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Daylighting in American industrial architecture: Three investigations

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Daylighting in American Industrial Architecture: Three Investigations

by

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DAYLIGHTING IN AMERICAN INDUSTRIAL ARCHITECTURE:
THREE INVESTIGATIONS

by

Michael J. Kuchta

During the early 20th century, American architects pioneered new building forms to meet the demands of a rapidly expanding industrial economy. Many factories used natural light in innovative ways to illuminate work spaces. In the 1940s, however, the large scale introduction of air conditioning and fluorescent lighting, combined with wartime production demands on America's factories, reduced the usefulness of natural light in architectural design.

An exploration of architectural daylighting finds new relevance for natural light in the architectural needs of a post-industrial society. A photographic survey of daylit buildings conveys a sense of the evocative qualities of light in space. A building design posits the importance of the sky as the "fifth side" of a building site, and employs daylighting to frame the sky and horizon on an otherwise banal plot of land in suburban Houston.
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Investigation I:
The Role of Daylighting in American Industrial Architecture

In 1907, architect Albert Kahn designed an automobile manufacturing and assembly building that would have a profound influence on modern factory construction. The Geo. N. Pierce Plant in Buffalo, New York introduced a novel building type to the industrial vocabulary: the infinitely-expandable single-story shed. The assembly building, only one of an industrial complex designed by Kahn and Boston engineers Lockwood Greene and Company, was framed in concrete and lit from above. A sawtooth monitor, a series of angled windows set into the roof structure, provided natural light for the production workers below. [Figures A-1, A-2]

Figure A-1: Geo. N. Pierce Plant, Buffalo, New York, 1907, by Albert Kahn. (Grant Hildebrand, Designing for Industry: The Architecture of Albert Kahn, p. 40).

Kahn's innovation made the factory walls unimportant as sources of daylight and structural support. The building was lit from above, not from the side, and could assume any
horizontal dimensions. It was supported by steel and concrete columns, not massive masonry walls, so the thin exterior walls could be easily removed to accommodate plant enlargement. The changes also facilitated continuous production because parts didn't waste time sitting on elevators or vertical conveyors. The Pierce Plant was "so ideally suited to assembly-line operations that it is startling to realize that they were not used there when the plant was completed,"¹ Kahn biographer Grant Hildebrand later wrote.

![Image](image)

Figure A-2: Geo. N. Pierce Plant, Buffalo, New York, 1907, by Albert Kahn. (Grant Hildebrand, Designing for Industry: The Architecture of Albert Kahn, p. 41).

The new design allowed for faster, cheaper construction as well. In multi-story buildings, construction crews must wait days for the concrete supporting one floor of the building to cure before beginning work on the next story. In contrast, all of the formwork for the Pierce Plant was put in

place simultaneously. The development of sprawling single-story industrial complexes was spurred too by the increasing economy of rail and truck transportation, which made feasible the construction of industrial plants on plots of cheap land outside congested center cities.

Given its flexibility, its suitability for assembly-line techniques, and its ease of construction, the top-lit shed promoted by Albert Kahn became a dominant form of industrial construction shortly after World War I. But the wide applicability of the one-story shed would not have been possible without the use of top-lighting strategies like the sawtooth roof - one of a number of daylighting devices, generically termed monitors, developed or used in early 20th century industrial architecture. The shapes of the monitors were determined by the structural systems which supported them and by the industrial processes they accommodated. [Figures A-3 through A-6]

Figure A-3: Monitor Types (from Duane Roycraft, Industrial Building Details, 2nd ed., p. 88)
The manufacture of rail cars, for example, required tall spaces for overhead cranes that moved parts, while the production of aircraft required wide column-free spaces, and steel foundries needed large roof openings to evacuate heat quickly. Almost all industrial processes of this era required large amounts of natural light because precision work was becoming increasing prevalent and because there were few practical means of high-coverage artificial illumination.

Figure A-4: Monitor Types, 1923. (Walter F. Ballinger, "Roof Types and Roof Surfaces", Architectural Forum, 39(1923):110.)

Figure A-5: Packard Forge Shop, Detroit, Michigan, 1910, by Albert Kahn (Hildebrand, Designing for Industry, p.64).
Rooftop daylighting techniques originated with the dormer windows of early New England textile mills and the roof ventilating devices of mid-nineteenth century iron forges. Daylighting in factory construction reached a peak in the building boom of the 1920s, but didn't stay popular for long. During the 1940s and 50s, advances in artificial lighting and air conditioning reduced the need for daylighting in factory construction. While almost all industrial structures built before World War II employed monitors for lighting or ventilation, only 60 percent of those built between 1940 and 1952 did.²

Daylighting methods were eventually removed from the kit of parts available to industrial architects. In 1960, the author of Industrial Architecture: An Analysis of International Building Practice complained that as many as 15 percent of newly-built factories still relied on daylighting "when artificial lighting and mechanical ventilation are so efficient".³ Today, it is difficult to find any new industrial plants designed with daylighting in mind.

The New England Textile Mill

Daylighting devices can be seen in some of the earliest American factory buildings: The textile mills built in

³Ibid., p. 49.
northern New England to turn raw cotton into thread and cloth. Many of these early 19th century mills incorporated clerestory windows for lighting the uppermost story. In some mills, windows were left closed, because thread was more durable in the humidity of human toil and might be broken by a passing breeze.4

The Old Slater Mill in Pawtucket, Rhode Island provides an early American example of clerestory lighting. The Slater Mill is named for British emigrant Samuel Slater, who began construction on the factory in 1793. It was the first structure in America built specifically for textile production. Slater's design was largely based on the British mill construction techniques he had studied as an apprentice. The frame consisted of heavy wood timbers, and the siding was of wood clapboards. The original building was two stories tall, 12 feet to a story, with an attic above the second floor for storage rather than production. The 30-foot-wide floors were free of interior columns, to allow flexibility in the placement of spinning machines, and were narrow enough to allow daylight from side windows to reach the center of each floor.5[Figure A-6]

In the early 1800s, the mill owners added a narrow "eyebrow" monitor to the sloped roof to light the attic. The small slit runs almost the length of the building, which was extended over the course of the 19th century to its current state. The eyebrow window design, borrowed from late-eighteenth century mills in England, became a standard element in many of the 1,400 textile mills built in New England prior to the Civil War.

The Cheshire Mill in Harrisville, New Hampshire is a prototypical example of the mill building. Built in 1846, it shows incremental changes in the building techniques used at

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6 Ibid., pp. 24-25.
the Slater Mill. The new mill employed "slow-burning" construction—a heavy masonry exterior with large interior wooden beams and columns—to allow factory hands time to escape from fire.


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7Ibid., pp. 72-73. The author notes that the "stone construction and clerestory monitor appear to have been derived from southern New England textile factories of several decades earlier".
Similar to the Slater Mill, the new building contained two full stories with a third floor lit by an eyebrow window. The Cheshire Mill clerestory provided only small slivers of light and ventilation. However, these windows made the attic level usable for production, rather than simply for storage, and thus increased the value of the owner's investment in the mill.


The versatility and economy of textile mill construction gave it wide applicability. Multi-story brick mill buildings were used by many 19th century industrial concerns, for the production of power looms, bicycles, sewing machines, and other commodities. [Figure A-9]

Across America, mill villages provided goods for a growing population that was becoming more urban and industrial. The mill building perched at the edge of a river
became a common element of the nineteenth century vernacular landscape. Few heavy timber mill buildings have been built in America since the onset of cast iron and concrete building technology in the late 1800s. But many of the sturdily-built mills have endured, and the versatility of their simple floor plans have often suited them to apartment and office conversions undertaken since the 1960s. [Figure A-10]

Figure A-10: The Baltic Cotton Mill, Baltic Connecticut, 1856, (Hambourg, Mills and Factories of New England, p.41).

A Second Tradition: Rooflighting in Steel Mills

The early 20th century iron and steel mills of the Pennsylvania river valleys also made use of rooflighting technology. The monitors in such mills were used primarily for ventilation, to evacuate heat and smoke from the coke fires needed to melt metal. In the exceedingly practical world of industrial building, their form was closely tailored to their purpose, and thus differed from that of the textile mills.
In Coatesville, Pennsylvania, a monitor-topped mill for rolling iron was built in the mid 1830s.[Figures A-11,A-12] The Lukens works, which had started in the 1790s, produced iron plates for use in steam boilers and ship hulls. Most of the lower portion of the wooden shed mill building was left unclad, because the high temperatures required to melt iron were hazardous to both workers and building.

Figure A-11: Lukens Rolling Mill, Coatesville, Pennsylvania, circa 1835. (Iron and Steel in America, p. 6.).

Figure A-12: Lukens Rolling Mill, Coatesville, Pennsylvania, circa 1835. (Joseph Butler, Jr., Fifty Years of Iron and Steel, p. 26).

Monitors were also used in 19th century rolling mills. Rolling mills are partially-enclosed buildings where iron and steel ingots are reheated and formed into various shapes for structural beams, plates, sheets, and bars. To encourage air movement, monitors in rolling mills were built fully-emerged from the roof plane, and were thus much taller than those in textile mills.

An 1866 engraving of the newly founded Keystone Bridge Works in Pittsburgh is typical of such industrial complexes. [Figure A-13] Keystone was steel baron Andrew Carnegie's first foray into the industry he later came to dominate. Iron bridges manufactured for the rapidly expanding railroad networks were built in the long brick mill buildings here.\(^9\) Like the New England textile mill, the rolling mill quickly became a widely-applied industrial building typology.

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The Daylight Factory

Traditional 18th century mill buildings, whatever their other features, were not especially generous providers of daylight. In the 1880's, however, Ernest Ransome, a British-born engineer working in California began to promote the use of steel-reinforced concrete in building construction. Ransome and other engineers who learned of his work introduced the "Daylight" factory, a multi-story reinforced concrete building, to American industry. Because their structural frames comprised only a small percentage of the exterior wall surfaces, Daylight factories featured large windows and dramatically improved daylighting conditions.

[Figures A-14, A-15]

Figure A-14: Larkin R/S/T Building, Buffalo, New York, Lockwood, Greene and Company. (Reynier Banham, A Concrete Atlantis, p. 94).

Because their frames were inherently stronger than masonry walls, they could be built considerably taller and at

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less material expense than could brick mills. On sites throughout the northeastern United States where land values and transport costs dictated a compact building form, the Daylight factory became a natural choice for industrialists.

Figure A-15: Larkin R/S/T Building, Buffalo, New York, Lockwood, Greene and Company. (Banham, A Concrete Atlantis, p.95).

One notable example of a Daylight factory is Albert Kahn's Building 10 at the Packard Motor Works in Detroit.[Figure A-16]. In Building 10, Kahn reduced the concrete structural members to previously-unseen slenderness, and exposed them on the facades with clearly articulated brick infill panels and large expanses of operable sash. The simple, almost mean detailing of Building 10 was destined to excite the sensibilities of early European Modernists some years later.\textsuperscript{11} For Kahn, however, economy was the paramount concern, not aesthetics, and it was economic imperative that led him to eventually abandon the Daylight factory.

\textsuperscript{11}Ibid., pp. 85-86.
The Top-Lit Single Story Factory

By the time European architects like LeCorbusier and Walter Gropius "discovered" American industrial architecture in the 1910s, the concrete-framed Daylight factories they admired had lost their place at the vanguard of factory construction. In his 1923 manifesto Vers une Architecture, LeCorbusier borrowed badly-screened images of American factories from a 1913 German publication, Jahrbuch des Deutschen Werkbunds. As Reyner Banham has noted:

these great factories were the very end of a tradition, a doomed building type, which, by the time it was taken up in Europe and before Mendelsohn set foot in Buffalo or Detroit, had already ceased to be modern enough to satisfy the needs of innovative American industry.¹²

What would satisfy industry, it became apparent, were single story buildings like Kahn's innovative Pierce Plant.

The Austin Company, a firm of industrial architects and

¹²Ibid., p. 19.
builders, developed a number of standard industrial buildings that could be erected in as little time as it took to write up construction contracts. In 1915 The Austin Company of Cleveland touted a single-story top-lit factory among its Standard Daylight Buildings. [Figure A-17]

![Elevation drawings of the Standard Daylight Factory](image)

*Figure A-17: Standard Daylight Factory, 1915, by The Austin Company (Martin Greif, *The New Industrial Landscape*, p. 69).*

Their standard repertoire included a number of top-lit buildings, like the sawtooth structure recommended "for any manufacturing process requiring well-diffused light", and a "Universal Type", "ideal because of its wide areas of unobstructed floor space".\(^{13}\) [Figure A-18]

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A New Austin Standard Building

Figure A-18: "Steelspan" garage, 1915, The Austin Company (Greif, p. 69).

The ethos of standardization, promulgated by Henry Ford as he filled the roadways of America with Model Ts, had reached industrial architecture. The Austin Company did its best to spread its products throughout the United States, opening offices in Detroit, Philadelphia, Pittsburgh, and Bridgeport, Connecticut in 1916. As America's industrial capacity expanded to meet the production demands of the First World War, single-story top-lit industrial facilities were established as a standard and widely-imitated building form.

The Post War Boom

During the 1920s industrial architects worked vigorously on the development of environmental-management strategies, like daylighting and enhanced air circulation. One advance in daylighting systems was the Super-Span, a truss system for sawtooth monitor roofs which was patented in 1921. Traditional sawtooth designs, like that of the Pierce Plant,
required support columns every 20 feet, restricting the flexibility of the work space. The Super-Span produced sawtooth window-lit spans of unlimited length 100 feet wide over the factory floor. [Figures A-19, A-20] A conventional Howe truss, running behind the face of the skylight, was supported by a truss running perpendicularly "whose bottom chord is at the same level as the valleys and whose top chord extends outside the 'sawteeth' connecting their peaks one to the other."¹⁴

Figure A-19: Super-Span Saw Tooth Roof. (Ballinger, pp. 112).

Figure A-20: Ardross Worstted Co Weave Shed, Philadelphia. (Ballinger, pp. 111).

In 1923 the Ballinger Company, an architecture and engineering firm, employed their patented truss design in the Atwater Kent Manufacturing Company in Philadelphia. [Figure A-21] Ballinger designed many Super Span factories in the northeastern United States, including one in which a 40,000 square foot publishing room required only three interior columns.15


The benefits of the single-story top-lit plant gave it a long shelf life by 20th century standards, some thirty years. As late as 1937, Architectural Record was still recommending the Ballinger roof truss system in its Building Types Survey of industrial plants.16

The Blackout Plant

During World War II, a number of factors conspired to diminish the usefulness of industrial daylighting in general, and top-lighting in particular. Primary among these factors were increases in the efficiency of electric lighting and the development of mechanical ventilation and air conditioning. Prior to the commercial introduction of fluorescent lighting by General Electric and Westinghouse in 1938, the incandescent bulb was the only practical source of artificial illumination for most factories. [Figure A-22]

Here's a new designing tool for Architects...

**FLUORESCENT LIGHTING**

WITH NEW G-E FLUORESCENT MAZDA LAMPS

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**Figure A-22: General Electric advertisement (Pencil Points, Dec. 1938, p. 13).**
In the late 1930s, fluorescent tubes were installed in many industrial plants which, because of pressing war demands, were running two or three shifts a day. Fluorescent lighting is more efficient and produces less waste heat than incandescent bulbs. Factory floors could be bathed in a higher level of artificial light without substantially increasing the temperature inside the plant.

Methods of mechanical ventilation and air conditioning had been pursued since the late 19th century, by inventors like Willis Carrier, for the refrigeration of cargo holds on ships, the cooling of liquids in breweries, and the drying of tea or tobacco, among other industrial uses. Human comfort was rarely the goal of climate control in these early explorations, however.\(^{17}\) Only in the 1930s did air conditioning for human use become feasible, most prominently in the 1932 PSFS Building in Philadelphia. [Figure A-23]

Widely acclaimed as the first International Style office building, its environmental innovations included a chiller plant on the middle floor and separate cooling zones for the sunny and shady sides of the building. Closed (but still operable) windows kept out soot from the busy street below, while hidden ducts cooled the stylish second floor banking hall. Although few other office buildings were built during the Great Depression of the 1930s or the ensuing war years, by the time a civilian economy resumed in the late 1940s,

automatic climate control had become a standard feature of commercial construction. In the meantime, industrial architects took up the charge of climate control.


The Simonds Saw and Steel Company in Fitchburg, Massachusetts, completed in 1939, was promoted at the time as the first completely windowless air-conditioned industrial facility in the world.\(^{18}\) Built by the Austin Company of Cleveland, it was to have as profound an influence on industrial architecture as had Kahn's Pierce Plant three decades earlier.\(^{[Figure A-24]}\) Austin's marketers, who had once touted the company's monitor-lit buildings, now began to promote their antithesis: the controlled conditions plant. Whether through marketing or happenstance, the windowless factory gained popularity with America's manufacturers as the nation plunged into World War II.

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\(^{18}\)Munce, p. 41.
Daylight versus Blackout

Although many new factories built during the war were daylit, growing defense concerns limited the appeal of natural lighting. Windows and clerestories not only let light in during the day shift, they let light out during the night shift, and would provide easy targets for enemy bombers, according to critics. Thus, the concept of the "blackout" plant developed out of wartime fears.

In 1945, a spokesman for the Albert Kahn firm noted that "as a result of wartime experience some industrialists are more receptive now than formerly to the idea of a blackout plant for civilian production." A few years earlier, Albert Low, vice president and chief engineer of the Austin Company, had written that "windowless or controlled-conditions plants provide uniform working conditions for multiple shift operation and have the inherent light-proof qualities needed for "blacking-out" a plant, and are

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consequently gaining increased acceptance." His firm had built the second controlled-conditions factory in America - the Allison aircraft engine plant in Speedway, Indiana, and went on to design eleven more such plants during the course of the war.\textsuperscript{21}(Figure A-25)

\begin{figure}[h]
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\caption{Allison Division, General Motors Corporation, Speedway, Indiana, 1939, by the Austin Company. (Industrial Buildings: The Architectural Record of a Decade, p. 13).}
\end{figure}

The artificially-lit factory was also promoted for use in industries requiring precision work - where changing light conditions could reduce a machinist's ability to inspect parts for uniformity. In conventional side-lit factories, workers either stood between the windows and the production line (casting shadows on their tools and tasks), or else faced the uncomfortable glare of a brightly illuminated wall of glass. Precision work could be difficult in toplit

\textsuperscript{20}Ibid., p. 33, January 1941.
factories too, especially when cloudy winter skies or dirty skylights reduced illumination.

Blackout plants were also promoted for their cleanliness. Dirt particles flying through open windows could upset the close tolerances of milling machines and other precision equipment. Chiller plants, in addition to cooling the air, washed it of dust, pollen, and other contaminants. In controlled-conditions factories the production floor was insulated and isolated from outside environmental conditions.

Although some production processes - like the manufacture of pharmaceuticals and food products - required more sanitary conditions than had airplane manufacturing, the cleanliness ethos transcended the absence of dirt. It extended to the appearance of buildings, and to the way architectural writers described a new crop of industrial buildings: "...the clean cut simplicity of this immense Vehicle Maintenance Shop...,"22 "...that esthetic appeal which only a thoroughly 'clean' building affords...,"23 "...this clean little manufacturing and office building...".24 The infiltrating air and dirt were described as if they were agents of Communism.

However attractive controlled-conditions industrial buildings were to cleanliness advocates, they came with

23Ibid., p.158, "Industrial Building for the Electrolux Corporation, Old Greenwich, Connecticut."
24Ibid., p.120.
psychological drawbacks to factory hands. Ventilation and temperature-control methods ran counter to human instinct. Artificial light cast an unchanging shadowless pall over the work place and the elimination of large window openings and clerestories meant that employees were less aware of outside conditions. Forced-air heating and cooling produced an even, gentle distribution of temperate air; in natural environments, by contrast, the radiant heat of fires and stoves produces large gradations of hot and cold air.

Architectural Record commented in 1941 that "there is still in many instances a continuing prejudice on the part of labor against working in walled-in areas, where no daylight or outside air are directly available."\textsuperscript{25} The Kahn firm noted that "there was noticeable restlessness and a let-down of morale among day-shift workers in blackout plants during the warm balmy days of the year."\textsuperscript{26}

The blackout factory represented a significant technological advancement during a war "won" by American ingenuity and technical prowess. For the manufacturers of instant mashed potatoes, plastic dinnerware and panty hose, consistency and evenness of product were paramount qualities, qualities which extended to the factory floors themselves.\[Figure A-26\]

\textsuperscript{25}Reid, p. 37, January 1941. 
\textsuperscript{26}Ibid., p. 152, November 1945, and p. 251, November 1949. In the place of true daylighting, industrial builders incorporated narrow horizontal "vision strips" placed at eye level "to remove any feeling of claustrophobia."
As a result, however, work environments became as bland and homogenized as the creamed corn and Wonder Bread they churned out. And, sadly enough, the architectural innovations which characterized factory construction during the previous half-century were put to rest in the name of progress.
Investigation II:
A Photographic Essay on Daylighting in Architecture

There is something profoundly unsatisfying about reading descriptions of buildings without actually seeing them or walking through them. It is nearly impossible to use words to describe the light filtering through the monitor of an old factory. Because so many of the buildings discussed in the preceding investigation no longer exist, have been radically changed or are inaccessible, this investigation is an attempt to capture and reveal qualities of light that would best be appreciated in person.

These photographs are not meant to negate, but to complement the history presented above. The architectural use of daylight is catalogued here in an admittedly personal way. The following images of factories, public buildings and houses provide examples of toplit and sidelite spaces, of spaces brought alive by single shafts of daylight, and of spaces illuminated by row upon row of windows. Which is to say, they are images which portray both the beauty and the versatility of natural light as it defines architectural space.

While most of the daylight buildings explored in the first section are based on complex structural systems, the means to manipulate daylight can also be very simple. Light is used effectively as an architectural accent in a house in Clear Lake, Texas, designed by architect Peter Waldman.
[Figure B-1] Glass block at the fascia height of a two-story dining room serves two functions: to splash light and color on adjacent walls, and to illuminate the ceiling.


In the Kimball Art Museum in Fort Worth, Texas, semi-circular slits in the barrel vaults call attention to the architecture, by accentuating the curve of the roof and illuminating the craftsmanship of the cast-in-place concrete and travertine walls.[Figure B-2] Louis I. Kahn is acknowledged as a master at the integration of light and space, and the Kimball is perhaps his most accomplished work in this regard. The barrel vault ceilings and their light diffusers bathe the museum walls in gentle daylight - so
gentle that it is of little use to the museum visitor who has come to see the museum's collection of paintings and sculpture. Even on bright Texas mid-afternoons, incandescent lights – hanging from Kahn's elegant light baffles like so much unnecessary fringe – are put to use.

Figure B-2: Kimball Art Museum, Fort Worth, Texas, 1966-72. Louis I. Kahn, architect. Photograph, 1990.

Michael Graves' use of daylighting at the Newark Museum is less self-consciously architectural than Kahn's, and perhaps more honest in its intentions. [Figure B-3] Museums have traditionally made good use of toplighting, to free up wall space for artworks. In the 1960s, museum curators became
more aware of the danger which the ultraviolet component of daylight poses to artworks, and have often sought to reduce natural light to lower levels than afford comfortable viewing. This light well at the Newark Museum is used to provide a break from the long dark corridors filled with precious objects. It also makes a visual connection to the sky from deep within the museum.

Figure B-3: Newark Museum renovation, Newark, New Jersey, 1989. Michael Graves, architect. Photograph, 1990.

A central core of light is also used in the Innova Building in Houston, but this time the light enters from high windows along three sides, rather than from the roof. (Figure
B-4] The daylight - which would be too bright if aimed directly onto work spaces - slices through the building like a diagonal fissure and is filtered through a five-story lobby. The offices are top-glazed to receive ambient light from the surrounding public space.


Glare is a critical issue in most daylighting situations. Sharp contrasts between the strong light coming through a window and the subdued brightness of an interior space can confuse the iris and be visually distressing. Building designers can make the gradation from bright area to dark more gentle by altering the depth and shape of the wall surrounding the opening, and by introducing mediating devices such as blinds. In a wedge shaped corridor at the Prague
Castle in the Czech Republic, rows of tall windows set into a masonry wall seem to glow. [Figure B-5] Ambient light is modulated by translucent curtains and by the depth of the wall, reducing overall contrast and glare.

![Diagram of Prague Castle](image.png)

*Figure B-5: Prague Castle, Prague, Czech Republic; renovations 1940-54, Otto Rothmeyer, architect. Photograph, 1992.*

Using fritted glass in the skylights at the United Airlines Terminal at O'Hare Airport in Chicago, Helmut Jahn provides an architectural equivalent of the sheer drapes at Prague Castle. [Figure B-6] Jahn's work at O'Hare draws upon the 19th century railroad stations which served as grand portals to new American cities. Like many of the vaulted train sheds, the United terminal makes great use of toplighting, through some refined and subtle detailing. The white framing elements reflect and transmit as much daylight
as structural steel can. Circular holes in the bents produce smaller regions of strong light and deep shadow. The resulting filigree of light-modulating elements produces pleasing contrast levels even in strong sun.

Figure B-6: United Airlines Terminal, O'Hare Airport, Chicago, 1987. Helmut Jahn, architect. Photograph, 1992.

Clearly related, if less elegantly detailed, are the roof forms of many toplit industrial sheds like the one built for the Marwais Steel company in Houston during the 1920s. [Figure B-7] As at O'Hare, a structural system composed of thin steel members modulates light entering high clerestories. The Marwais Steel building is a fairly standard example of an early 20th century toplit shed, exceptional only in that it hasn't been torn down and that it
is still used by a steel company. It is now functions as a warehouse for coils of sheet metal.

Figure B-7: Marwais Steel, Houston, Texas, 1924?, architect unknown. Photograph, 1993.

In contrast, the Seymour Manufacturing Company plant in Seymour, Connecticut has sat idle for nearly a decade, awaiting re-use or, more likely, demolition. [Figures B-8, B-9] The network of structural members, pipes, and electrical conduits which crisscross the overhead area is not as elegantly resolved as in Helmut Jahn's building.

Nonetheless, the monitors serve their fundamental purpose: to provide adequate, uniform illumination to the production floor. In Seymour, with bay doors open wide and light coursing through the monitors, distinctions between
inside and out begin to fade. Interior surfaces are in many instances as brightly lit as exterior walls.

Figure B-8: Seymour Manufacturing Company, Seymour, Connecticut. Photograph, 1993.

The quality that exists almost by chance in Seymour has been produced more consciously - even playfully - in the Fine Arts Library at the University of Pennsylvania. [Figure B-10] Hard and fast boundaries between interior and exterior are dissolved through the selection of materials, general proportions, and careful daylighting. Frank Furness has made the library's reading room into an intimate courtyard, with windows from upper floor classrooms overlooking the space, as in an Old World tenement. High windows and a stained-glass skylight provide ample light for reading.
Furness' playfulness with stone and iron is not easy to mimic. And in an age of on-line directories and CD-ROM books his Victorian-era reading room need not be reproduced. But the library's use of light and space, along with the other conditions explored in this photographic essay, are fertile ground from which to launch an exercise in architectural design.
Figure B-10: Fine Arts Library, University of Pennsylvania, Philadelphia, 1891. Frank Furness, architect. Photograph, 1992
Investigation III:
Land Planning and Building Design for a Site in Houston, Texas

The third investigation is an attempt to apply lessons from the previous two explorations of light and space - the first historical, the second, photographic - to an architectural design process. The first stage of the process involved choosing and analyzing a site and a building program which would be contemporary rather than nostalgic. In the design work which follows in the appendix, there were two critical issues: first, to reframe discussion on context and adjacency, and second, to establish a complex of architectural relationships to the horizon and sky.

Site Selection

The chosen site is a plot of land on the western edge of Houston's city limits. The property was a largely unmolested piece of prairie until 1978, when a group of real estate developers broke ground on an office/industrial development called Park Ten. The site was annexed by the City of Houston in the 1980s, and is still being built out. Within a one-mile radius, there is a flood control reservoir, a handful of low-density office buildings, some light industrial activity, new strip retail development, and a suburban housing
subdivision. All of the buildings were the first to occupy the land on which they rest. [Figure C-1]

![Figure C-1. Aerial photograph of site](image)

Few of these features are within reasonable walking distance of the site, but are easily accessible by car. The existing transportation infrastructure includes a four-lane boulevard, a heavily used freight rail line, and Interstate 10. [Figure C-2] The site is essentially flat, with few distinguishing natural features, save a handful of small trees. It is extremely typical of tracts currently being developed in suburban Houston. [Figure C-3]

Context and adjacency are critical architectural issues in dealing with any site. Here, though, responding to prominent
features of the natural and man-made environment - from terrain changes to neighboring historical buildings - is problematic if not entirely irrelevant. There are few prominent natural features: no great rivers or rolling hills, not even thick tree cover. The equally banal man-made environment consists mainly of the linear scars of transportation and power transmission.

Figure C-2: Interstate 10 at dawn, 1993.

Architects trained to design within the traditional fabric of American cities can be caught unprepared for such uninspiring sites. Often, they offer inadequate responses: either they work to create architectural interest from insignificant features of the land, such as old filling stations, dilapidated barns, minor hillocks, or else they
abandon any attempt to gauge the *genius loci* of the site, designing the same banal buildings seen in suburbia everywhere.

![Figure C-3: Site at sunset, 1993.](image)

There is, however, a feature which so dominates the flat open site as to be almost ignored - the sky. In Houston, with its violent and often rapidly-changing weather, sky conditions are quite often more interesting than any feature on the ground. And where the sky meets that ground, at the insistent and omnipresent horizon, there is considerable visual variety, albeit at a distance not usually considered by architects to be adjacent. The sky and the horizon, then,
will play an important part in architectural design on this site. [Figure C-4]

Figure C-4: East horizon at site, 1993.

The panoramic horizon survey reproduced in figure C-5 was an attempt to encapsulate the site and its surroundings in a way which no single photographic image could. The panorama distills a thin but undulating horizon line from the great washes of sky and ground. Building apertures will be placed with a view to this line, and manipulations of the landform can occur to heighten and problematize the sense of the horizon.

Program Selection

Having previously been untrodden prairie, the site demanded a program which was similarly virgin territory. The search for a building program which would be contemporary, if not futuristic, meant scouring daily newspapers for
technological breakthroughs, new ideas about organizing workplaces and homes, stories about turtles outgrowing their shells and hunting for new ones.

Figure C-5: Panoramic drawing of site horizon, ink on mylar.

An idea emerged from the April 14, 1993 issue of The New York Times. A front page article described the mounting piles of discarded electronic equipment which are quickly precipitating a national recycling crisis.\(^{27}\) The story noted the efforts of a New Jersey entrepreneur to reduce old computers to their component materials, which might then be sold for re-use. The businessman, Eric Buechel of Advanced Recovery Inc. in Belleville, New Jersey, was looking for a new facility to expand his burgeoning enterprise.

To the mind of a student of industrial architecture, the article's message was clear: potentially, a new building type

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lay in the piles of mainframes and circuit boards sitting in Eric Buechel's backyard. [Figure C-6] Thus emerged a building program: a new facility for Advanced Recovery Inc. to process and re-manufacture computer junk.

![Figure C-6: Discarded computer circuit boards at Advanced Recovery, Belleville, New Jersey, 1993.](image)

The program, based on Mr. Buechel's business plan and other research, consisting of four parts:

The first is a facility for the raw processing of obsolete computer equipment, in essence a small de-manufacturing plant. Discarded metal and plastic boxes would enter at one end, be assessed for reusability, be dis-assembled and then sorted by constituent materials: precious metals, bulk metals, glass, and plastic.
In the second phase of the process, the sorted materials are transported to small manufacturing facilities, operated by individual companies, to produce new goods. For the sake of efficiency, these facilities would be located on site. Combined with the de-manufacturing facility, these buildings would comprise a recycling campus, where the various companies could collaborate on research and development.

To dispose of the by-products of the recycling process, the third part of the program is a landfill. As the cycle of disassembly and re-use became more efficient, the landfill would receive less and less waste, so that the space dedicated to it might eventually be turned over to other use. To serve as a daily reminder of the need for recycling, the landfill would be centrally located on the site and be visible from roads and buildings.

Finally, to complete the cycle of the enterprise, a series of retail establishments would be located on site, where the recycled products would be sold or distributed, perhaps to return someday to the site an newly obsolete technology. [Figure C-7]

To link these four functions, a series of roads, pedestrian pathways, and parking areas were designed. Unlike many suburban building sites, the interstitial spaces here are as important to the sense of the horizon and sky as the buildings themselves. A series of distinct zones of open
space compete with the structures for architectural treatment.

Design Strategies

An understanding of site and program is essential to architectural design, but alone it does not completely resolve issues of organizing built space. We still need an additional set of variables to solve the equation, to suggest the orientation and form of the component structures. The industrial daylighting methods explored in the first two investigations will, with any luck, serve this purpose. [Figure C-8]

Toplighting can be seen as a way of interpreting the skydome or "fifth" side of the site. The suburban landscape of west Houston is strewn with single-story boxes with large floor plates, a building type ideally suited to toplighting. In such buildings, from the Sam's Warehouse a scant thousand feet east of the site to the car dealerships and chain restaurants a few miles down the highway, toplighting would
be a useful addition. In this context a toplit space can be a room with a view.

Figure C-8: Industrial Daylighting Photoconstruction, mixed media.
There are both practical and psychic imperatives for using natural light. As a practical matter, toplighting can provide more evenly-lit interiors than windows alone, reducing glare and uncomfortable contrast levels. [Figure C-9] And toplighting gives a designer the freedom to place natural light at any point within a building, either uniformly or to suit particular activities or architectural effects.

![Sidelighting](image1)

![Toplighting](image2)

Figure C-9: Relative overall light levels in side and top lit spaces (William Lam, Sunlighting as Formgiver for Architecture, p. 69).

By reflecting sky conditions through the course of the day, toplighting provides information that electric lights can not. Human beings have an instinctual need to sense the passage of time and changes in the weather. People who work in rooms without natural light frequently complain that they feel cooped up, isolated, or claustrophobic. Even in situations where daylight provides only a portion of the illumination appropriate to particular tasks, it can provide important visual cues to the passing of the day.
Post-Design Comments

The design drawings in the appendix display topping solutions to four different building conditions. In the processing center, where the computers are dismantled and transformed into raw materials, the program calls for a large flexible floor area with minimal wall surfaces. The deep floor plate makes visual contact with the outdoors a critical design element, because the distance to the nearest window is often more than 100 feet. The roof structure accommodates the need for outdoor views through a series of four curved monitors. The openings are biased toward the south, so workers can perceive the movement of the sun through the course of the day.

In the manufacturing buildings, where smaller enterprises would produce new goods from the recycled materials separated in the processing center, there is a less critical need for views of the sky, since large bay doors (and windows in the office wing) provide ample visual connection to the outside world. On the production floor, however, topping lighting is employed for general task illumination, and to provide daylight on days when the bay doors are closed because of bad weather.

In the landfill, there is an entirely different relationship to the sky and horizon. In fact, the horizon has been virtually eliminated. Only earth and sky are visible in this crater-like condition.
In the retail center, where the manufacturers' products are marketed and sold, there is less need for sky views, although toplighting can still be a benefit. Few windows distract the shopper's eye from the merchandise; instead, an array of conical skylights bathes the sales floor in daylight. It is, in this way, the most interior of the four architectural conditions on the site.

What began as an exploration of building form has become an exploration of land form, and what began as a relationship with the sky has become a relationship to the horizon. The west Houston prairie is commonly seen by Houstonians as an undifferentiated flat plane, devoid of inherent character and ultimately monotonous. The intent of this design, however, is to challenge these conventional interpretations of the prairie.

Thus, the landscape of the site has been deliberately altered. The long strip of parking between the street and the retail center is submerged a few feet, like a scar in the earth. The zones of earth on either side of the landfill tilt gently across the width of the site, rising into the air as if attempting flight. The pedestrian strip linking the main parking areas to the manufacturing center provides a canopy of modulating elements in the form of tree branches and leaves which prefigures the canopy of modulating structural elements inside the buildings.

And so, the design attempts to blur distinctions between outdoors and in, between earth and sky, between building and
landform. And it is the pioneering industrial architecture of Albert Kahn and the Austin Company and the Ballingers which has, however inadvertently, led the design in such a direction.
Bibliography

The American Architect and Building News, various issues:


Appendix: Design Drawings
Figure D-1: 1:200 Preliminary Site Models