B" SAMPLE BY TYPE OF ASSIGNMENT AT ISSUE AND NUMBER OF CAREER PATENTS

Type of Assignment	Categories of Patentees by Career Patents			
	1-2 Patents (Col. %)	3-5 Patents (Col. %)	6-9 Patents (Col. %)	10+ Patents (Col. %)
Not Assigned				
1870-71 subsample	82.4	88.6	87.7	75.3
1890-91 subsample	72.9	70.5	60.6	45.6
1910-11 subsample	85.0	78.1	57.5	39.3
Assigned Partial Share to Individual				
1870-71 subsample	10.3	3.6	4.1	5.5
1890-91 subsample	10.0	11.6	12.8	3.9
1910-11 subsample	7.5	6.5	5.8	2.8
Assigned in Full to Individual				
1870-71 subsample	2.9	5.0	2.5	8.8
1890-91 subsample	2.9	8.5	6.4	9.6
1910-11 subsample	1.5	3.2	1.7	3.2
Assigned to Company with Same Name				
1870-71 subsample	0.0	0.0	0.0	1.7
1890-91 subsample	0.0	1.6	3.7	6.1
1910-11 subsample	0.0	0.0	5.8	24.6
Assigned to Large Integrated Company				
1870-71 subsample	0.0	0.0	0.8	1.2
1890-91 subsample	1.4	0.0	0.5	9.9
1910-11 subsample	0.0	1.9	0.0	14.8
Assigned to Other Local Company				
1870-71 subsample	1.5	0.7	2.5	4.5
1890-91 subsample	10.0	3.9	5.3	15.9
1910-11 subsample	1.5	3.9	15.8	8.4
Assigned to Other Non-Local Companies				
1870-71 subsample	2.9	2.1	2.5	2.9
1890-91 subsample	4.3	3.9	10.6	9.0
1910-11 subsample	3.9	6.5	13.3	7.0
Number of Patents (n)				
1870-71 subsample	*68*	*140*	*122*	*749*
1890-91 subsample	*80*	*129*	*188*	*2060*
1910-11 subsample	*133*	*155*	*120*	*1777*

Notes and Sources: The table is based on a longitudinal data set constructed by selecting all of the inventors whose family names began with the letter "B" from three random cross-sectional samples drawn from the *Annual Reports of the Commissioner of Patents* for the years 1870-71, 1890-91, and 1910-11. We then collected from the *Annual Reports* all of the patents received by these inventors during the twenty-five years before and after they appeared in the samples, including information on whether and to whom the patents were assigned. Companies to whom the patentees assigned their inventions were classified as follows: We first checked to see whether the assignee was a company with the same name as the patentee. If not, we classified as "large integrated companies" all assignees for which financial information was reported in the *Commercial and Financial Chronicle* or in *Poor's* or *Moody's Manual of Industrial Securities* (indicating that the company was important enough to tap the national capital markets) or, alternatively, that were listed in an early-1920s National Research Council directory of companies with research laboratories. The remaining companies were divided into two groups: "other local companies," if the assignee was located in the same city as the patentee; and "other companies" for all the rest.

after they appeared in our sample, including whether and to whom the patents were assigned at issue. Table 3 divides the inventors into three different subsamples or cohorts (according to the cross-section from which they were originally drawn) and also by the number of patents they obtained over their careers. It then categorizes each of their patents according to whether it was assigned at issue, and if it was, whether the assignment was in whole or part to an individual or to a company. Assignments to companies were classified in the following way. We first determined whether the assignee was a company with the same name as the patentee (indicating that the inventor was likely a principal in the firm). If not, we classified as "large integrated companies" all assignees for which financial information was reported in the *Commercial and Financial Chronicle* or in *Poor's* or *Moody's Manual of Industrial Securities* (indicating that the company was important enough to tap the national capital markets) or, alternatively, that were listed in an early-1920s National Research Council directory of companies with research laboratories. The remaining companies were divided into two groups: "other local companies," if the firm was located in the same city as the patentee; and "other non-local companies" for all the rest.

Perhaps the most striking feature of the estimates presented in Table 3 is the changing assignment behavior of the most productive patentees (those with 10 or more patents over their careers). By the 1910-11 cohort, specialized inventors were assigning more than 60 percent of their patents at issue, whereas inventors with 5 or fewer career patents were still only assigning about a fifth. Moreover, the identity of the assignees to which these productive inventors were transferring their patents was changing as well. In the 1910-1911 subsample, 24.4 percent and 40.5 percent of the patent assignments made by this group went respectively to large integrated companies and to firms that bore the name of the patentee. Indeed, virtually all of the patents assigned to large integrated companies came from inventors with ten or more career patents, and the share of this productive group in patents assigned to companies that bore the same name as the inventor was almost as high.

Table 4. CHANGES IN THE DISTRIBUTION OF PATENTS IN THE "B" SAMPLE BY TYPE OF ASSIGNMENT AT ISSUE AND REGION

Type of Assignment at Issue	Region: New England (Col. %)	Region: Middle Atlantic (Col. %)	Region: East North Central (Col. %)
Not Assigned			
1870-71 subsample	76.1	75.6	83.0
1890-91 subsample	24.7	58.1	51.3
1910-11 subsample	35.0	38.1	44.6
Assigned Share to Individual			
1870-71 subsample	3.7	5.5	8.3
1890-91 subsample	3.8	5.3	4.8
1910-11 subsample	3.7	2.0	3.1
Assigned in Full to Individual			
1870-71 subsample	10.6	8.3	2.3
1890-91 subsample	7.8	4.5	18.3
1910-11 subsample	5.2	3.2	2.1
Assigned to Company with Same Name			
1870-71 subsample	0.6	2.3	0.5
1890-91 subsample	3.4	5.0	6.8
1910-11 subsample	23.0	2.7	31.4
Assigned to Large Integrated Company			
1870-71 subsample	0.0	0.0	0.0
1890-91 subsample	15.5	9.4	3.8
1910-11 subsample	23.0	22.1	4.1
Assigned to Other Local Company			
1870-71 subsample	7.5	3.9	1.0
1890-91 subsample	30.8	9.5	10.6
1910-11 subsample	3.7	8.2	8.4
Assigned to Other Company			
1870-71 subsample	1.6	4.4	0.0
1890-91 subsample	14.1	8.2	4.4
1910-11 subsample	6.5	23.8	6.4
Number of Patents (n)			
1870-71 subsample	*322*	*434*	*218*
1890-91 subsample	*555*	*947*	*707*
1910-11 subsample	*383*	*601*	*1050*

Notes and Sources: See Table 3.

As Table 4 shows, these patterns had a pronounced regional character. Inventors, especially highly productive ones, in the Midwest (East North Central states) were disproportionately likely to assign their patents at issue to companies that bore their names:[15] 56.7 percent of their assignments went to such firms and only 7.4 percent to large integrated enterprises. The pattern in the Middle Atlantic was just the opposite, with 35.7 percent of assignments going to large firms and only 4.4 to companies with the inventor's name. New England was an intermediate case, with 35.4 percent of assignments going to large enterprises and an equivalent number to firms that shared the name of the inventor. Although regional differences in industrial composition might in principle account for these disparities, the same qualitative pattern holds when we control for the sectoral classification of the patents.[16]

That the increase in assignments to large firms did indeed represent a decline in the independence of inventors is suggested by the drop that occurred contemporaneously in what we call "contractual mobility"—that is, the number of different assignees to whom the inventor transferred his patents over the course of his career. As Table 5 indicates, after rising between the 1870-71 and 1890-91 cohorts, the proportion of patentees who assigned their patents at issue to four or more distinct assignees over their careers decreased between the 1890-91 and 1910-11 subsamples. The fall was greatest in the Middle Atlantic where the proportion of assignments going to large enterprises was highest. Intriguingly, contractual mobility actually increased in the Midwest, where inventors were most likely to assign their patents to firms that bore their name. It seems that patentees who were able to attract investment in enterprises formed to exploit their inventions were also able to maintain a significant degree of independence.[17]

As might be expected, inventors found it easier to obtain this kind of financial backing if they could demonstrate early in their careers that they had the

[15] Because the estimates in Table 4 were computed over all of the patents received by our sample of "B" inventors, it is the behavior of the more productive inventors that is most clearly reflected in our results. They received the most patents and thus weigh most heavily in these averages.

[16] As our theory would predict, inventors whose patents were classified as being in sectors that would normally be considered as having more technical or capital-intensive technologies, such as electricity/telecommunications or heavy industry, were much more likely to assign their patents at issue and to make assignments to large firms or firms that shared their name than those whose patents were in sectors such as light manufacturing or agriculture/food processing. The different patterns across sectors do not account for the regional differences, however. For example, inventors who received patents classified as electricity/telecommunications or as heavy industry were much more likely to assign them to large companies (as opposed to firms with the same name) if they resided in the Middle Atlantic than if they resided in the East North Central states.

[17] As we shall see from the data on Cleveland, the relatively high proportion of patents not assigned in this region might also be taken as an indication of independence.

Table 5. CHANGES IN THE CONTRACTUAL MOBILITY OF "B" PATENTEES, BY REGION

	Region of Patentee				
Number of Assignees at Issue	New England (Col. %)	Middle Atlantic (Col. %)	East North Central (Col. %)	Other U.S. (Col. %)	*n*
No Assignees					
1870-71 subsample	51.2	64.8	60.5	57.1	*87*
1890-91 subsample	25.7	42.4	36.7	41.7	*69*
1910-11 subsample	34.8	48.4	55.0	60.4	*111*
1 Assignee					
1870-71 subsample	39.0	18.5	26.3	14.3	*38*
1890-91 subsample	28.6	12.1	38.3	33.3	*49*
1910-11 subsample	17.4	29.0	13.8	27.1	*46*
2-3 Different Assignees					
1870-71 subsample	2.4	9.3	5.3	21.4	*11*
1890-91 subsample	25.7	25.8	16.7	12.5	*39*
1910-11 subsample	34.8	12.9	18.8	10.4	*36*
4+ Different Assignees					
1870-71 subsample	7.3	7.4	7.9	7.1	*11*
1890-91 subsample	20.0	19.7	8.3	12.5	*28*
1910-11 subsample	13.0	9.7	12.5	2.1	*20*
Number of Patentees (n)					
1870-71 subsample	*41*	*54*	*38*	*14*	*147*
1890-91 subsample	*35*	*66*	*60*	*24*	*185*
1910-11 subsample	*23*	*62*	*80*	*48*	*213*

Notes and Sources: See Table 3. Each patentee is represented in the table by one patent that was randomly selected from his list of career patents.

"right stuff"—that is, that they had the ability to generate economically valuable ideas. In Table 6, we look at how the assignment behavior of inventors with ten or more patents evolved over their careers, using the earliest patent as the beginning of each inventor's career.[18] For all three cohorts, there is evidence that patentees were better able to transfer their property rights later in their careers than at the beginning. The proportion of their patents that were not assigned at issue fell with the passage of years, as did the proportion of those assigned in which the

[18] Unfortunately, small cell sizes preclude a regional breakdown of this table.

Table 6. CHANGES IN THE DISTRIBUTION OF PATENTS IN THE "B" SAMPLE BY TYPE OF ASSIGNMENT AT ISSUE AND STAGE OF PATENTEE'S CAREER

	Stage of Career (Col. %)		
Type of Assignment at Issue	≤ 5 Years Since First Patent	> 5 Years and ≤ 15 Years Since First Patent	> 15 Years Since First Patent
Not Assigned			
1870-71 subsample	81.9	75.3	68.9
1890-91 subsample	62.0	52.7	36.6
1910-11 subsample	45.6	50.3	32.1
Assigned Share to Individual			
1870-71 subsample	6.2	6.7	3.6
1890-91 subsample	4.0	5.4	3.0
1910-11 subsample	6.9	4.0	0.9
Assigned in Full to Individual			
1870-71 subsample	4.1	11.4	10.8
1890-91 subsample	12.1	11.1	8.0
1910-11 subsample	7.2	3.1	1.9
Assigned to Company with Same Name			
1870-71 subsample	0.4	0.0	4.8
1890-91 subsample	2.2	4.2	8.4
1910-11 subsample	1.3	17.1	35.4
Assigned to Large Integrated Company			
1870-71 subsample	0.0	0.0	0.0
1890-91 subsample	7.1	6.3	12.9
1910-11 subsample	12.1	7.3	19.2
Assigned to Other Local Company			
1870-71 subsample	6.6	3.1	7.6
1890-91 subsample	8.4	15.1	18.6
1910-11 subsample	17.1	11.7	4.1
Assigned to Other Company			
1870-71 subsample	0.8	3.5	4.4
1890-91 subsample	4.3	5.4	12.6
1910-11 subsample	9.8	6.5	6.3
Number of Patents (n)			
1870-71 subsample	*243*	*255*	*251*
1890-91 subsample	*323*	*651*	*1086*
1910-11 subsample	*305*	*479*	*993*

Notes and Sources: See Table 3. Only patents awarded to patentees with ten or more career patents are included in this table.

patentee maintained an interest. There is also evidence that those who managed to find a market for their early inventions were better able to pursue successful careers at invention. Indeed, what is most striking about the evidence in the table is the disproportionate extent to which assignments to companies bearing the inventors' name occurred in the later phases of patentees' careers. For the last (1910-11) cohort, only 1.3 percent of the patents obtained by inventors in the first five years of their careers went to companies that bore the patentee's name. During the next ten years of their careers the figure increased to 17.1 percent and, after 15 years had elapsed, to 35.4 percent. There was a similar, though less pronounced, pattern in assignments to large integrated companies. Although inventors often had to establish track records before they could secure good R&D positions with large firms, it appears that it was especially important for them to prove their inventive skill, either as independent inventors or as employees, in order to obtain backing for start-up or spin-off ventures.

The goal of our case study of Cleveland is to obtain, through detailed analysis of local sources, a more concrete sense of how such talented inventors were able to attract the attention and funds of the businessmen who would commercialize their technological discoveries. Our first step, therefore, was to contextualize our study by exploring the extent to which patterns of inventive activity in Cleveland were similar to those in the Midwest as a whole. To this end, we collected data on patents awarded to the city's inventors over three three-year periods: 1884, 1885, and 1886; 1898, 1900, and 1902; and 1910, 1911, and 1912. Focusing our attention on the most productive of the patentees, we selected from the full set of Cleveland inventors those who patented a minimum number of patents during each set of years and collected all of their patents for specific sets of year, categorizing them according to whether or not they were assigned at issue and to whom.[19]

We used essentially the same classification scheme as for the national sample, except that our Cleveland data enabled us to do better than simply check whether the company to which the inventor assigned a patent bore his name. By consulting city directories, we were in most cases able to determine whether the inventors were principals or employees of the firms to which they assigned their patents or whether they had no such long-term attachments with their assignees. For many inventors, moreover, we were able to obtain additional information that provided insight into their patenting careers and the ways in which they obtained financing for their activities. This information came mainly from manuscript collections, histories of individual firms, biographies and autobiographies, specialized encyclopedias, and contemporary newspaper reports. Summaries for the 1898-1902 sample are reported in the Appendix.

[19] See the notes to Table 7 for the years included in each sample.

Table 7. DISTRIBUTION OF CLEVELAND PATENTS BY ASSIGNEE TYPE

	1884-1886 sample	1898-1902 sample	1910-1912 sample
Type of Assignee, if Any			
Not Assigned At Issue			
Number	306	395	271
Percent	(77.7)	(47.1)	(44.8)
Assigned to Individual			
Number	33	30	27.5
Percent	(8.4)	(3.6)	(4.5)
Assigned to Company where Patentee is Principal			
Number	6	148	118.5
Percent	(1.5)	(17.6)	(19.6)
Assigned to National Company			
Number	5	95	121
percent t	(1.3)	(11.3)	(20.0)
Assigned to Local Company			
Number	25	77	58
Percent	(6.3)	(9.2)	(9.6)
Assigned to Other Company			
Number	19	90	10
Percent	(4.8)	(10.7)	(1.7)
Total Number of Patents	*394*	*839*	*606*

Notes and Sources: The 1884-1886 sample (42 patentees) comprises inventors who were Cleveland residents and who received three or more patents during 1884, 1885, and 1886 (except for John Walker whose name was too common for us to make precise matches). It includes the patents they were awarded in those years, as well as in 1881, 1882, 1888, and 1889. The 1898-1902 sample (36 patentees) consists of inventors who were Cleveland residents, obtained a patent in 1900, and had a total of at least three patents in 1898, 1900, 1902, plus several inventors resident in Cleveland and prominent enough to be profiled in the *Dictionary of American Biography*. This sample consists of all patents the inventors were awarded in 1892 through 1912, except for the years 1895, 1901, and 1904. The 1910-1912 sample (107 patentees) consists of inventors resident in Cleveland who received a patent in 1912 and at least three patents during 1910, 1911, and 1912. The patent record for this sample consists of their total patents for these three years.

As Table 7 shows, Cleveland inventors displayed roughly the same pattern of assignments that we observed in our national sample for the East North Central states. The proportion of patents assigned at issue and the proportion assigned to companies rose in similar ways. For example, the 1910-11 subsample of East North Central inventors assigned at issue 55.4 percent of their patents, 91 percent of them to companies, compared to 55.2 percent and 92 percent for the 1910-12 Cleveland inventors. But there were also some discrepancies. For example, assignments to large integrated companies appear to have been relatively more common, and assignments to related companies (as indicated by the company's name or by the position of the inventor) somewhat less so, among Cleveland inventors than those in the East North Central as a whole. This difference may be attributable to Cleveland's status as one of the largest industrial cities in the region, a notion that receives some support from Tables 8a and 8b, which break down the inventors in the first two samples by the number of patents each obtained during this period. We see that assignments to large integrated companies were disproportionately the work of productive inventors who were employees of firms (or at least were not principals). For example, Clinton A. Tower, a foreman and pattern maker for the National Malleable Castings Company, assigned the bulk of the 17 patents he obtained in our sampled years to his employer (see Appendix). Because Cleveland was home to a significant number of large companies, it was also home to the inventors who worked for them.

More importantly, however, the evidence shows that many productive inventors in Cleveland, like their counterparts in the East North Central states as a whole, assigned their patents to firms that bore their name and/or in which they were serving as officers. Despite their close attachments to such firms, however, productive patentees in Cleveland seem to have been able to maintain a considerable degree of independence. In this way too, they resembled their counterparts throughout the region. Although our data do not allow us to calculate measures of contractual mobility, Tables 8a and 8b show that the assignment patterns of highly productive inventors who were principals in firms were very different from those of highly productive inventors who were not.[20] Most significantly, principals assigned a much smaller proportion of their patents at issue. If we focus our attention only on patentees from the 1898-1902 group who obtained more than 15 patents in the years sampled, those who were not principals assigned fully three quarters of their patents at issue whereas the figure for principals was less than 40 percent.[21] That members of the latter group were able to retain ownership of such a high fraction of their patents suggests that they maintained a remarkable degree of autonomy vis à vis the other owners of their firms. Because these other owners

[20] We break down the data only for 1884-1886 and 1898-1902 because we did not collect patents for additional years for the 1910-1912 sample.

[21] It is worth noting that our examination of the more comprehensive listings of patent assignments stored at the National Archives for several of these highly productive inventors (including Sidney Short and Elmer Sperry) suggests that a number of their patents were assigned after issue.

Table 8a. DISTRIBUTION OF PATENTS BY ASSIGNEE TYPE, PATENTEE PRODUCTIVITY, AND RELATIONSHIP TO ASSIGNEE: 1884-1886 CLEVELAND SAMPLE

	Category of Patentee				
	<=15 Patents and Principal	<=15 Patents and Not a Principal	>15 Patents and Principal	>15 Patents and Not a Principal	*Total*
Patentees (n)	(14)	(21)	(5)	(2)	*(42)*
Patents Not Assigned					
Number	76	87	131	12	*306*
Percent	(90.5)	(63.0)	(97.0)	(32.4)	*(77.7)*
Patents Assigned to Individual					
Number	4	26	0	3	*33*
Percent	(4.8)	(18.8)	(0.0)	(8.1)	*(8.4)*
Patents Assigned to Company where Patentee is Principal					
number	3	0	3	0	*6*
percent	(3.6)	(0.0)	(2.2)	(0.0)	*(1.5)*
Patents Assigned to National Company					
number	1	4	0	0	*5*
percent	(1.2)	(2.9)	(0.0)	(0.0)	*(1.3)*
Patents Assigned to Local Company					
number	0	18	1	6	*25*
percent	(0.0)	(13.0)	(0.7)	(16.2)	*(6.3)*
Patents Assigned to Other Company					
number	0	3	0	16	*19*
percent	(0.0)	(2.2)	(0.0)	(43.2)	*(4.8)*
All Patents					
number	*84*	*138*	*135*	*37*	*394*
row (%)	*(21.3)*	*(35.0)*	*(34.3)*	*(9.4)*	*(100.0)*

Notes and Sources: See Table 7.

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Table 8b. DISTRIBUTION OF PATENTS BY ASSIGNEE TYPE, PATENTEE PRODUCTIVITY, AND RELATIONSHIP TO ASSIGNEE: 1898-1902 CLEVELAND SAMPLE

	Category of Patentee				
	1-5 Patents	6-15 Patents	>15 Patents and Principal	>15 Patents and Not a Principal	*Total*
Patentees (n)	(6 patentees, 1 principal)	(9 patentees, 5 principals)	(13 patentees, all principals)	(7 patentees, no principals)	(35 patentees, 19 principals)
Patents Not Assigned					
number	9	41	269	76	*395*
percent	(60.0)	(49.4)	(61.1)	(25.3)	*(47.1)*
Patents Assigned to Individual					
number	2	6	14	8	*30*
percent	(13.3)	(7.2)	(3.2)	(2.7)	*(3.6)*
Patents Assigned to Company where Patentee is Principal					
number	0	21	119	11	*151*
percent	(0.0)	(25.3)	(27.0)	(3.7)	*(18.0)*
Patents Assigned to National Company					
number	0	0	9	86	*95*
percent	(0.0)	(0.0)	(2.0)	(28.7)	*(11.3)*
Patents Assigned to Local Company					
number	4	14	27	34	*79*
percent	(26.7)	(16.9)	(6.1)	(11.3)	*(9.4)*
Patents Assigned to Other Company					
number	0	1	2	85	*88*
percent	(0.0)	(1.2)	(0.5)	(28.3)	*(10.5)*
All Patents					
number	*15*	*83*	*440*	*300*	*838*
row (%)	*(1.8)*	*(9.9)*	*(52.5)*	*(35.8)*	*(100.0)*

Notes and Sources: See Table 7. The small number of assignments made by patentees classified as non-principals to firms in which the patentee was a principal involve cases where the patentee's status as principal was brief.

included the main suppliers of capital to their enterprises, the question naturally arises how inventors were able to secure financial backing under such circumstances.

Informal Finance is not Automatic

All too often the willingness of investors to provide early-stage finance is ascribed simply to personal connections, as if it were self-evident that entrepreneurs would be able to command the savings of their families, friends, or other people with whom they had close personal associations. Although entrepreneurs may generally have found it easier to raise funds from people who knew them well than from perfect strangers, even the closest members of their families were often reluctant to put their money into ventures exploiting untried inventions unless they had some way of determining that the technology was likely to work and have a market. Parents, for example, could be quite ruthless in insisting that their sons establish the worth of their ventures before providing financial assistance.

A good example is Jacob Dolson Cox, founder of the Cleveland Twist Drill Company.[22] His father, also named Jacob Dolson Cox, was a Civil War general, Governor of Ohio, Grant's Secretary of the Interior, and a railroad president. His mother was the daughter of the great revivalist preacher and longtime president of Oberlin College, Charles Grandison Finney. Despite the ostensible advantages of his parentage, Cox set out at the age of seventeen to learn the iron business the hard way, becoming a skilled machinist and iron worker through stints of hard labor at the Cleveland Iron Company and the Cuyahoga Steam Furnace Company. In 1876, while in Buffalo, New York, on a failed attempt to secure a supervisory job in an iron mill, he met C. C. Newton, an inventor of metal cutting tools whose shop was in nearby Dunkirk. Cox thought that the cutting-tool business was technologically promising, and Newton was badly in need of money. The two agreed to form a partnership and move the firm to Cleveland. Cox's father was not willing to give his son the necessary funds, but he did agree to lend him the initial capital investment of $2000 (at 7 percent interest) and also to provide help in the form of orders from his railroad for tools. As the firm grew and established itself, Cox was able to secure additional support from his family. His father-in-law, Judge S. B. Prentiss, lent him $9,000 in 1879 to buy out his partner, and Prentiss, and to a lesser extent Cox's father, provided additional funding that the company needed to weather some tough years during the mid-1880s and emerge as the nation's leading producer of twist drills.[23]

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[22] The following account is based on Cox's autobiography, *Building an American Industry*. Though published in 1951, the narrative was originally written in 1905. See also "Recollections . . . How Acme-Cleveland Began in 1876" and "Speech, December, 1975—Draft #2," Container 1, Folder 1, and Minutes of Stockholders' Meeting, 7 Feb. 1905, Records of the Cleveland Twist Drill Company, Container 2, Folder 21, Acme-Cleveland Corporation Records, 1869-1982, Mss. No. 4507, Western Reserve Historical Society Manuscript Collections.

[23] Cox seems to have been equally adamant that his own sons had to earn positions of responsibility in the Twist Drill Company and not obtain them as a birthright. See letters from J. D.

Alexander E. Brown, son of Fayette Brown, a prominent Cleveland merchant banker, iron dealer, and manufacturer, similarly had to prove himself before securing his father's backing.[24] Born in 1852, Alexander attended Brooklyn Polytechnical Institute in the early 1870s and then took a job from 1873-74 as chief engineer with the Massillon (Ohio) Bridge Company. While in the company's employ, he invented a method of using scrap iron and steel to build bridge columns. Returning to Cleveland, he attempted to pursue a career as an inventor, in part by working alongside the arc-lighting pioneer Charles F. Brush at the Standard Telegraph Company, but he found himself so strapped for funds that even word that the Patent Office had approved his application for a hoisting-machine patent brought him little joy. As he complained to his older brother Harvey H. Brown in 1880, "I have spent so much time and money on this case, in what was necessary, but which . . . is only a loss or expense to me." He begged Harvey, an iron ore dealer, to help him defray the cost of obtaining the patent and also of acquiring the Canadian rights, promising him in exchange a quarter interest in the patent. As he explained, "I have my Electric Lamp patents to get yet, and they will cost like 'sin' for I will have to get English and other patents for them."[25] Shortly thereafter his father, who was himself an accomplished inventor, recognized the potential of the hoisting-machine patent to revolutionize the handling of cargo on the Great Lakes, and stepped in to organize the Brown Hoisting & Conveying Machine Company with a capital of $100,000. Fayette Brown took charge as president of the company; Harvey also played a managerial role, assuming the presidency upon his father's death in 1910; and Alexander became vice president and general manager, a position that allowed him to continue his creative work. Over the course of his career Alexander secured hundreds of additional patents, most of them related to hoisting machinery.

Fayette Brown was able to recognize the value of his son's invention because he had a technical background. In most cases, however, family members lacked such expertise and, like outside financiers, had to find some way of ascertaining whether the particular technologies in which they were being asked to invest had promise. There were a variety of ways in which prospective investors could obtain such assessments, but one of the simplest was to tap into the discus-

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Cox to his sons dated 7 Dec. 1902 and 28 Jan. 1903, Container 1, Folder 3, Acme-Cleveland Corporation Records.

[24] The following account is based on "Brown, Alexander Ephraim" and "Brown, Fayette," *Encyclopedia of Cleveland History*; "Brown, Fayette," *Dictionary of American Biography*; and Rose (1950), pp. 437-8.

[25] Letter from Alexander E. Brown to Harvey H. Brown, 30 July 1880, Container 1, Folder 1, Harvey Huntington Brown Paper, 1848-1923, Mss. 3342, Western Reserve Historical Society Manuscript Collections.

sions that inventors themselves were having about exciting new discoveries.[26] In the late nineteenth century certain kinds of enterprises were particularly well placed to be focal points for such conversations.

Because their stores were gathering places for people who made and bought the vast variety of products that they stocked, hardware dealers were good places to obtain information about new products and production processes, as well as to attract investors for new ventures. One reason why Cox decided to move his cutting-tool business to the city was that he was already "well acquainted with the principal hardware dealers in Cleveland, George Worthington & Company, and Wm. Bingham & Company, and also with some of the bankers" (Cox 1951, 87). Although it is not certain that Cox himself obtained any advantage from these connections, Worthington and Bingham were in fact major promoters of Cleveland industry. Worthington had founded the Cleveland Iron Company in 1849, and he and Bingham together organized the Cleveland Iron and Nail Works in 1863. Bingham's son, Charles W., who was trained in geology, mining, and chemistry, later organized one of Cox's major competitors, the Standard Tool Company, as well as the Parrish & Bingham Company, a producer of bicycle parts.[27] Similarly, two of the founders of the Cleveland Cap Screw Company, the acorn from which TRW ultimately grew, were hardware merchants. David J. Kurtz and Samuel M. Mathews had in the course of their business learned about a new electric welding technology invented by Elihu Thomson of Lynn, Massachusetts. They envisioned that it would enable them to reduce dramatically the cost of manufacturing cap screws in standard sizes, organized a company to license and exploit the technology, and, through their local connections, were able to raise about $80,000 in capital by selling equity in the proposed venture. They were not able to make the enterprise a success, however, until Cleveland automaker Alexander Winton, an early investor, bought control of the company and used the technology to produce engine valves for his cars (Dyer 1998).

Telegraph firms were even more important nodes of technological innovation. Western Union, the industry leader by the end of the Civil War, provided financial support for numerous inventions related to telegraphy, including early devices patented by Thomas Edison. Several of Western Union's top executives also backed Edison's research in incandescent lighting at Menlo Park (Taylor 1978; Israel 1992). One of Western Union's early manufacturing operations had been located in Cleveland. When the company decided to concentrate production in Illinois in early 1867, the plant's superintendent, George Shawk, bought the Cleveland shop's tools and equipment for $1,500 and went into business himself,

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[26] Another, more expensive, method was to hire a patent lawyer to investigate the merits of new technologies offered for sale. See Lamoreaux and Sokoloff (2003).

[27] "Bingham, Charles W.," "Bingham, William," and "Worthington, George," *Encyclopedia of Cleveland History*; Rose (1950), p. 217; Fogarty, et al. (n.d.), p. 3; Cox (1951), p. 112.

though he maintained close relations with his former employer. A couple of years later another Western Union employee, Enos Barton, joined Shawk's firm as a partner, his mother mortgaging the family farm to provide him with the $1,500 he needed for the investment. One of the inventors who hung out at Shawk's shop was Elisha Gray, who would later obtain a telephone patent that rivaled that of Alexander Graham Bell. Gray had studied physics at Oberlin College, where his technical creativity brought him to the attention of Jeptha Wade, president of Western Union and a member of the advisory board of the Oberlin school of telegraphy. When Gray obtained his first patent for a telegraph relay in 1867, Western Union provided financial support for him to continue working on this and related devices in the Cleveland shop, where Shawk's machinists built the prototypes. Gray and Barton became close friends and subsequently partners, when Gray bought Shawk out. Gray raised the money for the venture with financial assistance from another Western Union executive, Anson Stager, who gave him the funds he needed in exchange for an interest in a printer telegraph that Gray had invented (Adams and Butler 1999; Cooper and Schmitz 1993).

Although Western Union soon induced Gray and Barton to move to Chicago (a couple of years later, the partnership merged with the company's manufacturing department to form Western Electric), other telegraph-related businesses stayed in Cleveland and became important sources of support for new technologies related to electricity. One such enterprise was the Telegraph Supply Company of Cleveland, Ohio, which had been organized to exploit the inventions of George B. Hicks, developer of the Hicks telegraph repeater. In 1872, a young businessman named George W. Stockly bought a large interest in the company and took responsibility for the commercial side of its affairs, assuming the title of vice president and general manager. Shortly after Stockly joined the company, Hicks suddenly died. Stockly had no technical training and, to save his investment, took two steps. First, he brought in a new set of officers who were well connected and technologically expert. These included the patent solicitor Mortimer D. Leggett, who had previously served as U.S. Commissioner of Patents, and the banker James J. Tracy, who belonged to the "Ark," a natural-science club whose leading members were engaged, around the same time, in founding the Case School of Applied Science. Second, he began to form relationships with promising young inventors and invite them to come work in the Telegraph Supply Company's shops.[28]

[28] Stockly (1901); Letter from W. S. Culver to W. D. Stockley, 24 April 1928, Box 4, Folder 5, Charles F. Brush Collection, Kelvin Smith Library, Case Western Reserve University; Kennedy (1885); Orth (1910), Vol. 2, pp. 44-45; Rose (1950), p. 162; Cooper and Schmitz (1993), pp. 39-41; and "Leggett, Mortimer Dormer," and "Tracy, James Jared, Sr.," *Encyclopedia of Cleveland History*.

The Brush Electric Company

Among the young men whom Stockly encouraged was Charles F. Brush, whose invention of an arc-lighting system would spark Cleveland's technology boom.[29] Brush had been interested in electricity from an early age and had built his first arc light while still a student at Cleveland High School. During the late 1860s he attended the University of Michigan, majoring in mining engineering because the school did not yet have a program in electricity. He then returned to Cleveland and attempted to earn a living as an analytical chemist. When he found he could not make ends meet, he joined an iron-dealing partnership with his childhood friend, Charles Bingham. All the while, he continued to experiment in his spare time with electric lighting.[30]

Stockly, another long-time friend, hired Brush to do some consulting work for the Telegraph Supply Company. The two men got to talking about the future of electricity, and Stockly, impressed by Brush's ideas, offered him the use of the company's shop to develop his arc-lighting system. When Brush successfully demonstrated a new dynamo, Stockly negotiated a contract that gave Telegraph Supply exclusive rights to market the device in exchange for royalties. Brush's reputation as an inventor got a boost in 1878 when his dynamo won a competition at the Franklin Institute in Philadelphia, but it was the backing of Stockly and the other well-connected officers of the Telegraph Supply Company that translated Brush's technical triumph into a commercial success.[31]

Looking for a dramatic way to publicize Brush's invention, Stockly and his associates negotiated a contract with the city of Cleveland to light Monumental Park (now Public Square). Advance publicity brought out a large crowd the evening of April 29, 1879, when Cleveland officials threw a switch, and twelve

[29] Another inventor who a worked on electrical devices at the shop was Alexander E. Brown. See Rose (1950), pp. 437-38.

[30] See Kennedy (1885); Brush (1905); Gorman (1961); Eisenman (1967), pp. 11-26.

[31] Typescript of address by Charles F. Brush to the Franklin Institute, 18 April 1929, Box 9, Folder 11, Charles F. Brush Collection; Stockly (1901); Kennedy (1885); Brush (1905); Gorman (1961); Eisenman (1967), pp. 26-120; and "Brush, Charles Francis," "The Brush Electric Co.," and "Electrical and Electronics Industries," *Encyclopedia of Cleveland History*. See also the following documents: "Agreement between Charles F. Brush and Telegraph Supply Company," 7 June 1876, "Agreement between Charles F. Brush and Telegraph Supply Company," 24 March 1877, and "Memorandum of Agreement between Telegraph Supply Company and Charles F. Brush," 24 March 1877, all in Box 21, Folder 12, Charles F. Brush Collection.

Intriguingly, other boyhood friendships did not have similar benefits. For example, Brush lived during his high school years at the same boarding house as John D. Rockefeller, who despite his great wealth does not seem to have been a supporter of technological innovation. (In 1898 Elmer Sperry took Rockefeller for a ride in the electric automobile he had recently invented. Rockefeller refused to take over the controls and advised Sperry afterwards to move on to other things.) Later, however, Brush would join Frank Rockefeller in a real estate venture. Eisenman, (1967), pp. 18, 162-3; Hughes (1971), p. 87.

strategically placed arc lamps flooded the park with light. News of the event spread quickly throughout the country, generating a rush of interest in this new type of street lighting, followed by orders for installations. The successful demonstration also helped the officers of Telegraph Supply line up investors, and the next year the firm was reorganized as the Brush Electric Company with an authorized capital of $3 million, an enormous amount for the time.[32]

Brush Electric installed about eighty percent of the nation's arc-lighting systems during the early 1880s and made the business people who initially bought its stock rich. As Jacob D. Cox, founder of the Cleveland Twist Drill Company, later regretfully noted: "The original holders made immense sums of money but, as I had no funds to invest, I missed this rare opportunity" (Cox 1951, 90-91). Brush himself became a wealthy man, earning royalties on his patents in excess of $200,000 a year during 1882 and 1883. Indeed, his royalty account accumulated so quickly that the company fell behind on its payments, and to settle the debt, Brush agreed in 1886 to take $500,000 in stock.[33] By the second half of the decade, however, the company was losing ground to new competitors, and Brush, Stockly, and the other major shareholders sold out to the Thomson Houston Electric Company at what appears to have been a handsome price. According to a report in the *New York Times*, the controlling shareholders (Stockly, Tracy, Leggett, Brush, and Stockly's sister) owned 30,000 of the company's 40,000 outstanding shares and sold them for $75 each. The par value of the stock was $50, and its market price was estimated at that time to be $35.[34]

Whether the profits that these stockholders earned from their shares in Brush Electric had a demonstration effect that encouraged other local capitalists

[32] Brush (1905); Gorman (1961); Cox (1951), pp. 90-91. Subsequent negotiations between Brush and the company suggest that only half of the authorized capital was ever paid in. Brush himself did not take stock in the company until a number of years later. Instead, he agreed to assign all of his existing and future lighting-system patents to the enterprise in exchange for royalties. See "Memorandum of Supplementary Agreement between Brush and the Brush Electric Co. (formerly Telegraph Supply)," 1 Sept. 1880, and "Agreement between Brush and the Brush Electric Company," 27 July 1886, Box 21, Folder 12, Charles F. Brush Collection.

[33] As part of the deal Brush Electric's capital stock was reduced from $3 million to $1.5 million fully paid-in shares. The company then issued an additional $0.5 million in stock for Brush. In addition, the company promised that before making any dividends it would pay Brush "an amount not less than one fourth part of the whole sum proposed to be divided, . . . such payments to continue until [the company's] indebtedness shall be fully paid." "Agreement between Brush and the Brush Electric Company," 27 July 1886, Box 21, Folder 12, Charles F. Brush Collection. The royalty statements are in Box 15. Brush also sold his British and other foreign patents to the Brush Electric Light Corporation, Limited in England for a "very large price." According to a report published in *Scientific American* (2 April 1881, p. 211), "The sums paid for these foreign patents are . . . greater than have ever been paid for any other foreign patents obtained by an American."

[34] *New York Times*, 21 January 1890, p. 1; Eisenman (1967), pp. 112-14, 118-20, 162-3; Rose (1950), p. 477.

to invest in cutting-edge technologies is impossible to measure.[35] There is no doubt, however, that the men most visibly associated with the Brush enterprise had a comparatively easy time raising capital for their subsequent ventures. A good example is Washington Lawrence, a major investor in the Brush Company and, for a time, its general manager. In 1882 Lawrence took the unusual step of selling his interest and investing the proceeds in real estate, but he returned to the industry in 1886 to buy a controlling interest in the Boulton Carbon Company, a spin-off venture that supplied carbons for arc lights to Brush Electric and other firms. Lawrence reorganized Boulton as the National Carbon Company, bringing in wealthy investors such as Myron T. Herrick, a local lawyer who had founded a hardware company and who built the Society for Savings into a major financial institution, and Webb C. Hayes, son of the ex-president. He then used the firm as a vehicle to acquire competing enterprises and expand into batteries and other components of electrical systems, in the process creating one of the country's earliest industrial research laboratories.[36]

Another good example of the ease with which men associated with Brush Electric could raise capital for innovative projects is Brush's own promotion of the Linde Air Products Company. Brush became aware during the 1890s of the work of Carl von Linde, a German scientist who had developed a process for liquefying air. Linde wanted to market his invention in the U.S. but was prevented by a conflicting patent. Believing that Linde's invention had priority, Brush bought a one-third share in the patent and financed the necessary litigation. The case dragged on for several years, but Brush ultimately won and, after a brief period during which he and Linde disagreed about terms, set about organizing the Linde Air Products Company. In early 1907 he held a meeting in his office to present a prospectus for the company to a small group of prominent Cleveland businessmen. Virtually all of those present immediately agreed to invest, and the company was launched with a capital of $250,000 and with Brush as president, the chemical entrepreneur C. A. Grasselli as vice president, and J. L. Severance of

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[35] There is evidence, however, that interest in investing in electrical start-ups was sufficiently elevated that con artists were able to organize "wild cat" companies, "whose only purpose seemed to be to foist a lot of worthless stock upon a gullible public." Henry I. Hoyt, president of the Gramme Electrical Company, a trust that temporarily included all the major electrical lighting companies in the country, claimed that one important purpose of the monopoly was to stamp out such practices. These wild cat companies, he claimed, owned no patents and displayed other companies' machines to gullible investors as if they were their own. "'Why, Sir,' exclaimed Mr. Hoyt, indignantly, 'I have even had men come to me and ask to borrow dynamo-electric generators to exhibit in the offices of the so-called 'electric light companies.'" According to Hoyt, between forty and fifty such "speculative enterprises" were out raising capital. *New York Times*, 27 April 1881, p. 12.

[36] "Lawrence, Washington H." and "National Carbon," *Encyclopedia of Cleveland History*; Orth (1910),Vol. 3, pp. 14-18, 315-22.

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Standard Oil as Secretary-Treasurer.[37] After some initial technical problems, which Brush himself resolved, the enterprise grew rapidly. By 1910, R. G. Dun & Company gave it a credit rating of "excellent," despite having no information with which to measure its pecuniary strength, and by 1917 its authorized capital had increased to $15 million. In the latter year, the firm merged with National Carbon, Union Carbide, and other firms to form Union Carbide and Carbon Company, with Brush and the other investors exchanging their Linde stock for twice the number of shares in the new combine.[38]

Brush as the Hub of a Network of Inventors

The phenomenal profits that Brush and his associates earned in arc lighting gave them the clout they needed to command the attention and the funds of the city's capitalists, but such effects do not begin to capture the impact of Brush Electric on the technological development of Cleveland. Indeed, the company was from early on a magnet for ambitious young men who came to work in its shops, network with other technologically creative people, and catch the eye of investors eager to finance the next Charles Brush. Some of these young men were employees. For example, W. H. Bolton, founder of the Boulton Carbon Company (later National Carbon), was a foreman at Brush before organizing his spin-off enterprise in 1881 with capital supplied by Willis Masters, son of Irvine U. Masters, owner of a prominent Cleveland shipbuilding firm.[39] Others, however, were independent inventors whose experiments Brush executives encouraged at least in part to increase the demand for their electrical equipment. In 1883, for example, Edward M. Bentley and Walter H. Knight left their jobs at the Patent Office in Washington to seek backers for a plan they had devised for electrically powered streetcars. Stockly was among the first capitalists they contacted, and he agreed to invest in the firm, brought the young men to Cleveland, and put Brush employees to work building the necessary electrical equipment, including an experimental track. The very visible position that Bentley and Knight occupied at Brush enabled them to convince the East Cleveland Railway Company to lay a trial line and also to attract additional local (and national) backers to invest in the newly formed Bentley-Knight Electric Railway Company. Although the initial trials were successful and generated orders for streetcar systems in other cities, the

[37] See the following letters from Charles F. Brush: to Fred W. Wolf, 15 Feb. 1907, Cecil Lightfoot, 25 Feb. 1907, Carl Linde, 25 Feb. 1907, and Carl Linde, 5 Aug. 1907, Box 3, Folder 1, Charles F. Brush Collection.

[38] See *Wall Street Journal*, 15 Feb. 1917, p. 6, and 3 Oct. 1917, p. 2; R. G. Dun & Company (1910); Eisenman (1967), pp. 118-33, 162-3.

[39] "Masters, Irvine U." and "National Carbon," *Encyclopedia of Cleveland History*; Rose (1950), p. 476.

company subsequently ran into both technical and financial difficulties. In 1889 Thomson-Houston bought out most of its shareholders in order to gain control of the valuable Bentley-Knight patents.[40]

Similarly, another streetcar pioneer, Sidney H. Short, moved to Cleveland so that he could work in the Brush shops. Growing up in Columbus, Ohio, Short (like Brush) had early developed an interest in electricity, and he had amused himself as a child by equipping his parents' home with burglar alarms and other electrical devices. Later, while attending Ohio State during the late 1870s, he patented and sold a transmitter for telephones. Graduating in 1880, he accepted a professorial position at the University of Denver, where he taught physics and chemistry and pursued his research in electrical applications. Within several years he had demonstrated his "Joseph Henry," a trolley car driven by an electric motor around an elliptical track. In his own words, "so impressed were the capitalists then interested in my experiments that the Denver Tramway Company was at once organized" to build an electric streetcar in that city. Obtaining a contract for a system in St. Louis, he secured financial backing from an Ohio investor who arranged to have the necessary dynamos custom-made at the Brush Electric Company. Short then moved to Cleveland to supervise the work and experiment in the company's shops. Brush not only encouraged Short's efforts but helped to finance the resulting Short Electric Railway Company, which operated out of a Brush building.[41]

The career of John C. Lincoln, founder of the Lincoln Electric Company, provides further insight into the connections and opportunities that Brush's shop had to offer young would-be inventors.[42] The son of an impoverished minister, Lincoln developed an interest in electricity during his high-school years and pursued it at Ohio State by taking all of the relevant courses the university offered. He also worked during his spare time for the company that installed Columbus's first electric streetcar line. With the help of a relative, he secured a position at

[40] This is another example of an ultimately unsuccessful venture that made a lot of money for its investors. The firm, which was organized in New York, was initially capitalized at $1 million, with much of this amount being issued in exchange for patents. Other early investors included officers of the Gramme Electric Company of New York. Brush Electric billed the new company for the equipment its employees built. See the testimony of Edward M. Bentley and Walter H. Knight in Rudolph M. Hunter v. Walter H. Knight, Interference Case 10,553, Interference Case Files, 1836-1905, Records of the Patent Office, Record Group 241, National Archives II. See also *New York Times*, 9 September 1884, p. 8; 6 September 1888, p. 8, 1 September 1889, p. 2, 29 October 1889, p. 1, and 30 October 1889, p. 9; Toman and Hays (1996), pp. 32-33; Rose (1950), pp. 402, 465; and "Technology and Industrial Research," *Encyclopedia of Cleveland History*.

[41] Short (1899); Smith 1955); "Sidney Howe Short"; "Short, Sidney Howe," *Dictionary of American Biography*; Moley (1962), pp. 33-34.

[42] The following account is based on Moley (1962), pp. 31-72; Dawson (1999), pp. 11-31; and "Lincoln Electric Co." and "Reliance Electric Co.," *Encyclopedia of Cleveland History*.

Brush Electric in 1888, enrolling in a training course that Brush had created for his employees. About a year later, Brush introduced Lincoln to Short, who promptly hired him to assist in demonstrating and installing his electric streetcar system. While traveling in Short's employ, Lincoln obtained his first patent, an electric brake for streetcars, which he sold for $500 to the great inventor Elmer Sperry (who was then also working on streetcars at the Brush facility).

Lincoln returned to Cleveland and to Brush Electric as Short's superintendent of construction in 1892, but the two men had a falling out when Short blamed Lincoln for the failure of a component. Shortly thereafter Lincoln joined forces with Samuel K. Elliott and his brothers, W. H. and Emmett, in an enterprise to manufacture electric motors. This venture too originated in a Brush connection, for Samuel was a fellow student in the training course. Lincoln designed a motor that quickly gained a respected place in the market, and in 1895 the four men organized the Elliott-Lincoln Electric Company with financial backing from members of a local family named Crawford. Times were hard, and Lincoln fought with his associates over the future direction of the business. Forced out of the company, in 1896 he started his own venture to produce electric motors, the Lincoln Electric Company. The firm's initial capital came from his own meager savings, but given the reputation he had already established though his work with Brush and Short, Lincoln was able to build up the business rapidly by custom designing motors for local firms.[43] By the end of the next decade, he had spun off the production of motors to the Lincoln Motor Works (later Reliance Electric) with capital supplied by Cleveland industrialist Peter M. Hitchcock (a relative who was an early supporter of Brush and who had originally gotten Lincoln the job there), and was increasingly devoting his energies to the development of the arc-welding equipment for which the firm would soon become famous. In the meantime, he wrote a popular handbook on electricity that sold 40,000 copies, invented an automobile powered by a variable-speed electric motor that he considered his greatest invention, and designed generators for electric vehicles that allowed owners to recharge their car's batteries in their own garages.

The Brush firm was also the incubator for the Cowles Electric Smelting and Aluminum Company, the brainchild of Eugene and Alfred H. Cowles, whose father was a prominent Cleveland newspaper publisher. Eugene started out as a journalist, but began to study electricity and its possible uses for smelting after covering an early exhibit of Brush lighting for his father's paper. In 1880 he left the news business to organize and manage the Brush Electric Light and Power Company, the Brush affiliated utility in Cleveland. His brother Alfred was at that time studying physics and chemistry at Cornell, but the two brothers soon joined

[43] Lincoln started his firm with $200 or $250 (the accounts vary) that he earned from designing a motor for Herbert Dow. When he incorporated the firm in 1906, however, it was capitalized at $10,000.

forces in New Mexico, where Eugene, a tuberculosis sufferer, had gone for health reasons and to inspect mining properties. The proximity of the mines to good sources of water power stimulated the brothers to pursue ideas Eugene had about electric smelting. Lacking the equipment they needed to experiment, they returned to Cleveland and to the Brush works, successfully built their first furnace, applied for a patent, and in 1885 organized their company.[44]

Although some observers were initially skeptical about whether the process would be economical (Brush scoffed that it was simply an expensive way to burn coal), their successful operation at the Brush facility silenced doubters. By 1886 Brush himself was using Cowles aluminum to make hubs for armatures. Moreover, financiers could visit the Brush works, see the Cowles' furnaces in operation, and calculate production costs. With capital supplied by their father and other investors who came to inspect the operation (most notably zinc smelter Frederick William Matthiessen, who became the company's president), they built a larger plant in Lockport, New York, where they could obtain cheap power from Niagara Falls (the local Brush Electric Light and Power Company had generated the first hydro electricity there just a few years earlier).[45]

The company did well until 1893 when it was shut down by court order in a patent dispute. Although in 1903 Cowles emerged from the litigation victorious with a hefty financial settlement, ten years of enforced idleness had done its aluminum business irreparable harm, and it licensed its patents to the defeated party, the Pittsburgh Reduction Company, later ALCOA. Meanwhile, a group of investors had organized the Electro Gas Company to use the Cowles technology for the production of calcium carbide, the main component of acetylene gas. The application was discovered and patented by Thomas L. Willson, who had worked for a short-time at Brush and presumably had there become familiar with the Cowles's smelting methods. The Cowles Company received 12.5 percent of the capital stock of the new firm in exchange for a license to use its furnace patents. In 1898 Electro Gas was reorganized as Union Carbide, which, as we have seen, later

[44] Testimony of Eugene H. Cowles, Bradley and Crocker v. Cowles and Cowles, Case 12,615, Interference Case Files; *Biography of Alfred Hutchison Cowles* (1927); Cowles (1958); "Cowles Electric Smelting Furnace" (1886).

[45] Matthiessen, who lived in Illinois, was invited by Alfred Cowles to invest in the firm, which he did after spending time in Cleveland observing the furnace in operation. Testimony of Frederick William Matthiessen, Lossier v. Willson v. Cowles & Cowles v. Rogers v. Darling v. Boguski v. Gratzel, Case 14,039, Interference Case Files. On Brush's reaction and subsequent use of the aluminum, see Cowles (1958), p. 34; and *Scientific American*, 15 May 1886, p. 303; The Cowles brothers may also have gotten financial help from Eugene's father-in-law, the wealthy private banker E. B. Hale, before the marriage ended in a spectacularly messy divorce that made national news in 1890. See *New York Times*, 10 June 1890, p. 1, 31 August 1890, p. 1, 24 December 1890, p. 6.

merged with two other Brush-related concerns, National Carbon and the Linde Air Products Company, to form the Union Carbide and Carbon Corporation.[46]

By the late 1880s the Brush factory had become to such an extent the location of choice for inventors working on electrical projects that technologically creative people continued to gravitate to the site even after Brush and his associates sold out to Thomson-Houston. It was at Brush, for example, that Walter C. Baker invented his electric automobile, organizing the Baker Motor Vehicle Company in 1898 with the assistance of his father-in-law, Rollin C. White, one of the founders of the White Sewing Machine and Cleveland Machine Screw Companies.[47] Around the same time, Elmer Sperry developed his own electric vehicle in the same facility. Sperry had originally been enticed to Cleveland (and to Brush) by Washington Lawrence and other major investors associated with National Carbon. Collectively known as the Sperry Syndicate, this group contracted with Sperry in 1890 to develop a prototype for an electric streetcar, promising that, if the prototype proved workable, the syndicate would either form its own company to build the cars or sell or license the patents to another company that would. This arrangement was very early stage financing. Although Sperry already had some patents in the area, he had not yet developed a working model. Sperry developed his streetcar over the next couple of years and, in 1892, the syndicate arranged to exploit the invention in a joint venture with the Thomson-Houston Electric Company (which a few months later became General Electric). The resulting Sperry Electric Railway Company contracted to pay Sperry a lucrative salary as consultant in addition to a share in the company's profits.[48]

When Sperry got interested in the idea of an electric automobile a few years later, he again turned to the syndicate for financial help. Its backing provided the support he needed to develop his vehicle (at Brush), which was then licensed to the Cleveland Machine Screw Company (Sperry received stock in the company and the position of electrical engineer). In 1900 the American Bicycle Company bought this business, along with Sperry's patents, and the next year assigned Sperry's electric storage battery inventions to the National Battery Company. Sperry helped to get this enterprise up and running and served for a short time as its general manager (Hughes 1971, 80-88; Hritsko 1988, 12-13; Wager 1986, 221-23).

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[46] The contracts licensing to Electro Gas patents owned by Alfred H. Cowles and the Electric Smelting and Aluminum Company are in the British Alcan collection, UGD 347/21/27/15, Glasgow University Archives. See also, *Biography of Alfred Hutchison Cowles* (1927); and Cowles (1958).

[47] "The Baker Motor Vehicle Company," *Men of Ohio*; Wager (1986), pp. 205-18; "The Baker Materials Handling Co.," "Baker, Walter C.," and "Technology and Industrial Research," *Encyclopedia of Cleveland History*.

[48] See Hughes (1971), pp. 70-73; Cooper and Schmitz (1993), pp. 11, 57; Rose (1950),p. 465; and "Electrical and Electronics Industries," *Encyclopedia of Cleveland History*.

The spate of mergers and buyouts that followed the formation of General Electric in 1892 also spurred a number of Brush-connected inventors to form independent enterprises. For example, employees of what had been Brush's lamp affiliate, the Swan Lamp Manufacturing Company, formed the Adams-Bagnall Electric Company in 1895 (Covington 1999). Similarly, after Short sold his streetcar company to General Electric in 1893, he reentered the business almost immediately by joining forces with the Walker Manufacturing Company, a cable and machinery builder, to develop an electric traction system. By this time, his abilities as an inventor in this promising new field of technology were so well appreciated that he was able to mobilize financial support on what seem to be remarkably favorable terms. For example, in a contract dated July 1, 1896, he agreed in return for generous compensation and the title of vice president to work for the company and to assign it the rights to all of his patents that he then owned and controlled, as well as to inventions he would patent in the future, in the areas of "Dynamo electric machinery, Street Railway motors and car equipment, Arclighting machinery, and Alternating machinery." Although we do not know what salary he received, his contract specified that he would be paid an additional royalty of "20 cents per horse power upon all of the electrical apparatus sold and delivered to customers," and that the assignments of his patents would be revoked if the royalties due were not paid within three months of the delivery of the apparatus, or if the company failed to sell and deliver electrical equipment totaling at least $300,000 in any calendar year. Most telling, however, is the contract's "reversionary clause," which specified that, if Short were to leave the employment of the Walker Company, the rights to all of his patents would revert back to him. The implication is that Short's participation in the company was so desirable that he was able to find individuals willing to invest in developing his technology, despite having the right to withdraw at any time with all of the assets he had brought to the firm.[49] Indeed, the next year a group of New York capitalists who were "largely interested in street railway and electric lighting systems in many of the principal cities" (they included ex-Governor Roswell P. Flower, Anthony N. Bradey, James W. Hinkley, and Perry Belmont, brother of August Belmont) bought a controlling interest in Walker and negotiated with Short and the company's other officers for the sale of the firm and its assets to Westinghouse in 1898.[50] Short then left for England to help set up a company that would exploit his traction patents in Europe. When he died suddenly of appendicitis in London in 1902, he left an estate valued at about two and a half million dollars (Smith 1955).

[49] The assignment contract is dated 1 July 1896, but was not recorded at the Patent Office until 5 Jan. 1898. See Liber V-56, p. 322, Records of the Patent and Trademark Office, Record Group 241, National Archives II.

[50] *New York Times*, 24 Nov. 1897, p. 2, and 18 Sept. 1898, p. 10; Moley (1962), p. 57.

The Limited Role of Formal Financial Institutions

Completely missing from the foregoing narrative is any role for formal financial institutions in the founding either of the original Brush Electric Company or of the many start-ups and spin-offs that came out of Brush cluster. The entrepreneurs who organized and promoted these new ventures secured investment capital largely by relying on personal connections. These could be familial, as when the father of Eugene and Alfred Cowles provided most of the initial capital for the Cowles Electric Smelting and Aluminum Company; they could result from friendships, as when George Stockly agreed to support Brush's initial work in electrical lighting; or they could be based on the recommendations of men who had established their expertise in the community, as when Brush secured backing for the Linde Air Products Company simply by assuring local businessmen of the merits of the technology. In all of these cases, however, validation of the technology by experts connected with the hub was crucial to the inventors' ability to mobilize capital. In addition, association with a hub enterprise could in and of itself be a means of attracting both attention and funds. Thus Knight and Bentley's very visible position at Brush enabled them to raise venture capital as far away as New York.

The wealthy Clevelanders who bought shares in these new high-tech enterprises seem to have been motivated by the returns they expected to earn from owning and holding them rather than by the profits they could reap by selling them off after an initial run-up in price. Although a few investors cashed out their investments relatively early (as Lawrence did when he sold off his Brush stock), this practice seems to have been quite uncommon. A search of Cleveland newspapers indicates, for example, that from the time of the formation of the Brush Electric Company until the late 1880s, when the idea of selling or merging the firm was beginning to be discussed, the only mention of Brush shares available on the market occurred around the time Lawrence was selling out.[51] Before the formation of the Cleveland Stock Exchange in 1900, the only firms associated with the Brush hub for which share prices were quoted in the Cleveland papers were Brush Electric itself and the Walker Manufacturing Company. Even after the formation of the exchange, we do not see much trading in the equities of concerns associated with this hub. The one major exception, National Carbon, was listed on the exchange from the very beginning, but it was by that time a consolidation of a large number of previously competing firms.

This is not to say that formal financial institutions played no role in the financing of these firms. Once enterprises associated with the hub got off to a good start, they were undoubtedly able to tap into other sources of finance, particularly trade credit from suppliers but also short-term commercial loans from banks and

[51] *Cleveland Plain Dealer*, 3 Jan. 1882, p. 8.

other financial intermediaries. Here the overlapping network of financiers was likely to have played an important role. Some of the men who invested their savings in the new firms were also officers and directors of banks. For example, James J. Tracy, one of the original incorporators of Brush Electric, became vice president of the Society for Savings after a long career in various other Cleveland financial institutions.[52] Similarly, Myron T. Herrick, a member of the Sperry Syndicate and one of the initial investors in National Carbon, was secretary-treasurer and then president of the Society for Savings, a founder of the Euclid Avenue National Bank, a director of the American Exchange National Bank, and a director of the Garfield Savings Bank.[53] Some of the inventors and other businessmen involved in these start-ups and spin-offs also helped to organize financial institutions during this period—Brush himself was a founder and vice president of the Euclid Avenue National Bank—and it is likely that they did so because they thought their companies would benefit (Eisenman 1967, 162). But it is important to emphasize the secondary role of such formal financial institutions. The primary role was played by local businessmen who hoped to replicate the experience of the investors who had made so much money from their initial stake in Brush Electric. Moreover, the information networks that formed around the Brush enterprise helped to convince them that they could invest in these cutting-edge enterprises with some assurance of success. An innovative firm that could develop and vouch for new inventors was more important to the encouragement and commercialization of invention than were formal financial institutions.

The White Sewing Machine Hub

In Cleveland the Brush Electric Company was one of the earliest and most important examples of an enterprise around which extensive overlapping networks of inventors and financiers formed. But it was not the only such hub. To give one more additional extended example, in the machine-tool sector the White Sewing Machine Company played a similar role, assisting complementary enterprises and spinning off a host of new firms. The founder, Thomas H. White, had moved his small sewing-machine company to Cleveland in the late 1860s, and, in combination with Howard W. White (his half-brother) and Rollin C. White (no relation), formed what later became known as the White Sewing Machine Company.[54]

[52] "Tracy, James Jared, Sr.," *Encyclopedia of Cleveland History*; Orth (1910), Vol. 3, 44-45.

[53] "Herrick, Myron Timothy," *Encyclopedia of Cleveland History*; "Ohio Governors" (n.d.).

[54] "Register"; and White Motor Company, "Important Milestones in White Motor History: Chronological Highlights of Present and Predecessor Organizations (1859-1949)," Container 4, Folder 39, Thomas H. White Family Papers Collected by Betty King, Ms. 4725, Western Re-

Once the firm was well established, White began to encourage vertically related ventures. For example, White played a major role in convincing the fledging precision machine-tool firm of Warner and Swasey to move from Chicago to Cleveland. White helped the two partners find a suitable location for their shop, fed them information about potential customers, and assured them that "If anyone undertakes to squeeze you, let me know, and I will see that they don't." He also stepped forward when they needed a respected businessman to guarantee a contract.[55] White played an even more important role in the success of Theodor Kundtz's furniture company, providing financial backing as well as buying the major part of its output. At the time, sewing-machine furniture consisted of little more than tables on which the machines were bolted. With White's support Kundtz innovated by designing and patenting convertible tables which, when not in use for sewing, closed up to become attractive pieces of furniture.[56]

Like many other enterprises using machine-tool technology, the White Sewing Machine Company made a number of products over the years besides sewing machines. These included kerosene street lamps, roller skates, phonographs, bicycles, and precision tools. Thomas White's son, Rollin H., was a gifted inventor who had double majored in mechanical and electrical engineering at Cornell. When Rollin developed a new kind of flash boiler for steam vehicles in 1899, the White Sewing Machine Company added the production of automobiles. The vehicles proved so successful that the Whites spun off production into a separate automobile concern, the White Company, in 1906.[57] Bowing to trends in

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serve Historical Society Manuscript Collections. See also Hritsko (1988); Rose (1950), p. 336; and "White, Rollin Charles," and "White, Thomas H.," *Encyclopedia of Cleveland History*.

[55] See the letters from Thomas H. White to Warner and Swasey dated 12 Jan. 1881, 28 Jan. 1881, 25 May 1881, and 15 June 1881, Box 36, Folder 3; Ambrose Swasey, "Address," 19 May 1920, Box 17, Folder 2; Reminiscences of Worcester R. Warner, 11 Jan. 1927, Box 1, Folder 3, Warner and Swasey Collection, Kelvin Smith Library, Case Western Reserve University. Francis F. Prentiss, one of the partners with Jacob Cox in the firm that became the Cleveland Twist Drill Company, also helped to lure Warner and Swasey to Cleveland. See "Recollections of George D. Phelps," 18 August 1939, Box 20, Folder 7, and letter from Cox and Prentiss to Warner and Swasey, 30 March 1881, Box 36, Folder 3, Warner and Swasey Collection.

[56] As his business grew, Kundtz expanded into new products from school desks to church pews to bicycle wheels, many of which were based on his own inventions. Later he also built automobile bodies for the Whites. By 1910, Kundtz headed a vertically integrated enterprise that employed 2500 workers in five plants and was the largest consumer of hardwood in the state of Ohio. Eiben (1994), pp. 13-14, 20-3, 25-6, 48-9; Hritsko (1988), p. 29; Rose (1950), pp. 529, 693; and "Kundtz, Theodor," *Encyclopedia of Cleveland History*.

[57] According to Hritsko (1988, 13-19), Thomas H. White bought a steam car from Locomobile in 1899 and gave Rollin H. responsibility for maintaining it. Frustrated by the unreliability of the car's engine, Rollin developed an improved boiler and offered to sell his invention to Locomobile. When Locomobile refused to buy it, the Whites decided to develop their own car. See also White Motor Company, "Important Milestones in White Motor History"; "Twenty Years of Knowing How: Tracing the Development of The White Company and its Product Through Two

popular demand, in 1909 the company began producing gasoline vehicles, the main components of which were designed by other companies, and began to phase out the production of steam cars in 1911. Forced to spend more of his time simply managing production, Rollin had comparatively little outlet for his creativity and was stimulated by a visit to a Hawaiian plantation owned by another brother, Clarence, to turn his energies toward designing agricultural equipment. He invented the first crawler-type tractor and, with Clarence's help, founded the Cleveland Motor Plow Company in 1916 (later renamed the Cleveland Tractor Company and shortened to Cletrac). Once Cletrac's success was assured, he founded another car company, the Rollin Motor Company, in 1923. That venture lasted only a few years, though the cars it produced embodied notable technological advances.[58]

Earlier, in 1890, the Whites had spun off their machine-tool business as a separate concern, the Cleveland Machine Screw Company, headed by Rollin C. White. This firm also diversified its output (Rose 1950, 336). Rollin H. and his brother Windsor (who also had engineering training) were then working at the Screw Company, and they developed a new type of "safety bicycle." The company acquired a local bicycle stamping concern, the A. L. Moore Company, and it produced the bicycles until it sold off this part of its business to the American Bicycle consolidation in 1898.[59] As already discussed, Elmer Sperry arranged for the Cleveland Machine Screw Company to produce the electric car he had designed at Brush, assigning the company his patents in exchange for shares of its stock and agreeing to assume the position of electrical engineer. This business, along with Sperry's patents, was also sold to American Bicycle in 1900 (Hughes 1971, 88; Hritsko 1988, 12-13; Wager 1986, 221-23).

Around the same time, Walter C. Baker founded his own company to produce the electric vehicles he had designed in a Brush shop. Financial backing for the company came from his father-in-law, Rollin C. White, the president of Cleveland Machine Screw Company. Baker's father, George W. Baker, had been an inventor and long-time employee of the White Sewing Machine Company. Walter attended the Case School of Applied Science and after a brief stint as a civil engineer, returned to work at the Screw Company. There he invented a revo-

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Decades of Transportation Achievement," *The Albatross*, 9 (1921), pp. 4-5, in Container 4, Folder 39, Thomas H. White Family Papers; Wage (1986), pp. 53-60; Rose (1950), p. 620; and "White, Rollin Henry," *Encyclopedia of Cleveland History*.

[58] Letters from Henry Merkel to Betty King, 4 Jan. 1991 and 14 Jan. 1991; Report 3, Alice Lunn to Betty King, 29 Dec. 1990; Report 10, Alice Lunn to Betty King, 11 March 1991; and photocopy, "28 Years of Constant Improvement Behind Cletracs," Container 4, Folder 34, Thomas White Family Papers; Hritsko (1988), pp. 45, 49-50; Wager (1986), pp. 63-66, 186-8; Rose (1950), p. 730.

[59] Report 3, Alice Lunn to Betty King, 29 Dec. 1990, Container 4, Folder 34, Thomas White Family Papers. See also Hritsko (1988), pp. 13-14.

lutionary anti-friction ball bearing that could be used for bicycles, carriages, and automobiles, and with the assistance of his father-in-law and several other men, organized the American Ball Bearing Company in 1895, the same year he received his patent.[60]

By the time the later enterprises associated with the White hub were organized, the formal financial institutions that Cleveland's industrialists had helped to create were more accessible to high-tech start-ups and spin-offs. The Whites' automobile venture, for example, was listed on the Cleveland Stock Exchange in 1912—just six years after its formation. Nonetheless, the role played by such institutions in the creation and promotion of new firms was still relatively minor. As in the case of the firms associated with the Brush hub, early investment still came primarily through local informal channels. Moreover, informal finance was just as dependent as it had been in the earlier case on the validation provided by trying out an invention in a hub enterprise.

Cleveland and Beyond

By the turn of the century inventors were finding it increasingly necessary to form long-term attachments with firms in order to continue their inventive activity. The conventional story is that they responded to the difficulties they faced in maintaining their independence by moving into employment positions in the R&D facilities that large-scale enterprises were beginning to build. Our data suggests that the conventional story may indeed be correct for inventors in the Northeastern region of the country, especially the Middle Atlantic states, but that the dominant pattern in the Midwest was for inventors to become principals in companies formed to exploit their inventions. Why this regional pattern developed is beyond the scope of this paper to explain. One possible hypothesis is that the well-developed financial markets of the Northeast efficiently funneled the bulk of that region's savings into the large-scale enterprises increasingly headquartered there. The Midwestern economy, however, was not yet fully integrated into the national financial system (Davis 1965). It may well be that, because capital markets in the Midwest were more confined to local investment projects, they offered greater opportunities to entrepreneurs seeking funds for start-ups to exploit new technologies. It may also be that boosters committed to building up their local economy (and their own enterprises in the process) helped to create an environment that encouraged wealthy Midwesterners to invest locally.

The main contribution of our study has been to detail the channels through which local pools of capital flowed into high-tech enterprises in one Midwestern

[60] Orth (1910), Vol. 2, pp. 332-32; "The Baker Motor Vehicle Company," *Men of Ohio*; Wager (1986), pp. 205-18; and "The Baker Materials Handling Co." and "Baker, Walter C.," *Encyclopedia of Cleveland History*.

city, Cleveland, during the second industrial revolution. We find that formal financial institutions played a supporting or secondary role and that venture capital was mainly mobilized informally. Family and friends contributed significant amounts of capital, as did upstream or downstream enterprises who had special reasons to encourage the development of complementary businesses. Other funds came from business people in the local community (and elsewhere) who were eager to follow the example of those who had gotten rich from investing in cutting-edge technologies.

Whether they were family members or strangers, however, people were only willing to put their savings into new ventures if they had good reason to believe that the investments would pay off. Well-known inventors such as Sperry could readily attract capital because they had established reputations for generating economically significant technologies. Inventors who were just starting their careers needed some other way to signal that their ideas were promising. Here Cleveland's industrial hubs played a critical role. Because they were collecting points for technological expertise, they served an important vetting function. Inventors seeking validation for their ideas gravitated to these hubs. So did business people in search of profitable investments. In this way, the networks that formed around innovative firms like Brush Electric and the White Sewing Machine Company became engines of local economic development. They encouraged the geographic concentration both of technological creativity and venture capital. They also matched inventors who had promising ideas with business people who possessed the managerial skills needed to transform these ideas into productive enterprises. In the process they sparked a technology boom that helped to transform Cleveland from a medium-size city specializing in the handling and processing of resources into one of the largest and most prosperous industrial centers in the nation.

The story we have told is not unique to Cleveland. In other cities important enterprises played similar roles. For example, Steven Klepper (2007 forthcoming) has argued that the Olds Motor Works was the Detroit equivalent of the Brush Electric Company. Founded it 1901, it was the first automaker to locate in Detroit. It was also one of the earliest volume producers in the industry, and by purchasing large quantities of parts from independent suppliers, it created incentives for other firms to be founded in (or move to) Detroit. Although the Olds Motor Works did not survive the decade as an independent firm, Klepper argues that its demand for parts was critical for the formation and success of Cadillac, Ford, and Buick, which in turn spun off large numbers of new enterprises. Collectively these four firms generated 22 employee spin-offs, which in turn led to 19 more. These and other employee spin-offs accounted for a growing percentage of new entrants to the U.S. auto industry, rising from 7 percent in 1895-1904 to 35 percent after 1910. Moreover, because spin-offs had higher survival rates than firms whose founders lacked experience in the industry, their share of industry output rapidly came to exceed their share of entrants. The Detroit enterprises spawned by Olds, Cadillac, Ford, and Buick were particularly successful, resulting in the industry's increasing concentration in Detroit.

According to Klepper, employees tended to leave their positions and form new firms when they had ideas about automobile designs and technologies that their employers were not able or willing to exploit. As a consequence spin-offs helped to maintain the industry's (and Detroit's) technological dynamism. Precisely because of their innovative character, however, spin-offs faced problems raising capital from investors who had wealth but not technological expertise. As in the case of Cleveland, they depended on networks of people with experience in the industry to convey information about the merits of their projects to potential backers. In addition to spin-offs, therefore, incumbent firms in Detroit gave rise to networks of venture capitalists who mediated between the carmakers and outside financiers.

More recently, the Fairchild Semiconductor Company has served as a breeding ground for large numbers of high-tech firms in the area of northern California known as Silicon Valley. The company began in 1957 when a group of talented engineers left the Shockley Semiconductor Company to form their own firm. Because Fairchild was building a business in an industry that did not yet really exist, it had difficulty obtaining the components and machinery it needed. To solve the supply problem, its executives helped some of its engineers found related enterprises. Other employees left to exploit new ideas of their own, an exodus that was accelerated by management problems at Fairchild, which was controlled by a camera company in the East. Indeed, one by one each of the founding engineers left to start other businesses, among them Advanced Micro Devices, Intel, and LSI Logic (Saxenian 1994).

Like Brush and Oldsmobile, Fairchild did not endure as an independent firm. But like its two second-industrial-revolution predecessors, it formed the heart of overlapping networks of managers and financiers. Most of the engineers who headed new firms in Silicon Valley in the 1960s had previously worked at Fairchild, and they credited the training they had obtained and the connections they had made at "Fairchild University" for their success. "To this day," according to AnnaLee Saxenian (1994), "a poster of the Fairchild family tree, showing the corporate genealogy of the scores of Fairchild spin-offs, hangs on the walls of many Silicon Valley firms."[61] Several studies have documented the key role that Fairchild engineers played in the founding of new semiconductor companies that in turn spun off still more companies. Over the entire period 1947-1986, for example, the centrality of Fairchild engineers in formation of new firms was 1.7 to

[61] Saxenian (1994) also reports that at a 1969 semiconductor conference in Sunnydale, California, about 95 percent of the attendees had worked at Fairchild.

2.1 times that of its nearest rival, Fairchild spin-off Intel (Assimakopoulos, et al. 2003; Castilla, et al. 2000). Moreover, Fairchild also played a key role in the region's blossoming network of venture capitalists. Arthur Rock, one of the original backers of Fairchild Semiconductor, formed a venture capital partnership with a lawyer named Tommy Davis in 1961, and the two men raised $3.5 million to invest in new Silicon Valley enterprises from several Fairchild founders. Other Fairchild executives such Donald Valentine and Eugene Kleiner also formed venture capital firms. Just as Fairchild begot spin-offs, so did these early venture capital firms, which in turn raised funds from the founders of Fairchild spin-offs. The availability of venture capital attracted entrepreneurs from elsewhere in the nation and the world, and the concentration of entrepreneurial talent in turn brought in more capital. By the end of the twentieth century, half of the venture capital firms in the U.S. were located in Silicon Valley (Saxenian 1994; Kenney and Florida 2000; Castilla, et al. 2000).

Of course, being associated with a hub enterprise was not the only way in which inventors could raise capital for new ventures. Intermediaries ranging from patent attorneys in the late nineteenth century to investment bankers and venture capital partnerships today have long specialized in vetting new technologies on behalf of potential investors.[62] But recent studies of Silicon Valley suggest that communities in which technological networks formed around hub enterprises like Fairchild Semiconductor had fundamentally different dynamics than places where entrepreneurs raised funds in different ways. For example, Saxenian (1994) has argued that the more flexible network relationships that characterized Silicon Valley enabled firms located in that area to remain on the technological cutting edge and respond more agilely to changing market conditions than their counterparts in Boston's Route 128 region who operated in a very different organizational environment.[63]

Half a century after the founding of Fairchild Semiconductor, Silicon Valley still seems to be maintaining its technological dynamism. Detroit's innovative period appears to have been much shorter. Within about twenty-five years of the formation of the Olds Motor Works, a few large automakers came to dominate the industry, and new entries, whether by spin-offs or anyone else, dwindled to a trickle. The result, according to Klepper (2007 forthcoming), was a loss of technological creativity that would ultimately leave the industry vulnerable to international competition. What happened to Cleveland is not so clear. One possible reason for the apparent loss of its technological dynamism may simply be that the city (and perhaps the Midwest generally) lost ground as the national economy became more integrated over time and R&D became increasingly concentrated in regions with a comparative advantage in invention, such as the Northeast or the

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[62] For examples, see Lamoreaux and Sokoloff (2003); and Gompers and Lerner (2001).

[63] See also Almeida and Kogut (1999); and Castilla (2003).

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West. In particular, R&D previously conducted in the Midwest may have shifted to one of these other regions as firms located there were merged into national enterprises with centralized R&D facilities. It is also possible, however, that Cleveland's transformation from a vibrant center of manufacturing and new technologies to a decaying rustbelt city was a consequence of the destructive impact of the Great Depression on the local capital markets that had earlier nurtured the establishment of new high-tech enterprises. Whether these or other hypotheses can explain Cleveland's steep decline is a subject for future research.

Appendix: Cleveland Inventors, 1898-1902 Sample

Anderson, Valerius D. 13 patents in sampled years, no assignments at issue. Nearly all of the patents were for "presses" designed to extract oil from seeds. *Was a principal in a firm that bore his name but did not assign to it at issue.*

> 1897-8 *Cleveland Directory*: president and treasurer of the V. D. Anderson Co.
> 1906-7 *Directory*: not listed.
>
> Anderson was born around 1830. His work history began in 1855 in a tin shop in Milton, Wisconsin, that made hoops for skirts and repaired tin roofs. He moved to Kewanee, Illinois, invented and patented a steam boiler, and formed a company to commercialize his invention. He next moved to Springfield, Ohio where he managed the Mast-Foos Company, a boiler manufacturer, that was later acquired by International Harvester. Anderson left Mast-Foos in 1876. In 1880 he moved to Cleveland, where he invented a rendering tank for use by butchers. "Sales of these tanks dropped when packinghouses started to replace butcher shops, causing Mr. Anderson to develop and turn to the manufacture of fertilizer dryers." He ran the business out of his home, where he was assisted by two of his sons and two younger brothers. In 1888 he founded the V. D. Anderson Company, and in 1893 the company moved into a small factory on the west side of Cleveland. Among his most important inventions was a steam trap in 1893 (which "not only made his fertilizer dryer the most efficient, but also expanded his market into steam specialties around the world") and a press for extracting oil from seeds (or degreasing the cooked byproducts of butchers) that the company commercialized itself (Anderson International Corp. n.d.; Rose 1950, 440-41).

Avery, Henry C. 10 patents in sampled years. Assignee at issue: Avery Stamping Company (1 patent in 1899, 2 in 1902, 3 in 1905—retained share of the 3 in 1905). Most of his patents dealt with railway ties, but he also patented designs for "non-refillable receptacles" and for a "pneumatic tire." *Was a principal in a firm that bore his name and assigned most of his patent to it at issue.*

> 1897-8 *Cleveland Directory*: secretary and manager of the Avery Stamping Company.
> 1906-7 *Directory*: not listed.

Baker, Walter C. 8 patents in sampled years. Assignees at issue: American Ball Bearing Machine (one patent in 1898). His patents covered designs for antifriction bearings, grinding machines, motor vehicles, a voltmeter, a transmission for automobiles, and a cloth-cleansing device. *Was a principal in a firm that bore his name and also in another company formed to exploit his inventions, but did not assign most of his patents to these firms at issue.*

> 1897-8 *Cleveland Directory*: president, American Ball Bearing Co.
> 1906-7 *Directory*: vice president, Baker Motor Vehicle Co.

> Baker was born in Hinsdale, New Hampshire, in 1868 and moved to Cleveland with his parents at the age of three. His father, George W. Baker, was an inventor and long-time associate of the White Sewing Machine and Cleveland Machine Screw Companies. Walter attended Case School of Applied Science, graduating in 1891. That same year he married Fannie Elizabeth White, daughter of Rollin C. White, one of the founders of the White Sewing Machine Company and president of Cleveland Machine Screw, where Baker went to work after a stint as a civil engineer. In 1893 Baker helped establish his reputation by exhibiting his "Electrobat," a light electric vehicle equipped with bicycle-type wheels, at the Chicago Exposition. Around the same time, Baker invented a revolutionary anti-friction ball bearing that could be used for bicycles, carriages, and automobiles, and with the assistance of his father-in-law and several other men, organized the American Ball Bearing Company in 1895, the same year he received his patent. Baker became president of the new company, which produced axles for horse-drawn vehicles and then for automobiles, and served in that capacity until 1918, when the firm merged with thirteen other concerns to form the Standard Parts Company (Baker stayed on as consulting engineer). In 1897 Baker built an electric automobile with F. Philip Dorn, secretary of the Ball Bearing Company. The two men worked on the car in a building at the Brush Electric Company shop, where their friend Elmer Sperry was also developing an electric car. While Cleveland Machine Screw geared up to produce Sperry's vehicle, Rollin C. White and his son, Fred R. White, left to help Baker and Dorn organize the Baker Motor Vehicle Company in 1898. Baker held the post of vice president and mechanical engineer of that company until 1906, when he gave up his formal position in order to concentrate his energies more fully

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on the Ball Bearing Company. Baker was also a director of the Peerless Motor Car Company and helped engineer that company's cars. He was an extraordinarily talented inventor who counted Thomas Edison among his friends (Edison bought his first electric car). Later Baker worked with Lee DeForest on the development of amplifiers for radio (Orth 1910, Vol. 2, 332-35; "The Baker Motor Vehicle Company," *Men of Ohio*; Wager 1986, 205-18; "The Baker Materials Handling Co." and "Baker, Walter C.," *Encyclopedia of Cleveland History*; Hansler Industries n.d.; Linde Lift Truck Corp. n.d.).

Ball, Herman F. 6 patents in sampled years. Assignee at issue: Chicago Railway Equipment Company (one patent in 1898). His patents included designs for a "brakebeam," a car buffer, and a key for a journal box. *Was an employee but did not assign his inventions at issue.*

1897-8 *Cleveland Directory*: general car inspector for the L.S. & M.S. Railway Co.
1906-7 *Directory*: no occupation listed

Brown, Alexander E. 17 patents in sampled years. Assignees at issue: Brown Hoisting Machinery Company (assigned to this company all patents except 2 in 1899 and 1 in 1900). Virtually all of his patents related to hoisting. *Was a principal in a firm that bore his name and assigned most of his patents at issue to the firm.*

1897-8 *Cleveland Directory*: vice president and general manager of the Brown Hoisting & Conveying Machine Co.
1906-7 *Directory*: same

Alexander E. Brown was born in Cleveland in 1852. He father, Fayette Brown, was a private banker and iron dealer. A graduate of Central High School, Alexander studied civil engineering at Brooklyn Polytechnic Institute in 1872. He worked as chief engineer at the Massillon (Ohio) Bridge Company in 1873-4, where he developed a method of using scrap iron and steel to build bridge columns. He then returned to Cleveland and pursued a career as an inventor (in part by working on lamps along with Charles F. Brush). He invented a hoist that partially automated the unloading of cargo at Great Lakes ports. With his father, he organized the Brown Hoisting & Conveying Machinery Company in 1880 with a capital of $100,000. The Browns incorporated the firm in 1893. Also in 1893 they organized the Elwell-Parker Electric Company of America to supply the hoisting firm with electric motors. Alexander died in 1911 (Rose 1950, 437-8, 546; "Brown, Alexander Ephraim," *Encyclopedia of Cleveland History*).

Brown, Fayette. 1 patent in sampled years, not assigned at issue. Patent was for "counterbalancing mechanism for floating derricks." *Was a principal in a firm that bore his name and also in other companies. Was a "Great Inventor," most of whose patents were outside the sample period.*

> 1897-8 *Cleveland Directory*: member of the partnership Harvey H. Brown & Co., agents and dealers in iron ore and pig iron (H. H. Brown was his son) and president of the Brown Hoisting & Conveying Machine Company.
> 1906-7 Directory: same
>
> Fayette Brown was born in North Bloomfield, Ohio, in 1823, the youngest of nine children. His father, Ephraim, had joined with a friend to purchase that township, moved there from New Hampshire, and became a leader in this "transplanted New England Community." At 18, after finishing his education in local public schools, he worked in Pittsburgh for his brother's wholesale dry-goods firm, becoming a partner in 1845. He moved to Cleveland in 1851 and formed a banking partnership with George Mygatt (Mygatt & Brown), taking over the business when Mygatt retired in 1857. He closed the business and became a U.S. Army paymaster in 1861. He resigned his commission in 1862 and returned to Cleveland as the general manager and agent of the Jackson Iron Company. He remained in that position for the next 25 years. During that period he secured four patents dealing with blast furnaces (issued in 1884 and 1885). He also became interested in Great Lakes shipping and invested in a fleet of lake steamers for transporting iron ore. In 1880, he organized Brown Hoisting Machinery Company in 1880 to exploit the inventions of his son, Alexander E. Brown. Fayette served as president of that company until his death in 1910. He also served as president of the Union Steel Screw Co., the National Chemical Company, and the G. C. Kuhlman Car Company; as general manager of the Stewart Iron Co. of Sharon, Pennsylvania; and as receiver of the Brown, Bonnell Co. of Youngstown, Ohio ("Brown, Fayette," *Dictionary of American Biography*; "Brown, Fayette," *Encyclopedia of Cleveland History*; Rose 1950, 437-8; Orth 1910, Vol. 3, 429-31).

Burnham, Frank A. 7 patents in sampled years, all assigned at issue to the Chandler and Price Company. The patents pertained to printing presses and milling machines for paper. *Was an employee of the firm to which he assigned his inventions at issue.*

> 1897-8 *Cleveland Directory*: superintendent of the Chandler and Price Company.
> 1906-7 *Directory*: not listed

Champ, Joseph [H]. 8 patents in sampled years. Assignee at issue: Bishop & Babcock Company (2 in 1898 and 2 in 1900). Patents were for fluid pressure regulators, tire inflators, a coin-controlled apparatus, and an "implement for imparting vibratory devices." *He was an employee and then a principal in the firm to which he assigned his patents at issue.*

> 1897-8 *Cleveland Directory*: vice president of the Bishop & Babcock Company, which owned the Cleveland Mfg. Co. and Cleveland Tack Works, producers of faucets, pumps, brass goods, tacks and nails.
> 1906-7 *Directory*: same
>
> Champ was born in Cleveland in 1857. His parents were British immigrants. He attended public schools and then, in 1873, began learning the plumbing trade. He obtained a job with Bishop and Babcock, manufacturers of air pumps, brass goods, and tacks and nails in 1880 and was promoted to partner and general superintendent in 1890. He became vice president and general manager of the Bishop & Babcock Company in 1895. He also became president of the Julier Baking Company in 1902, remaining a director when he resigned that position in 1906. He served as a director of the Standard Welding Company and organized the Cleveland Savings Bank, serving as its president for one year (Orth 1910, Vol. 2, 185-6).

Cleveland, William B. 4 patents in sampled years, no assignments at issue. Patents were for "forming electrical connections" and a "valve for hydraulic presses." *Was a principal in a company, but did not assign his patents to it at issue.*

> 1897-8 *Cleveland Directory*: president of Forest City Electric Company
> 1906-7 *Directory*: same

Coffin, Walter E. 5 patents in sampled years, all assigned at issue to National Malleable Castings Company. Patents were for car couplings and a "draftbar attachment." *Was an employee of the firm to which he assigned his inventions at issue.*

> 1897-8 *Cleveland Directory*: salesman
> 1906-7 *Directory*: salesman for National Malleable Castings Co.
>
> Coffin began to work for National Malleable Castings in 1896. He was a pioneer developer of railroad specialties for the company and later Consulting Engineer to its Railroad Department (National Malleable and Steel Castings Co. 1943, 10).

Cowles, William B. 11 patents in sampled years, 1898-1907. Assignees at issue: Long Arm System Company (1 patent in 1898, 1 in 1899, 1 in 1902, 1 in 1903, 2 in 1906, and 1 in 1907); Cleveland Trust Co, trustee (1 in 1903). Patents were generally for bulkhead doors and various systems for opening and closing them. *Was a principal in a company and assigned most of his patents at issue to it.*

1897-8 *Cleveland Directory*: architect.
1906-7 *Directory*: vice president of the Long-Arm System Co.

Dunlany, William P. 3 patents in sampled years, all joint with H. R. Palmer. Assignee at issue: International Fac-Similegraph Company (1 patent in 1900). Patents were for a facsimile telegraph and a "marking machine." *Appears to have invented as a side line and was not connected with his assignee.*

1897-8 *Cleveland Directory*: doctor
1906-7 *Directory*: not listed

Eastwood, Arthur C. 34 patents in sampled years. Assignee at issue: Electric Controller and Supply Company (1 patent in 1900, 5 in 1902). Patents were for an electric motor, magnetic clutch, "motor starting," "motor controlling," and a controller for electric motors. *Was a principal in a firm and assigned a small proportion of his patents to the firm at issue.*

1897-8 *Cleveland Directory*: not listed
1906-7 *Directory*: vice president of Electric Controller and Supply Co.

Edson, Eugene R. 29 patents in sampled years. Assignees: Buckeye Fish Company (4 patents in 1900); Edson Reduction Machinery Company (1 in 1902, 6 in 1903, 2 in 1905). Patents were for reducing and rendering fish or other material, making gelatin, extracting oil, and disposing of foul odors. *Was a principal in a firm that bore his name and assigned some of his patents at issue to it.*

1897-8 *Cleveland Directory*: president of the E. R. Edson Co. (fish)
1906-7 *Directory*: president of the Edson Reduction Machinery Co.

Gilbert, Charles L. 3 patents in sampled years, none assigned at issue. Patents included designs for a traveling bag and a telescope case. *Appears to have invented as a side line and did not assign at issue.*

1897-8 *Cleveland Directory*: two listings—an agent and a cashier at the Erie Railroad freight depot
1906-7 *Directory*: two listings, one for a cashier and one for a "coml trav."

Hall, James R. 6 patents in sampled years, none assigned at issue. Patents included designs for a fish hook, bait bucket, paint can, and water heating apparatus. *Appears to have invented as a side line and did not assign at issue.*

1897-8 *Cleveland Directory*: retired

1906-7 *Directory*: not listed

Jeavons, William R. 16 patents in sampled years, 1899-1907. Assignee at issue: United Blue Flame Stove Company (2 in 1899). Patents included designs for a burner, a hydrocarbon burner, and an oil burner. *Was an employee but appears not to have assigned his patents at issue (or at least not most of them) to his employer.*

1897-8 *Cleveland Directory*: superintendent.
1906-7 *Directory*: supervisor at the Cleveland Foundry Co.

Kundtz, Theodor. 13 patents (3 co-patented with others who assigned their shares to him) in sampled years, none assigned at issue. Patents included designs for sewing machine cabinets and tables for sewing machines. *Was a principle in a firm that bore his name but did not assign his patents at issue to it.*

1897-8 *Cleveland Directory*: manufacturer of sewing machine cabinets
1906-7 *Directory*: Sewing Machine Cabinet Works

Kundtz was born in Metzenseifen, Austria-Hungary, in 1852 and migrated to the U.S. and to Cleveland in 1872 at the age of 20. His first job was with a small woodworking firm (the Whitworth Co.) that made sewing machine cabinets. The owner went bankrupt after a damaging fire. Kundtz and three other employees (George Gebbard, Charles Simon, and Edward Genee) bought the remaining assets and started the Cleveland Cabinet Co. One by one Kundtz bought out his partners until he was the sole proprietor of the Theodor Kundtz Cabinet Works by 1878. He supplied all the cabinets for the White Sewing Machine Co. As the business grew, Kundtz expanded into new products from school desks to church pews to bicycle wheels, many of which were based on his own inventions. Later he also built automobile bodies for the Whites. By 1910 Kundtz headed a vertically integrated enterprise that employed 2,500 workers in five plants and was the largest consumer of hardwood in the state of Ohio. He died in 1937 (Eiben 1994, 13-14, 20-3, 25-6, 48-9; "Kundtz, Theodor," *Encyclopedia of Cleveland History*; Rose 1950, 529, 693).

Long, Timothy. 5 patents in sampled years. Assignee at issue: Browning Engineering Company (1 patent in 1902). Patents include designs for a car-dumping apparatus, a hoisting and conveying machine, and a Merry Go Round. *Cannot tell whether was employee or independent, but if he worked for a firm he did not assign the bulk of his inventions to it at issue.*

1897-8 *Cleveland Directory*: machinist
1906-7 *Directory*: Timothy F. Long was a machinist

Morris, William L. 14 patents in sampled years, 1898-1905. Assignees at issue: Austin Cartridge Company (1 patent in 1898, 2 in 1899, 2 in 1900, 1 in 1902, and 1 in 1905); N. Bellers of Bernie, MO (share of a patent in 1899). Patents include designs for a "shell-loading machine," "cartridge loading," "churn motor," "tree protector," "printing device," and "apparatus for punching gun wads." *Was an employee and then perhaps independent but did not assign his patents at issue to his employer.*

> 1897-8 *Cleveland Directory*: superintendent for J. F. Randall (steam engineering, mill architect, electric lighting and electric railway plants)
> 1906-7 *Directory*: mechanical engineer

Neuhs, Werner. 4 patents in sampled years. Assignee at issue: W. E. Krumsoy (share of a patent in 1898). Patents include devices such as a flat iron, baker's oven, and smoke preventing device for furnaces. *Was an employee at least by 1906-7, but there's no indication that he assigned to his employer at issue.*

> 1897-8 *Cleveland Directory*: bricklayer.
> 1906-7 *Directory*: superintendent

Palmer, Herbert R. 3 patents in sampled years, all joint with William P. Dunlany. Assignee at issue: International Fac-Similegraph Company (1 patent in 1900). Patents were for a facsimile telegraph and a "marking machine." *Cannot tell whether was an employee or independent.*

> 1897-8 *Cleveland Directory*: mechanical engineer
> 1906-7 *Directory*: mechanical engineer

Potter, John A. 14 patents in sampled years, none assigned at issue. Patents were for a forging press, casting apparatus, and for iron and steel manufacturing generally. *Was a principal in a company but did not assign to it at issue.*

> 1897-8 *Cleveland Directory*: vice president of the Cleveland Steel Co, manufacturers of steel and copper plates.
> 1906-7 *Directory*: not listed

Rogers, John R. 38 patents in sampled years, all of which he assigned at issue to Mergenthaler Linotype Company. Patents were for various types of linotype machines. *He was a principal in a firm that bore his name and then an employee of the firm to which he assigned his inventions.*

> 1897-8 *Cleveland Directory*: not listed
> 1906-7 *Directory*: not listed

> Rogers was born in 1856 in Roseville, Ill. After attending Berea College in Kentucky and then Oberlin (A.B. 1875), he taught in the Michigan public schools and then at Berea College. From 1877-1881 he was superinten-

dent of schools in Lorain, Ohio. He then did engineering work for the railroads for two years in Iowa and Michigan, returning to Lorain to teach until 1888. He got interested in mechanical type setting, obtained a patent in 1888 for a machine for "making stereotype matrices," and moved to Cleveland, Ohio, where he organized the Rogers Typograph Co. Rogers introduced a typesetting machine in 1890 whose production was enjoined the next year for infringing on Ottmar Mergenthaler's linotype invention. Several years later another of Rogers's inventions involved him in a three-way interference suit with Merganthaler and another inventor named Jacob W. Schuckers. Rogers bought Schuckers' patent, which was subsequently validated. Mergenthaler then bought Rogers's firm in 1895, and Rogers went to work for the consolidated company (Merganthaler Linotype) in Brooklyn as a consulting engineer and head of the firm's "experimental department." He died in 1934 ("Rogers, John Raphael," *Dictionary of American Biography*; Schlesinger, ed. 1989, 59, 66-68).

Sears, Charles. 13 patents in sampled years, none assigned at issue. All patents related to typewriting. *Was a principal of a firm that bore his name but did not assign his patents to it at issue.*

1897-8 *Cleveland Directory*: manager of the Sears Typo-Matrix Co
1906-7 *Directory*: not listed

Seaver, John W. 26 patents in sampled years, some joint with Charles H. and/or Samuel T. Wellman. Assignees at issue: Wellman-Seaver Engineering Company (1 patent in 1898, 4 in 1900, 2 in 1902, and 2 in 1903); Wellman-Seaver-Morgan Engineering Co. (4 in 1903, 2 in 1905, and 1 in 1907). Patents included inventions for a gas producer, a shipbuilding crane, furnace filling, blast furnace charging, and ore storage and delivery. *Was a principal in a firm that bore his name and to which he assigned many of his inventions at issue.*

1897-8 *Cleveland Directory*: vice president of the Wellman-Seaver Engineering Co. (engineers and contractors, Bessemer and open-hearth steel, etc.)
1906-7 *Directory*: chairman of the board of Wellman-Seaver-Morgan

Seaver was born in Madison, Wisconsin, in 1856 and then moved with his parents to Buffalo, New York. At the age of 13 he took a job in the machine shop of the Shepard Iron Works, attending school in the evenings. Five years later he moved to the Howard Iron Works, which designed and built marine engines. He was promoted to Assistant Superintendent at the age of 20. After a stint in the partnership of Seaver & Kellogg, where he built the first steel railroad cars in the U.S., he took a position with the Kellogg Bridge Works and then, in 1880, became chief engineer of the

Iron City Bridge Works in Pittsburgh. In 1884 he assumed the same title at the Riter-Conley Co. and earned a reputation designing blast furnaces, steel works, oil refineries, and other industrial structures. In 1896 he joined Samuel T. and Charles H. Wellman to found Wellman-Seaver Engineering (later Wellman-Seaver-Morgan), assuming the position of vice president. The firm operated extensive plants in Cleveland and Akron, manufacturing ore and coal handling machinery, car dumpers, hoisting engines, water power, steel plant and railroad equipment, and other heavy machinery. He remained a director of that firm until his death in 1911, but in 1906 joined a consulting practice with James E. A. Moore ("John W. Seaver" 1911; "Seaver, John Wright," *Encyclopedia of Cleveland History*).

Short, Sidney H. 32 patents in sampled years. Assignees at issue: Walker Company of New Jersey (5 in 1899); Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa. (4 in 1900 and 1 in 1902). His patents related to electric motors, railway cars, and electric trolleys. *Was a principal in a firm that bore his name and then a principal in Walker Manufacturing Company, to which he assigned five patents. He was neither a principal in nor an employee of his other assignee, Westinghouse.*

1897-8 *Cleveland Directory*: vice president of the Walker Company (electrical machinery).
1906-7 *Directory*: deceased

Short was born in Galena, Ohio, in 1858 and grew up in Columbus, where his father was a manufacturer. He developed an early interest in electricity, which he pursued by studying physics at Ohio State. Graduating in 1880, he accepted a professorial position at the University of Denver, where he taught physics and chemistry and pursued research in electrical applications. After demonstrating his invention of electric trolley car, local capitalists organized the Denver Tramway Company to build an electric streetcar in that city. Obtaining a contract for a trolley system in St. Louis, he secured financial backing from an Ohio investor who arranged to have the necessary dynamos custom-made at the Brush Electric Company. Short then moved to Cleveland to supervise the work and experiment in the company's shops. Brush not only encouraged Short's efforts but helped to finance the resulting Short Electric Railway Company, which operated out of a Brush building. Short sold the company to General Electric in 1892 and then reentered the business almost immediately by joining forces with the Walker Manufacturing Company, a cable and machinery builder, to develop an electric traction system. Short served as vice president of that company until Westinghouse bought control in 1898.

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That same year, Short left for England to help Dick, Kerr & Company, Ltd., prepare to manufacture his railway equipment, assuming the position of technical director of the English Electric Manufacturing Company. He died in England in 1902, leaving an estate worth about 2.5 million dollars (Short 1899; Smith 1955; "Short, Sidney Howe," *Dictionary of American Biography*; Moley 1962, 33-34).

Sperry, Elmer A. 52 patents in sampled years. Assignees at issue: Cleveland Machine Screw Company (2 in 1898 and 4 in 1900); National Battery Company (3 in 1902, 5 in 1903, and 1 in 1905); General Electric (1 in 1903); Safety Car Heating and Lighting Company (1 in 1906); Goodman Manufacturing Company, Chicago (1 in 1907). His patents pertained to motor vehicle storage batteries, gearing, electric railways, preserving perishable goods, a heating apparatus, and refining tin. *He maintained his status as an independent inventor, forming only temporary attachments with the firms to which he assigned patents.*

1897-8 *Cleveland Directory*: manager of the Sperry Engineering Co. (motor carriages)
1906-7 *Directory*: not listed

Sperry was born in 1860 in Cortland, New York. He attended Cortland Normal, finishing in 1880, and also sat in on lectures at Cornell, where he discussed technical problems with Professor William A. Anthony. With backing from the Cortland Wagon Co, he developed an arc lighting system and then incorporated the Sperry Electric Light, Motor, and Car Brake Company of Chicago in 1883. The company was not very successful and went through several changes in ownership. From 1888-92 he ran the Elmer A. Sperry Co. of Chicago, a research and development enterprise. Inventions he made during that time led to the formation of the Sperry Electric Mining Machine Company in 1889 and the Sperry Electric Railway Company in 1892. He moved his family to Cleveland in 1893, where he worked on streetcar inventions with the aid of local financiers. Cleveland backers also financed his work on electric automobiles. In 1898 he convinced the Cleveland Machine Screw to tool up to produce his cars in quantity. He assigned his patents on electric vehicles to the company, receiving stock in return and for a time worked as the company's chief electrical engineer. In 1900 the American Bicycle Company took over this business (and Sperry's patents). The same deal led to the formation of the National Battery Company to manufacture a storage battery invented by Sperry. He then got interested in electrochemistry, moving to Brooklyn, New York, in 1905 to work on a detinning process for the American Can Company. He remained in New York for the rest of his life (he died in 1930), turning out inventions ranging from gyro stabilizers and compasses for ships to devices to control and direct machine gun batteries to automatic pilots for aircraft to detectors to spot flaws in railroad tracks. Sperry either assigned the resulting patents to existing companies or helped financiers organize companies (usually bearing his name) to exploit them commercially (Hughes, *1971*; Hunsaker 1955).

Stearns, Frank B. 1 patent in sampled years, not assigned at issue. Patent was for a gripper for a printing press. *Was a principle in a firm that bore his name. Was a "Great Inventor," most of whose patents were outside the sample period.*

1897-8 *Cleveland Directory*: not listed
1906-7 *Directory*: president of the F. B. Stearns Co.

Stearns was born in 1878 in Berea, Ohio. He graduated from the University School in Cleveland in 1894 and then went to the Case School of Applied Science, leaving after one year to pursue his longstanding passion for automobiles. With capital provided initially by his father, who owned a stone quarry and speculated in real estate, he organized the F. B. Stearns Co. in 1898, serving in the office of president. The company's automobiles embodied many of Stearns's inventions. In 1912, however, Stearns recognized the superiority of a new engine design by Charles Y. Knight and joined forces with that inventor to offer the famous Stearns-Knight automobile. In 1918 a dispute over engineering policies spurred him to retire, but he continued to serve the firm as a consultant. During the 1920s he worked on diesel engines and obtained sixteen patents. He died in 1955 ("Stearns, Frank Ballou," *Dictionary of American Biography*; *Los Angeles Times*, 9 Feb. 1913, p. VII5; Collection Register, Frank B. Stearns Diary, 1915, Ms. 3481, Western Reserve History Society Manuscript Collections).

Sundt, Oscar. 5 patents in sampled years. Assignee at issue: Garrett-Cromwell Engineering Company (4 patents in 1902). Patents included a rope transmission, charging buggy, and rotary shears. *May have been an employee of the firm to which he assigned most of his patents.*

1897-8 *Cleveland Directory*: draftsman
1906-7 *Directory*: not listed

Tower, Clinton A. 17 patents in sampled years. Assignee at issue: National Malleable Castings Company (all patents except 1 in 1899 and 2 in 1903). Patents were generally for car couplings. *Was an employee of the firm to which he assigned most of his inventions.*

1897-8 *Cleveland Directory*: patternmaker
1906-7 *Directory*: same

Tower was a foreman of National Malleable's pattern shop when he developed a railroad coupler that could connect and lock automatically but could also be unlocked by a lever on the side of the car. In 1892 he applied for a patent on the device, which National Malleable then commercialized (National Malleable and Steel Castings Co., *National Malleable and Steel Castings Co*. 1943; Rose 1950, 555).

Van Develde, John. 5 patents in sampled years. Assignee at issue: H. H. Hyman (shares of 2 patents in 1898). Patents included devices for a paper barrel and for barrel making. *Cannot determine occupation or relationship with assignee.*

1897-8 *Cleveland Directory*: two listed, one a boltmaker and the other assistant general manager of the Wilson-Clark Co. (oil and water purifiers)
1906-7 *Directory*: not listed

Wellman, Charles H. 27 patents in sampled years, many joint with Samuel T. Wellman and/or John W. Seaver. Assignees at issue: Wellman-Seaver Engineering Company; Wellman-Seaver-Morgan Engineering Co; J. Kennedy, Pittsburg, PA, trustee (assigned all patents except 2 in 1898, 1 in 1900, 5 in 1903, 1 in 1905, 2 in 1906, 2 in 1907). Patents include devices for furnace charging, ingot heating, and the manufacture of basic open hearth steel. *Was a principal of the firm to which he assigned most of his patents.*

1897-8 *Cleveland Directory*: engineer of the Wellman-Seaver Engineering Co
1906-7 *Directory*: deceased

Organized the Wellman-Seaver Engineering Company (later Wellman-Seaver-Morgan) with John W. Seaver (see above) and his half-brother Samuel T. Wellman (see below).

Wellman, Samuel T. 21 patents in sampled years, many of them joint with Charles H. Wellman and/or John W. Seaver. Assignees at issue: Wellman-Seaver Engineering Company; Wellman-Seaver-Morgan Engineering Co; J. Kennedy, Pittsburg, PA, trustee; C. H. Morgan (assigned all patents except 3 in 1898, 1 in 1899, 2 in 1900, 2 in 1905, 1 in 1906, and 2 in 1907). Patents concern railway cars, gas purifiers, methods of treating steel for casting, and the manufacture of basic open hearth steel. *Was a principal of the firm to which he assigned most of his patents.*

1897-8 *Cleveland Directory*: president of the Wellman-Seaver Engineering Co.
1906-7 *Directory*: president of Wellman-Seaver-Morgan and of Electric Controller and Supply Co.

Wellman was born in 1847 in Wareham, Massachusetts. His father was an iron worker who rose to the position of superintendent of the Nashua Iron Company. Wellman attended local public schools and then studied engineering at Norwich University in Vermont until he enlisted in the Union Army in 1863. After the Civil War he worked as a draftsman and engineer at the Nashua works, earning recognition by successfully constructing a Siemens regenerative gas furnace under license from the German firm. Wellman was immediately hired by Siemens's U.S. representative, J. T. Potts, to help build furnaces at other works. After he left Siemens's employ, he built an open-hearth furnace (the first commercially successful one in the United States) for the Bay State Iron Company using a plan designed by French engineers. In 1870 he returned to Nashua to take charge of charge of building and running the firm's new steel department. Then in 1873 he moved to Cleveland to do the same for the Otis Iron & Steel Company. He received an ownership interest and the title of chief engineer and superintendent and stayed with the firm for sixteen years. During this time he obtained a number of patents for inventions that included a hydraulic crane and an open-hearth charging machine. In 1886 Wellman built an experimental furnace at Otis and produced the first basic open-hearth steel in the U.S. Because the process was slower than the more conventional acid process, the firm discontinued the experiment. In 1889, Wellman left the company and worked briefly as a consultant for the Illinois Steel Company. In 1890 he and his half brother, Charles, founded the Wellman Steel Company, which operated a rolling mill in Chester, Pennsylvania, until it failed in 1895. The next year the Wellmans joined forces with John W. Seaver to organize the Wellman-Seaver Engineering Company, a consulting firm that built iron and steel works on contract. Thomas R. Morgan joined the firm in 1901, and it was reorganized in 1903 as the Wellman-Seaver-Morgan Company, an Ohio corporation, in order to acquire the assets of the Webster, Camp & Lane Company of Akron. Wellman served as president of the American Society of Mechanical Engineers in 1900-01 and also served at various times as director of East End Bank & Trust, Dime Savings & Banking, Cleveland Trust, Iroquois Portland Cement, and Dow Chemical. He died in 1919 (Wellman 1902; Letter from Samuel T. Wellman to F. W. Ballard, 12 June 1917, Samuel T. Wellman Collection, Kelvin Smith Library, Case Western Reserve University; Sicilia 1989; Misa 1995, 77-80, 152, 177; "Wellman, Samuel Thomas," *Dictionary of American Biography*; "Dravo Wellman Co.," *Encyclopedia of Cleveland History*; Wellman Engineering Co. 1956; Rose 1950, 388-89, 429, 488, 568-69, 582).

White, Rollin H. 25 patents in sampled years. Assignees at issue: A.L. Moore Company (1 in 1898); White Sewing Machine Company (1 in 1900, 4 in 1902, 8 in 1903, 3 in 1905, 1 in 1906, and 1 in 1907). Patents include "steering mechanisms for autos," "airpumps for autos," "golfclub," "gasoline burner," and "transmission." *The businesses to which he assigned many of his patents were associated with his family. He later became a principle in a firm formed to exploit his inventions.*

> 1897-8 *Cleveland Directory*: superintendent of A. L. Moore Co. (bicycle material).
> 1906-7 *Directory*: superintendent of the automobile department of the White Sewing Machine Co.
>
> White was born in Cleveland in 1872. His father, Thomas H. White, was a founder of the White Sewing Machine Company, the Cleveland Machine Screw Company, and other concerns. Graduating from Cornell in 1894, Rollin went to work at his father's various companies. While he was working at the A. L. Moore Company, which his father had acquired, he and his brother Windsor developed a bicycle which the Sewing Machine Company then manufactured and distributed. In 1899 Rollin invented a flash boiler for steam automobiles and introduced the first White steamer in 1900 (he raced the cars, setting a world record for steam cars in 1901). Rollin's cars (and later trucks) were produced by the White Sewing Machine Company until the family incorporated the White Company in 1906. Rollin became its vice president but mainly supervised technological development and production, while two of his brothers took charge of the business aspects of the firm. Rollin always felt underappreciated by his family and left the company in 1914 to pursue inventions in agricultural equipment. He incorporated the Cleveland Motor Plow Company (later Cletrac) in 1916. Still president of Cletrac, he returned in 1923 to automobiles with the incorporation of the Rollin Motor Company. He died in 1962 ("White, Rollin Henry," "White, Thomas H.," "The White Motor Corp.," and "Cletrac, Inc." *Encyclopedia of Cleveland History*; Hritsko 1988; Wager 1986, 53-68, 186-89; and Rose 1950, 620, 730. See also Letters from Henry Merkel to Betty King, 4 January 1991 and 14 January 1991; Report 3, Alice Lunn to Betty King, 29 December 1990; Report 10, Alice Lunn to Betty King, 11 March 1991; and photocopy, "28 Years of Constant Improvement Behind Cletracs," Folder 34; and White Motor Company, "Important Milestones in White Motor History"; and "Twenty Years of Knowing How: Tracing the Development of The White Company and its Product Through Two Decades of Transportation Achieve-

ment," *The Albatross*, 9 (1921), pp. 4-5, Folder 39, Container 4, Thomas H. White Family Papers).

von Zweigbergk, Thorsten. 26 patents in sampled years. Assignees at issue: Walker Company (6 in 1898); Westinghouse Electric and Manufacturing Company (1 in 1900). Patents included a controller, magnetic brake, and motor starting device. *Was a principal in a firm that bore his name but his status at the time he assigned to Walker and Westinghouse is not known.*

1897-8 *Cleveland Directory*: T.L.A.
1906-7 *Directory*: president of the Von Zweigbergk Controller Co.

von Zeigbergk was born in Sweden in 1871, entered the United States in 1892, and was naturalized in 1899 (Cayahoga County Genealogy and History n.d.)

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