

Glass and Light

The Influence of Interior Illumination on the Chicago School

The classic myth of the Chicago School's demise at the hands of the 1893 Columbian Exposition ignores the complexity and timing of the experiments in skin and structure that gave Chicago's commercial architecture its extraordinary vitality from 1871 to 1922. In particular, the role of illumination — both natural and artificial — had profound consequences for the era's dialogues between frame and cladding. New evidence links the architecture of the era with the economics of plate glass, electrical distribution, and lamp technology. It suggests that the rise and fall of the Chicago "skyscraper style" traced the balance among construction, performance, and material during a time of volatile technical developments and building economics.

At the very moment when the Chicago school gained a mastery of the new means which it had created, its further development and influence were abruptly choked off. The event which directly effected this change was the Chicago World's Fair of 1893.

Mercantile classicism had been developing and gaining strength in New York since the eighties, but it won its country-wide ascendancy at the World's Columbian Exhibition of 1893.

Siegfried Giedion¹

[T]he real problem with the Chicago School buildings was that, because of these big glass areas, they were difficult to keep comfortable. . . . When electric lighting came in, they began to cut down the window size. . . . For many years there was this great myth that . . . the Columbian Exposition came along. . . . This was how the Chicago School ended. But I don't think this is true, because firms like Holabird & Roche were building the same kind of buildings for the next 15 or 20 years."

John A. Holabird²

Among the more compelling myths of modernism, the death of the Chicago School at the hands of Daniel Burnham and the 1893 Chicago World's

Columbian Exhibition remains one of the most potent.³ As distilled by Siegfried Giedion in *Space, Time and Architecture*, Burnham's choice of "timid . . . secondhand" beaux-arts classicism for the architecture of the fair is said to have arrested the development of postfire Chicago architecture. In this assessment, Giedion relied on the words of Louis Sullivan, who famously railed against Burnham's "nausea of overstimulation."⁴ According to the myth, once having broken Sullivan's will and thus his career, Burnham attempted to foist his "cerebral meningitis" on Sullivan's greatest pupil, whose presence of mind and sturdy moral fiber in resisting the new style became the stuff of heroic modernist legend.

This is a powerful tale, and the climactic image of Frank Lloyd Wright refusing to go over to the dark side of Burnham's beaux-arts vision has clouded, perhaps, a more rational assessment of the Chicago School's descent into mercantile classicism. The tidy myth of the Chicago School's demise ignores several inconvenient facts.⁵ Sullivan, for example, was a full participant in the planning of the fair. More intriguing, however, construction in Chicago continued to develop and exploit the fundamental recipe of the "Chicago Style" — expressed steel skeletons with lightweight, relatively transparent building envelopes — for a generation after 1893. In fact, the flowering of mercantile (as

opposed to civic) classicism in Chicago did not occur in force until the late 1910s.⁶

A simple listing of two hundred major structures built in the Loop between the 1871 fire and World War II reveals a counternarrative to Giedion's simplistic duel of styles. The earliest experiments with tall commercial buildings in Chicago consisted of masonry structures with punched openings, beginning with the Nixon Building by Otto Matz (1871) and occurring as late as the Monadnock Building (1891) by Burnham and Root. The First Leiter store by William Le Baron Jenney (1879) began a parallel experiment in expressed skeleton structures with glass infill panels. This approach included Jenney's Home Insurance Building (1885) and his Second Leiter Building (1891).⁷ Masonry skins were superceded by lightweight bay windows hung outboard of steel skeleton structures beginning with the Caxton Building by Holabird and Roche (1890) and running through the Railway Exchange Building by Daniel Burnham (1904). The curtain wall and the skeleton structure were eventually integrated into the standard image of the Chicago School: expressed steel skeletons in terra cotta enclosures containing tripartite windows, larger than those of the skeleton buildings but not as dominant as those of the curtain wall structures. This phase, which finds its earliest example in the Marquette Building by Holabird and Roche (1895), accounted

for the majority of commercial construction in the Loop until 1907, with major examples occurring as late as the LeMoyné Building by Mundie, Jensen, and McClurg (1914). Beginning in 1907, however, solid curtain walls that took advantage of the pliability of terra cotta into various forms of ornament rose steadily to prominence. With nods toward neo-Gothic decoration and art deco by the financial crisis of 1929, the punched masonry envelope replaced the weaving together of structure and skin as the dominant mode of commercial construction in Chicago.

The tidy story of “Uncle Dan” Burnham and his wrecking of the Chicago School principles is thus too simplistic and chronologically untenable. The “school” was actually a complex group of experiments in skin and structure. Its demise between 1910 and 1925 cannot be attributed to the fair, which occurred a good fourteen years prior to Burnham’s Edison Building (1907), Chicago’s first major experiment in applying beaux-arts compositional principles to a typical office block. Burnham’s office was in fact one of Chicago’s strongest proponents of tectonic experimentation, being responsible for the paradigmatic curtain walls of the Reliance and Fisher Buildings (1895–1896) and the expressed frames of the Merchant’s Loan and Trust Building and the Marshall Fields Store (1901–1902).

Having partially exonerated Burnham, we are left asking what other factors led to the decline of the School’s principles. One particular aspect of Chicago construction — illumination of the office interior — suggests that the development and decline of the Chicago skyscraper style can be explained as a balance between available technologies, their costs, and performance requirements for the commercial market. Tenants’ lighting needs demanded continual adjustments to the typical building skin, adjusting proportions of glass and solid material as the economics of illumination changed. The lightening and solidifying of the Chicago skyscraper skin allowed and required new

approaches to tall building aesthetics, but to suggest the opposite is to mistake cause for effect. Beaux-arts composition occurred as an elevational strategy only when these parameters permitted solid skins. Necessarily, style and ornament were afterthoughts to issues of structural engineering, material availability, and financial balance.⁸ The expansion and contraction of the “Chicago Window” provides an alternate narrative to that of a stylistic battle royal, in which the interwoven roles of illumination and cladding disprove the stylistically conceived rise and fall of the “Chicago School” and demonstrate important connections between architecture, regional economics, and industrial experimentation.

The Tall Office Building Technically Reconsidered — The Role of Daylight

The development of Chicago construction between 1871 and the turn of the century has usually been seen as a structural achievement. The skeleton frames developed by Jenney, Sullivan, and Holabird and Root among others were its most visible legacies. However, this focus on the skeleton has ignored other technical developments, including fireproofing; mechanical, electrical, and plumbing services; the safety elevator; and the conception of the building skin as an autonomous constructional system.⁹

The role of lighting in the development of the tall office building is ripe for reappraisal. Advances in structural engineering by the 1880s had not been matched by advances in illumination. Instead, the majority of ambient and task lighting in the buildings of the era was provided by daylight, as artificial illumination was expensive, inefficient, and dangerous. Jenney, writing in *Inland Architect* in 1891, stated that the skeleton frame was in fact a response to the need to bring daylight through the building skin. The fundamental requirement of the Home Insurance Company in commissioning his

revolutionary office block in Chicago in 1883, he claimed, was for “small offices, all of which must be well lighted,” and thus that “proper space might be left for windows” in the elevations.¹⁰ Likewise, John Welborn Root, Burnham’s partner until 1891, believed that the skyscraper’s “great architectural problem” was fundamentally the provision of light.¹¹ By 1893, architects had codified lighting requirements for offices, with a consensus that 9-foot-wide offices should be no deeper than 15 to 16 feet, and that windows in such offices should be a minimum of 4 by 6 feet to provide light levels adequate for office tasks.¹² The Home Insurance Building’s dramatically attenuated frame graphically demonstrates daylight’s importance, as the cost of the steel skeleton remained quite high relative to masonry construction until 1896.¹³ Thus, the fabric of early Chicago skyscrapers shows a tension between the spatial requirements of steel and terra cotta columns — what Montgomery Schuyler would term the commercial block’s *data of design* — and requirements for light to penetrate building façades.

It is, therefore, surprising to see a lingering solidity in the buildings of the 1880s, including the Rookery by Burnham and Root (1886), the Auditorium by Adler and Sullivan (1889), and the Monadnock by Burnham and Root (1891). Whereas these last two buildings were among the first in Chicago to be wired for electric light, they relied exclusively on natural light during the day. Yet their façades were often only half glazed, with the remaining skin composed of terra cotta, brick, or dressed stone. None of these suggest the “skyscrapers of glass and iron” described by Giedion. Even the most vitrine-like of the group — Jenney’s First Leiter Store (1879) or his Ludington Building (1891) — deployed glass in small, double-hung windows. Vast expanses of glass would not be seen until the Caxton Building by Holabird and Roche (1890) and the crystalline skin of the Reliance Building by Burnham and Atwood (1895).

Commercial buildings’ “data of design” changed dramatically after 1890. Following the

developments of the skeleton frame, the emergence of the mostly glass curtain wall radically changed the appearance and function of the Chicago skyscraper. Around 1900, the Chicago window retreated into a more boldly expressed rejuvenation of the skeleton frame, finally disappearing behind predominantly solid skins of masonry, stone, or terracotta. This trajectory of the Chicago window followed two major technical developments in building illumination: plate glass windows and electric incandescent lighting. The story of the rise and fall of the Chicago School can be traced through the data of design inherent in these two technologies and their effect on the building envelope's composition.

The Role of Plate Glass in the Development of the Chicago Window

Glass in 1880 was a relatively crude building material. Prior to 1890, the vast majority of window glass was produced by one of two hand methods. Molten glass was spun on the end of a punty to achieve flat panes in the Crown process, whereas Cylinder glass was blown into a test-tube shape and then flattened on a cutting table.¹⁴ Both methods were slow and labor intensive, and both produced thin, brittle, and wavy products that proved unacceptable for high-end commercial applications.¹⁵

A third method of flat glass production, casting, produced a consistent, nearly flawless product capable of much larger sizes, but at a prohibitive cost. The production of plate glass involved heating super-pure elements to a temperature greater than 3,000 degrees F and pouring the molten material onto a casting table where it was rolled to achieve a uniform thickness.¹⁶ Castings — often up to 60 square feet — had to cool in a controlled kiln for two to three days to prevent breakage from thermal stress.¹⁷ Plates were then ground and polished for up to six hours per side. Grinding and polishing wasted more than half of each plate's thickness, adding to the material's already significant manu-

facture costs.¹⁸ The need for capital investment combined with these expenses to limit the production of plate glass in America until the last quarter of the nineteenth century. In 1880, it was first used in skyscrapers of particular distinction, but economy dictated that it be used only in relatively small panes, and for a small percentage of the overall skin.

The economic development of plate glass had profound implications for Chicago construction. Along with considerable capital and material expenses, plate glass production was a voracious consumer of fuel for its melting pots and annealing kilns. The industry therefore tended to locate in regions rich in coal or natural gas, particularly the "coal belt" in western Pennsylvania. By 1880, five American firms had established factories for the production of polished plate glass, including the American Plate Glass Company, which established a plant on the Mississippi River at Crystal City, Missouri, 350 miles by river and canal from downtown Chicago.¹⁹ Glass manufacture eventually spread to other gas-rich regions, as it proved easier to ship raw materials and finished products than to transport the fuel itself.

Natural gas was discovered underneath Waldron, Indiana, in August 1890, when an underground deposit exploded catastrophically. Subsequent exploration revealed that the field extended north to Kokomo and Muncie, fewer than 150 miles by rail from downtown Chicago.²⁰ By the time of this discovery, Chicago had become one of the country's primary markets for polished plate glass. The material's largest American distributor, George Kimball, was one of twenty-three window glass businesses in the Loop, supplying Crystal Plate from Missouri to major building projects of the 1880s including the Monadnock, Studebaker, and Pontiac buildings.²¹ Recognizing the convergence of free energy and a keen market, glass manufacturers rushed to north-central Indiana in the fall of 1890. The hastily formed Diamond Plate Glass Company invested \$2 million in a plant at Kokomo, employing one

thousand glass workers within two months of the gas discovery.²² By the end of the year, a second plant had opened in Elwood, twenty miles southeast of Kokomo. Pittsburg Plate Glass and others quickly followed suit, and for the next decade the "gas belt" counties of Indiana were second only to western Pennsylvania in the production of architectural plate glass.

Kokomo's proximity created an unprecedented supply of relatively inexpensive plate glass in Chicago during the 1890s. The synergistic economic relationship between Indiana suppliers and Chicago contractors was aided by the isolation of the Midwest from shipping ports on the East Coast.²³ Direct rail links between central Indiana and the downtown warehouses of suppliers aided distribution and provided competition for canal-borne glass from Crystal City. The combination of a nationwide depression in 1894 and overenthusiastic production further reduced prices nationwide during the mid-1890s, although Chicago's market remained robust throughout the decade.²⁴ Simultaneously, companies developed new techniques that allowed faster, more accurate production, including the use of rotating polishing tables and the continuous annealing lehr. Prices, which had dropped steadily in the previous two decades, imploded with the onset of rudimentary mass production in the 1890s.²⁵ Indiana plate glass undercut national rates by a few cents per square foot, reflecting the difference between coal purchased in Pennsylvania and the free natural gas supply around Kokomo. Transportation costs to Chicago from plants throughout the Midwest were 30 percent less than to New York or Boston, focusing the synergy of market and production in Chicago.²⁶

The effects of freely available and affordable plate glass can be read in the dramatic changes in Chicago's building façades during the 1890s. Although plate glass had already been used to great effect (and at great expense) in the elevations of high-quality buildings such as the Rookery (1885–1886) and the Monadnock (1889–1891), the majority of these structures' elevations were solid,

reflecting the relative cost of glass versus stone or brick. As the availability of plate glass increased in the early 1890s, the balance of performance and cost dictated a recasting of this equation. Large windows proved to be technically feasible and economically viable as early as the Tacoma Building by Holabird and Roche (1890), constructed as glass prices nationwide averaged \$0.51 per square foot.²⁷ Throughout 1892 and 1893, the typical Chicago skyscraper continued to use double-hung windows of increasing size, as in Burnham and Root's Ashland Block (1892) and Holabird and Roche's Congress Hotel (1893). Beginning in 1894, however, large, unbroken central bays of square glass appeared, notably in Adler and Sullivan's Stock Exchange and in the end elevations of the Old Colony Building by Holabird and Roche. The tripartite Chicago window, made possible by the large kilns in both Missouri and Indiana, found its most extensive application in two 1895 buildings — the second Stuedebaker Building, by S.S. Beman, and the Reliance. In both cases, individual windows of nearly 30 square feet formed the majority of the major elevations, with solid spandrel panels sized only to provide some measure of safety and comfort to occupants within.²⁸ (Figures 1–3.) The Reliance Building, famous for having a façade of “two-thirds glass,” used polished plate glass in its unique two-bay Chicago windows to provide offices with 6-foot-high apertures unbroken by intervening mullions. The Reliance is better known, but the Fisher Building, also by Burnham and Atwood (1896), further proved the economics of the predominantly glass curtain wall, substituting enormous double-hung windows for the fixed panes of the Reliance and becoming known as Chicago's first “building without walls.”²⁹ As with the Reliance, its skin was more than two-thirds glass, creating extraordinarily bright interiors in rooms and corridors lit by clerestories. Subsequent work by Burnham, particularly the Railway Exchange Building of 1904, continued the theme of the double-hung window in a light terra cotta skin. Meanwhile, work by Holabird and

Roche — notably the Mandel Brothers Store and the Ayer Building (both 1900) — perfected the large tripartite window, using large panes of fixed plate glass from the Indiana and Missouri plants. By the turn of the century, commercial architecture throughout the Midwest included skins of up to 85 percent polished plate glass, reflecting its availability and the regional focus of the industry.³⁰

From this point forward, however, the Chicago window contracted, retreating into a more prominent structural frame during the first decades of the twentieth century. Several “classic” Chicago buildings show a reversal in the development of the glass skin, back toward a predominantly solid mass with expressed frames. The Schlesinger and Mayer Store by Sullivan (1899), the Gage Group by Holabird and Roche with Sullivan (1899), and the Foundation Hall building by E.R. Krause (1904) all demonstrate this transitional moment. By 1910, the typical commercial office building in Chicago was a hybrid of expressed structure, gradually retracting windows, and increasing areas of solid wall that required new approaches to ornament and aesthetic treatment. The last Chicago School buildings showing a clearly expressed frame — the LeMoyné Building by Jennie and Mundie and the Lumber Exchange by Holabird and Roche — were completed in 1915. These, however, were exceptions to a developing typology that continued the fireproofed steel skeleton but abandoned the transparency of earlier curtain walls. Buildings of the 1910s by Burnham and others show a developing realization of the tall office building as a solid, punched mass in which the push-pull of window and frame was gradually suppressed. Burnham's ponderous building for Peoples Gas of 1911, for example, contrasts sharply with his much more ethereal 1904 Railway Exchange only a block away. Following Burnham's death in 1913, his successor firm Graham, Anderson, Probst, and White discarded any sense of lightness or transparency in favor of solid blocks whose stone faces were decorated in a default beaux-arts style. By 1920, every major commercial skyscraper under construction in

the Loop adhered to a formula of steel skeletons with predominantly solid punched masonry or stone skins. Effectively, the Chicago School was finished.

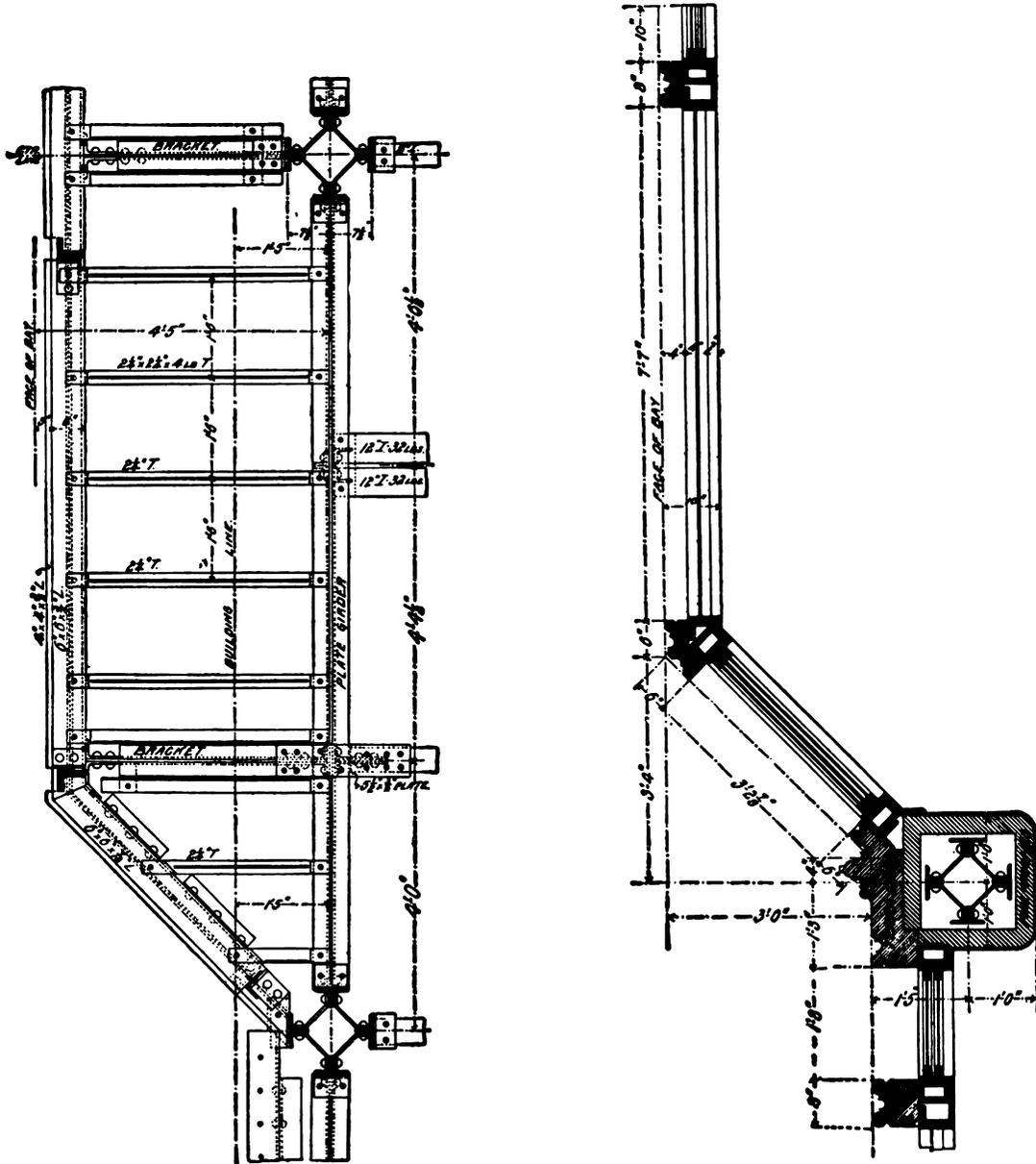
Electricity and the Solid Skin

If plate glass was important to the rise of the Chicago window, electric lighting was crucial to its fall. The glass curtain wall of the 1890s can be attributed to the balance between the cost of plate glass and the need for interior illumination. The onset of the more vigorously expressed frame during the 1900s and the opaque exteriors of the 1920s paralleled changes in the economics of electrical service and the incandescent lamp. The demise of the Chicago window can be partly explained by the rise of glass prices around the turn of the century and during World War I, but lighting technology, which changed definitively between 1895 and 1920, provides a more compelling rationale.

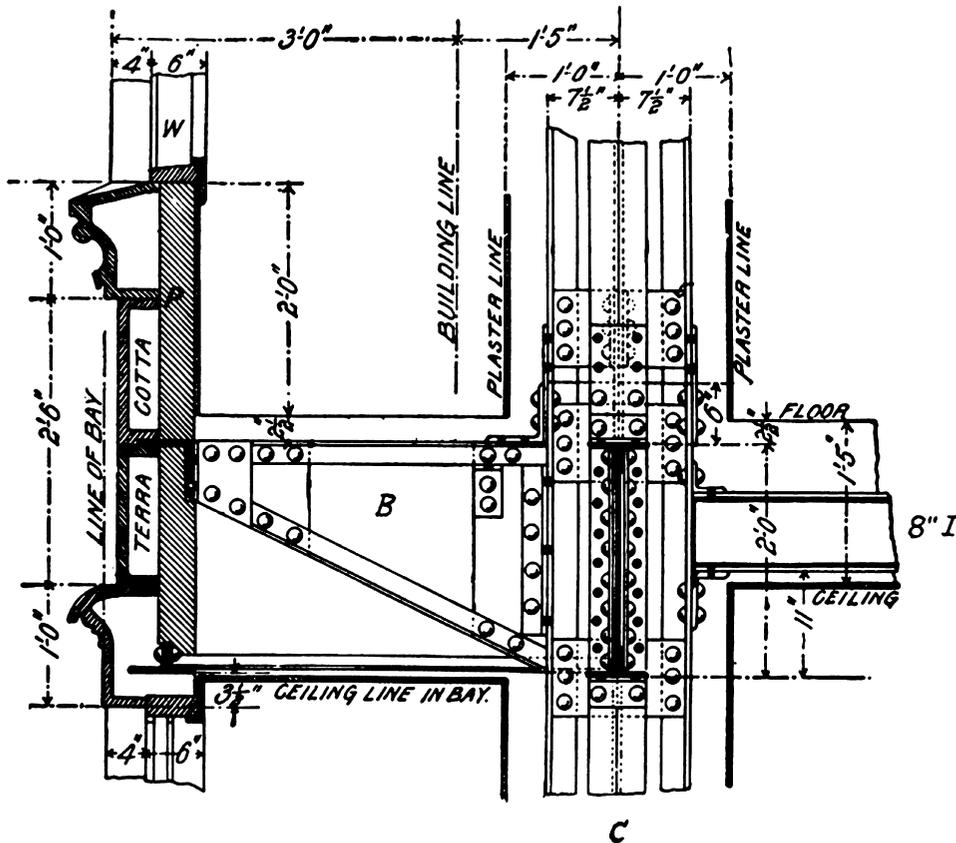
The complete reliance of early office buildings on daylight had obvious shortcomings: in winter, the working day was short, and the radiant effects of large single-glazed panes made it difficult to maintain comfortable temperatures.³¹ While the flanking windows in a “Chicago” bay induced some ventilation, the size of the light-gathering panes proved troublesome during summer, particularly on south and west façades. That the environmental penalties of such large windows were so thoroughly accepted during the 1890s shows just how important daylight was to the functioning of a typical office.

Gas and electricity provided supplements to natural light throughout the nineteenth century. Illuminating gas extracted from coal was first introduced as a piped service in Chicago in September 1850.³² In 1858, the Peoples Gas Light and Coke Company obtained a monopoly on gas service in the city, and its pricing made gas lighting prohibitively expensive for all but luxury hotels and clubs until the 1890s.³³ Scientifically derived designs for interior gas burners made the service relatively safe, but the threat of fire or asphyxiation was always present.

1. Plan details of the Reliance Building by Daniel Burnham and Charles Atwood (1895). The classic Chicago curtain wall. The Reliance took advantage of glass production in Indiana in the early 1890s, providing 6'-0" square panes with only 2'-0" sill heights, a measure of the need for daylight and the relatively low cost of polished plate glass versus electricity during the decade. (Contemporary postcard image, W.G. MacFarlane Co., Toronto.)



2. Section detail of Reliance Building.
 3. Reliance Building. (Credit: Author)



The 8-to-12 foot-candles of light from a typical gas burner were not adequate for fine bookkeeping work, and the combination of two or more burners to add light for fine tasks brought with it added heat and greater risk of fire.³⁴ By 1893, competitors were suggesting that the entire gaslight industry was obsolete, and well-publicized accidents hinted that its dangers and cost outweighed its usefulness.³⁵

Electric lighting was demonstrated in Chicago in April 1878, but it did not present an immediately palatable solution. Arc lights saw general use in outdoor applications during the 1880s, but their poor color rendition, lack of brightness control, and high operational costs made them unsuitable for indoor office use.³⁶ Beginning in 1879, Edison's filament lamps began to provide a practical alternative, and, after their demonstration in New York in 1882, incandescent lighting should have been the obvious choice for interior illumination of offices. However, the first generation of carbon filament bulbs produced no greater candlepower than gas burners, and they required constant attention and replacement. More pressing, problems of supply, infrastructure, and the related high cost of electric power prevented it from immediately replacing gas illumination.

Electricity was accepted slowly in Chicago. Following the introduction of the arc lamp in 1878, various individual companies packaged and sold electric plants consisting of generating dynamos, wiring, and fixtures. The cost of the dynamos made electricity expensive, and its first commercial customers in Chicago were the same high-end hotels clubs and department stores that had pioneered gas lighting a generation earlier.³⁷ In 1888, Edison's Chicago company opened its first central station on Adams Street, which proved inadequate to the growing demand and led almost immediately to a second central station on Harrison Street southwest of the main business district.³⁸ These massive investments kept rates high throughout the 1890s, forcing Edison to purchase competing supply



companies to maintain customers. Electricity's crude delivery and installation compounded its supply-side problems. Only Chicago Edison was capable of providing service at a large neighborhood-scale, but even their direct-current technology limited service to areas of approximately one quarter of a square mile.³⁹ Only in 1897 would the transmission losses of direct current be overcome by alternating current, which could be supplied to substations with little loss and converted back to direct current there, near the customer base.

Beginning with the deep-walled Monadnock in 1889, high-end developments in the Loop had typically included electric wiring in their specifications.⁴⁰ The curtain-wall buildings of this decade were also, surprisingly, wired for electric light; in fact, the Fisher Building was the first tall building to contain dedicated shaft space for electric risers.⁴¹ Likewise, the Reliance Building offered ceiling fixtures and wall-mounted outlets for its tenants upon opening in 1895.⁴² Other buildings of the era, notably Burnham's Merchant's Loan and Trust Company, were simultaneously praised for their extensive exposure to daylight and their state-of-the-art electric installations.⁴³ This apparent paradox — the glass skyscraper supplied with artificial illumination — can again be explained in economic terms. Because of the difficulties in supplying adequate power to the Loop, rates for electricity stayed constant throughout the decade, around the "luxurious" price of \$0.01 to \$0.02 per candlepower lamp hour (\$0.17 to \$0.34 in 2002 prices).⁴⁴ This cost was matched by the need to replace the carbon filament bulbs every eight hundred hours, as their incandescent material evaporated rapidly. It was, therefore, cost effective until at least 1900 to rely entirely on daylight to illuminate offices whenever possible, even where electric lighting was an option.⁴⁵ Artificial illumination was reserved for internal corridors, where levels could be kept low, and for operation during the evening hours or during inclement weather.

Two factors led to the gradual decrease in the cost of electric lighting in Chicago between the

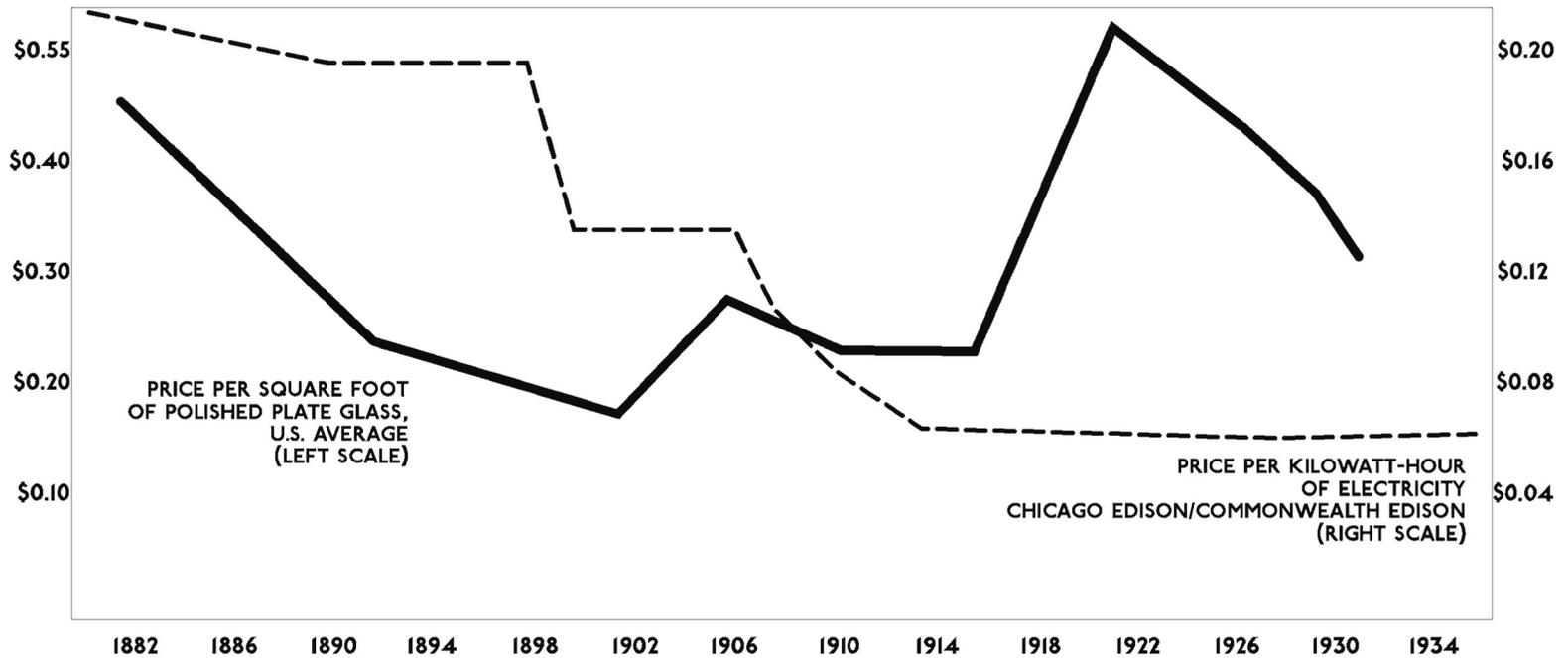
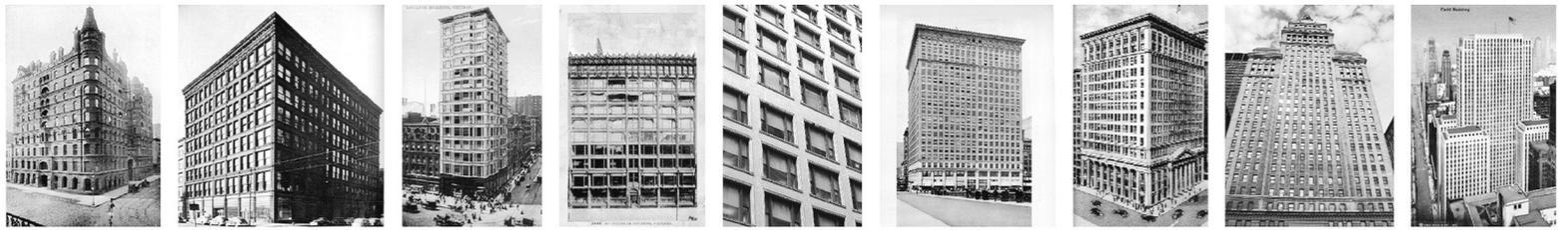
appearance of the Reliance Building in 1895 and the more solid buildings of the 1910s. Following the consolidation of the local industry under Edison during the mid-1890s, Samuel Insull led a restructuring of the finances of the municipal power supply, creating a "massing of production" that increased their customer base by restructuring rates based on peak demand in addition to total consumption.⁴⁶ Chicago Edison also adopted a combination of alternating and direct current during this time, using substations to increase distribution range and efficiency. Additional incentives such as free wiring and lamps led to explosive growth; whereas the company installed approximately fifty thousand incandescent lights per year from 1893 to 1898, it averaged more than two hundred thousand per year between 1898 and 1902.⁴⁷ This expansion allowed further reductions in rates, which by 1912 had dropped to \$0.07 per kilowatt-hour (\$1.30 in 2002 dollars) from \$0.20 (\$4.15 in 2002 dollars) between 1888 to 1898. As rates fell, electricity use per capita during this period increased from 36.6 kWh per person in 1902 to 306.8 kWh per person in 1912.

Buildings of the Insull era (1898–1907) thus demonstrate an ambivalence between solid and void that neatly illustrates the growing affordability of electric lighting as a supplement to daylight. Whereas buildings of the earlier era (the Reliance and Fisher in particular) sought to maximize exposure, buildings of this later period deployed more modest tripartite Chicago windows, deeply inset within vigorously expressed frames. Holabird and Roche's Boston, Kresge, and Republic buildings (all 1905) demonstrate the balance sought between solid and void, daylight and structure. The expressed piers of this period's buildings occasionally gave rise to beaux-arts ornamentation, but even these followed the general formula of a balanced elevation, with large, though not dominating windows set into a minimal, though not radically so, structural frame. (Figure 4.)

The balance between electricity, daylight, and structure was simultaneously affected by the collapse of the Indiana plate glass industry. The gas fields near Kokomo were exhausted after 1900, forcing much of the manufacture of plate glass to move back to Pennsylvania or on to the new oil fields of the Southwest.⁴⁸ For a brief period, from 1897 to about 1901, the gap between inexpensive, locally produced polished plate and electricity as an affordable way to illuminate areas far from daylight was met by a series of ingenious applications of prismatic glass led by the Luxfer Prism Company.⁴⁹ Luxfer was short lived as a supplier of window glass, however. After its purchase by Pittsburg Plate Glass in 1900, Luxfer ceased its promotional campaigns for prismatic windows, focusing instead on basement lights. This rapid departure suggests that by this point electricity was gaining widespread acceptance as a replacement for daylight, obviating the need for expensive prismatic glass.

Electricity's new affordability in Chicago was gradually matched by illumination technology itself. Although carbon filament bulbs had improved, they remained dim, expensive, and short lived. Developments in gas and arc lighting proceeded as well, and it was not uncommon to find incandescent gas mantles used in commercial buildings as late as 1915. Enclosed and "flaming" arc lamps were also often used until around 1920, though they were not surprisingly regarded as inferior and unsafe. Lamps with metallic filaments appeared in 1905, however, and their reliability, controllable output, and affordability completed the revolution in electric lighting. By 1908, the industry had settled on tungsten as a durable filament, and was producing more than one million bulbs a year. The new lamps were available in not only the 16 candlepower version, which matched the output of the best carbon lamps, but also in 25, 50, and 100 candlepower, enabling their use for a wide range of situations, notably book-keeping.⁵⁰ Metallic filaments also produced less heat, enabling them to be grouped into large fixtures. Continuous development of filaments, bulbs,

4. Polished plate glass prices, 1890–1930 plotted against electric rates in Chicago, with a timeline of contemporary building skins. Building images from *One Hundred Twenty-Five Photographic Views of Chicago* (Chicago: Rand-McNally, 1902) and the author's collection.



and fixtures increased efficiency, and the cost of incandescent electric candlepower in Chicago fell below that of gas for the first time in 1914.⁵¹ Subsequent studies suggested increasing the newly affordable artificial light for a typical work space from 3.3 to 5.9 foot-candles, boosting productivity and contributing to the downward spiral of lighting costs as the scale of production and installation continued to grow.⁵²

World War I escalated building prices between 1914 and 1922, during which construction in Chicago halted. When it resumed, the fundamental equations of the prewar period were void. Glass production dipped during the war, and, as the industry recovered, it found itself a victim of higher wages and material costs far out of proportion to other building material suppliers.⁵³ The price of electricity, however, continued to fall after the war. Consumption increased to support military produc-

tion, funding larger, more efficient power plants and substation infrastructure. Whereas glass returned to its historically high prices in the 1920s, artificial illumination became a technically refined, inexpensive reality.

It follows that an era of relatively massive, solid-skinned buildings occurred between World War I and the technical developments of World War II. Structures of this era, beginning with the Drake and Wrigley buildings (1920 and 1921) and continuing through the Field Building (1934), all display elevations that are significantly less than 50 percent glass. The large Chicago window disappeared entirely, to be replaced by the small double-hung window, and the resulting skins — now predominantly stone, terra cotta, or masonry — afforded a more elaborate ornamental approach. This led to a period of strict mercantile classicism that included the Strauss Building on Michigan Avenue by Gra-

ham Anderson Probst and White (1924) and the Pure Oil Building by Thilbar and Fugard (1926). A period of neo-Gothic inspiration followed, begun by Hood and Howells' Tribune Tower (1925) and including the Mather Tower on Wacker Drive by Herbert Hugh Riddle (1928). Later art deco experimentation was cut short by the depression but included the Civic Opera and office tower by Graham Anderson Probst and White (1929), the Board of Trade by Holabird and Root (1930) and the Field Building by Graham Anderson Probst and White (1934). These three stylistically differentiated groups shared a fundamental inversion of Chicago School principles, replacing glass with stone or masonry as the primary elevational material and relying, increasingly, on electric lighting for office illumination. Large panels of glass compared unfavorably with the easy availability and steady price of stone, and the performance of the tungsten bulb

5. The Merchant's Loan and Trust Bank by Daniel Burnham (1901). One of many transitional structures, built as glass prices rose and electricity prices fell around the turn of the century. With better provision for interior lighting, the Chicago window retreated into solid, structural frames. Typical elevations of this era are approximately 60 percent glass, as opposed to the 80 percent glazed façade of the Reliance. (From *One Hundred Twenty-Five Photographic Views*.)

mitigated the need for the large Chicago window and its associated costs and environmental difficulties. Eventually, even the light court disappeared from the typical office block due to the economics of floor rental and the commercial quality of artificial light.⁵⁴ The bulky Merchandise Mart by Graham Anderson Probst and White of 1931 demonstrated that daylight had by that point ceased to be a factor as it dispensed entirely with light courts despite its floor plates of more than 200,000 square feet. Although views and some measure of daylight continued to be desirable in office buildings, economics and climate control dictated that these be provided through relatively small windows in a solid, well-insulated skin. Functional illumination was, from this point forward, to be provided exclusively by electricity.⁵⁵ (Figure 5.)

Conclusion

The window diaphragm in Chicago skyscrapers opened and closed in response to a complex system of prices, performance, and systems, matching John Welborn Root's earlier prescription for the tall office building. Concluding his 1890 essay, "A Great Architectural Problem," Root turned to natural selection in describing the appearance of new architectural forms in the Loop:

To other and older types of architecture these new problems are related as the poetry of Darwin's evolution is to other poetry.



They destroy indeed much of the most admirable and inspiring of architectural forms, but they create forms adapted to the expression of new ideas and new aspects of life. Here, vagaries of fashion and temporary fancies should have no influence; here the arbitrary dicta of self-constituted architectural prophets should have no voice. Every one of these problems should be rationally worked out alone, and each should express the character and aims of the people about it.⁵⁶

Daylight, plate glass, and electricity constituted material conditions that influenced and, at times, determined the composition of these building envelopes. Onto these façades were projected aesthetic and stylistic aspirations, but to propose that the latter somehow drove the former, as Giedion would have us believe, is to ignore the economic conditions and material facts of the era. Glass skins were adopted despite well-documented environmental penalties as long as glass was locally available and relatively inexpensive in proportion to its illumination performance. Solid skins reemerged during the 1920s in response to a new balance, one formed by lingering climatic issues posed by the Chicago window, the changed availability of plate glass, and dramatic improvements in the cost and performance of electric illumination. A technically driven evolution in the fabric of the typical Chicago skyscraper—from solid to skeleton to curtain wall to frame and back to solid—enabled the flowering of both the Chicago School and mercantile classicism. At smaller scales, stylistic preferences for ornament changed, but the coarser-grain issues of massing and cladding were heavily influenced by the problem of illumination and the technologies available to meet its requirements. It is interesting to note that no such determinant role was played by glass or electricity in smaller-scale types, houses in particular, or in civic buildings wherein the fine balance between cost and performance was not as onerous. The speculative financial conditions of the commercial skyscraper account for the decisive role played

by illumination in its development and for the seemingly evolutionary nature of the building skin.⁵⁷

This is not a perfect chronology, nor does it prove that glass and light were the only factors in play during the rise and fall of the Chicago School. Throughout the era, there existed anomalous responses to questions of illumination, skin and style—here one thinks in particular of Burnham's resolute "White City" experiment for the Marshall Fields annex (1892). Likewise, the inclusion of other building types in this chronology reflects the complicated history of the era. The tendencies of hotels, for example, to use electric light relatively early and at high prices—and for department stores to employ larger show windows of polished plate during the electric era—point out the specificity of the commercial block examples. But the overall correspondence between construction materials, illumination technology and costs, and the transparency of the Chicago skin presents a convincing picture of an economically driven building industry, one that sought out and developed precisely costed solutions to a variety of interrelated problems.

Surely powerful aesthetic and stylistic forces were at work in Chicago after the 1893 fair, and architecture, like all professions, needs its heroic myths. It is, however, all too easy to see in Burnham and his successors a convenient morality tale based on their betrayal of earlier aesthetic—even moral—principles. Yet Burnham was neither the first, nor certainly the last Chicago architect to transform a career as a gifted experimentalist into one of lucrative (though formulaic) production. He remained in touch with the fundamental economics of building design and construction throughout his career, and his later hybrid and more purely classical buildings were as rigorously conceived, in terms of building costs and performance, as were his earlier works. Burnham's great talent was to extract the elegance he could out of consistently evolving financial formulae, to see in the era's rapidly evolving data of design the potential for aesthetically coherent works. To recognize this, however, we must accept

the words of Root's inspiration, Darwin, and allow that there is a grandeur in this view of architecture, not as an autonomous discipline but as an activity interwoven with the economics of the productive society and industrial milieu surrounding it. In turn-of-the-century Chicago, the balance among performance, resources, and aesthetics can be visualized through the constructional fabric of the era's architecture, its elegantly expressed data of design changing as technology and economics traced their influence onto building skins. Such dramatic shifts in the function and construction of the Chicago skyscraper came about not through the bombastic cultural struggles imagined by Sullivan and Giedion, but rather through the mundane and everyday facts of construction and function, not least of which was the light on a bookkeeper's desk.

Notes

1. Siegfried Giedion, *Space, Time and Architecture*, 3rd. ed. (Cambridge: Harvard University Press, 1954), 392.
2. Masami Takayama, "Good Buildings, Cheap: Interview with John A. Holabird," *Process Architecture* 35 (December 1982): 22–23.
3. The phrase "Chicago School" is slippery, as noted by H. Allen Brooks, "Chicago School: Metamorphosis of a Term," *Journal of the Society of Architectural Historians* 25/2 (May 1966): 115–18. My intent is to describe the body of experiments in multistory commercial construction in Chicago between 1871 and 1920.
4. Louis Sullivan, *The Autobiography of an Idea* (1923; reprint, New York: Dover, 1956), 324–25.
5. The Chicago "myth" has been challenged before on largely stylistic grounds, notably by Dmitri Tselos in "The Chicago Fair and the Myth of the 'Lost Cause,'" *Journal of the Society of Architectural Historians* 26 (December 1967): 259–68.
6. The earliest demonstrably beaux-arts skyscraper in the Loop was built not by Burnham, but by William Le Baron Jenney, for New York Life, a twelve-story building still standing at La Salle and Monroe Streets (1894). Chicago's major civic monuments of the era—beginning with the Newberry Library (1892) and including the Art Institute (1893), the Public Library (1897), and the Federal Building (1905)—were consistently neoclassical.
7. The term *skeleton construction* and its attribution solely to Jenney, or even Chicago, has been a continuing source of contention. See Gerald Larson and Roula Mouroudellis Geraniotis, "Toward a Better Understanding of the Evolution of the Iron Skeleton Frame in Chicago," *Journal of the Society of Architectural Historians* 46/1 (March 1987): 39–48. The debate over the role of the Home Insurance Building as the world's "first skyscraper" was begun by a biased report by historian Thomas Tallmadge upon its demolition in 1934. See Thomas Tallmadge, ed., *The*

Origin of the Skyscraper: Report of the Committee Appointed by the Trustees of the Estate of Marshall Field for the Examination of the Structure of the Home Insurance Building (Chicago: Ralph Fletcher Seymour/Bethlehem Steel, 1939). Defining a specific moment as the founding of either the skyscraper or skeleton frame is moot, as the phenomenon is better described as the gradual accretion of various technical factors. See Carl W. Condit, "The Two Centuries of Technical Evolution Underlying the Skyscraper," in Lynn S. Beedle, ed., *Second Century of the Skyscraper* (New York: Council on Tall Buildings and Urban Habitat, 1988), 11–24. The parlor game of parsing the term *skyscraper* is most alarmingly played in J. Carson Webster, "The Skyscraper: Logical and Historical Considerations," *Journal of the Society of Architectural Historians* 18/4 (December 1959): 126–39. For a cogent summary of the controversy's history, see Rosemarie Haag Bletter, "Invention of the Skyscraper: Notes on Its Diverse Histories," *Assemblage* 2 (1987): 110–17.

8. For the suggestion that electric light has played a role in the demise of the Chicago window, see Carol Willis, "Light, Height and Site: The Skyscraper in Chicago," in John Zukowsky, ed., *Chicago Architecture and Design, 1923–1993* (Munich: Prestel, 2000), 119–40; and Daniel Bruegmann, *The Architects and the City* (Chicago: University of Chicago Press, 1997), 494, in addition to the quote from John Holabird, above. See also Carol Willis, *Form Follows Finance: Skyscrapers and Skylines in New York and Chicago*. (New York: Princeton Architectural Press, 1995). The role of daylighting and electric lighting on the economics of office development is discussed by Earle Shultz and Walter Simmons, *Office in the Sky* (Indianapolis: Bobbs-Merrill, 1959), 18–31, 128–35. To the author's knowledge, however, no study has linked this transformation with the local developments in the electric light industry described below, nor has such a study been done of the influence of the plate glass industry on the Chicago window's conception.

9. Carl Condit, *The Chicago School of Architecture* (Chicago: University of Chicago Press, 1964), 79; and George Hill, "Some Practical Limitations in the Design of Office Buildings," *The Architectural Record* 2 (1892): 445–48; and "The Modern Office Building," 4–5.

10. William LeBaron Jenney, "The Chicago Construction, or Tall Buildings on a Compressible Soil," *The Inland Architect and News-Record* 18/4. (November 1891): 41. See Frank A. Randall, *History of the Development of Building Construction in Chicago* (1949; revised and expanded by John D. Randall, Chicago: University of Illinois, 1999), 119.

11. John Welborn Root, "A Great Architectural Problem," *The Inland Architect and News-Record* 15/5 (June 1890): 68.

12. George Hill, "Some Practical Limitations in the Design of Offices Buildings," *The Architectural Record* 2 (April–June 1893): 448.

13. Barr Ferree, "The Modern Office Building," *The Inland Architect and News Record* 27/1 (February 1896): 4.

14. Fay V. Tooley, *Handbook of Glass Manufacture* (New York: Ogden, 1960): 227–34.

15. A.U. Howard, "Plate Versus Cylinder Glass," *The Inland Architect and News Record* 28/4 (November 1896): n.p.

16. "The American Plate Glass Industry," *Scientific American* 72/10 (March 9, 1895): 151.

17. Shirley P. Austin, "Glass," *Twelfth Census of the United States of America* (1900), 962–63.

18. "Manufacture of Plate Glass," *Scientific American* 24/20 (May 18,

1901): 304, 311. See also Ralph Howard, "How Plate Glass Is Made," *Scientific American* 123/1 (July 3, 1920): 14.

19. Austin, "Glass," 962.

20. "Natural Gas Phenomenon in Indiana," *Scientific American* 63/10 (Sept. 5, 1890): 145.

21. Kimball supplied Crystal Plate Glass for most of the larger buildings of the 1880s. See *Industrial Chicago* (Chicago: The Goodspeed Publishing Co., 1891), 793.

22. H.C. Hovey. "Manufacture of Plate Glass at Kokomo, Indiana," *Scientific American* 63/16 (Oct. 18, 1890): 241.

23. Victor S. Clark, *History of Manufactures in the United States*, vol. 2 (New York: McGraw-Hill, 1929), 502.

24. *Ibid.*, vol. 3, 262.

25. The continuous annealing *lehr* was essentially a linear cooling oven whose automated belts eliminated the need to maintain numerous individual cooling kilns. In 1880, only 1,700,227 square feet of plate glass were cast in the United States, at an average cost of \$0.51 per square foot (\$10.00 per square foot in 2002 terms). By 1900, the industry was producing nearly 35 million square feet of polished plate glass per year, at an average cost of only \$0.30 per square foot. Prices and quantities from 1900 United States Census.

26. United States Tariff Commission, *Flat Glass and Related Glass Products: A Survey Covering the Principal Producing and Trading Countries, With Particular Reference to Factors Essential to Tariff Consideration* (Washington: United States Government Printing Office, 1937), 109.

27. Jenney's Second Leiter Store of 1891 used an unprecedented quantity of glass from Crystal City. See *Industrial Chicago*, 793.

28. Beman incorporated prototypical Chicago windows in the first Studebaker building (now the Fine Arts building), executed in 1885. These windows were originally divided into eight separate lights, indicative of the difficulties in transporting large plates to the region.

29. "Technical Review: The Fisher Building, Chicago — A Building Without Walls," *The Inland Architect and News-Record, Special Supplement* 27/4. (May 1896): n.p.

30. In 1906, the "new school" of window design was to be found in "Pittsburg, Wheeling, Louisville, Cincinnati, Cleveland, Columbus, Indianapolis, Chicago, Detroit, [and] Milwaukee." All of these cities were directly accessible from a center of plate glass production — Pittsburgh, New Albany/Louisville, Kokomo, and Crystal City. George Wilfred Pearce, "Notes on some Western Installations," *The Illuminating Engineer* 2/11 (January 1908): 792–93.

31. Boilers and forced air systems were both developed during the late 1800s, and literature of the day (indeed as late as 1915) suggests that conditions in skyscraper offices were often intolerable due to summer heat gain and winter heat loss. See "The Environments of Large Buildings," in Reyner Banham, *The Architecture of the Well-Tempered Environment* (Chicago: University of Chicago Press, 1969), 71–92.

32. *Industrial Chicago*, 270.

33. Hugo Grosser, "Gas and Electric Light Service: Chicago," *The Annals of the American Academy of Political and Social Science* 27 (Jan. 1906): 202.

34. Louis Bell, *The Art of Illumination* (New York: McGraw-Hill, 1912), 12.

35. "Decadence of the Use of Gas as an Illuminant," *The Inland Architect and News Record* 20/6 (Jan. 1893): 60.

36. Harold L. Platt, *The Electric City: Energy and the Growth of the Chicago Area, 1880–1930* (Chicago: University of Chicago Press, 1991), 3–29.

37. *Ibid.*, 34.

38. *Ibid.*, 53–54, 75–76.

39. "Alleged Combination of Electric Companies," *The Inland Architect and News-Record* 19/2 (March 1892): 18. See also "Remarkable Bidding for Electric Lighting," *The Inland Architect and News-Record*. 19/3 (April 1892): 30.

40. Platt, *The Electric City*, 38.

41. "Technical Review: The Fisher Building, Chicago — A Building Without Walls," n.p.

42. Wm. S. Monroe, "Electric Lighting of Modern Office Buildings," *The Architectural Record* 6: 110.

43. E.C. Clark, "Technical Review, the Merchant's Loan and Trust Co. Bank Building, Chicago," *The Inland Architect and News-Record* 37/3 (April 1901): 7, 16.

44. Arthur Vaughn Abbot, C.E., "Electrical Engineering for Architects," *The Inland Architect Supplement: Technical Review of the Interesting Development of the Building Arts* 34/6 (Jan. 1900): 17–23.

45. *Ibid.*, 17.

46. Platt, *The Electric City*, 59–94.

47. *Ibid.*, 108.

48. United States Census reports, 1880–1930.

49. Various advertisements for Luxfer Prism Co., Luminous Prism Co., and Holophane Glass, *The Inland Architect and News Record*, 1898–1901.

50. By comparison, today's typical 60W incandescent lamp produces around 170 fc.

51. M. Luckiesh, *Light and Work: A Discussion of Quality and Quantity of Light in Relation to Effective Vision and Efficient Work* (New York: Van Nostrand, 1924), 82.

52. Cecil D. Elliott, *Technics and Architecture: The Development of Materials and Systems for Buildings* (Cambridge: The MIT Press, 1992), 233–70.

53. Warren Scoville, *Studies in Economic History: Revolution in Glass-making* (Cambridge: Harvard University Printing Office, 1948), 264–65.

54. Meredith Clausen, "Frank Lloyd Wright, Vertical Space, and the Chicago School's Quest for Light," *Journal of the Society of Architectural Historians* 44 (March 1985): 66–74.

55. Willis, *Form Follows Finance*, 132–43.

56. Root, "A Great Architectural Problem," 67–71.

57. The difficulty of the term *evolutionary* as applied to architectural development is cogently laid out by Peter Collins, *Changing Ideals in Modern Architecture* (London: Faber and Faber, 1965), 153, as noted by Tom Peters, *Building the Nineteenth Century* (Cambridge: The MIT Press, 1996), 30. Collins notes that Darwin's architectural analogy in explaining natural selection, that of a builder selecting stones for a wall, neatly separates the productive "causes" of the stones from the "uses" to which they are put. Thus, the act of "selection" is different from — but related to — the act of "production." The relationship between plate glass (or electricity) and its use in Chicago may thus be described as the awareness on the part of Burnham, Holabird, and Root, et al. of the technological milieu in which their work occurred, and the intelligent selection from this for use in architectural applications.