By C.C. Sullivan, Contributing Editor

BIGGER WINDOWS, MORE GLASS: EFFICIENT, SAFE, INSPIRING

ERIC LAIGNEL, COURTESY SPACESMITH

For the headquarters of MarketAxess on three floors of 55 Hudson Yards in New York City, open exterior glass expanses and a three-story-tall floating staircase with modern glass balustrades and guardrails welcome visitors.

LEARNING OBJECTIVES

After reading this article, you should be able to:

- DISCUSS the opportunities for health and psychological benefits of increased glazing.
- DESCRIBE the trends leading to large glass panel sizes and the design and implementation strategies to ensure occupant comfort, energy efficiency, and wellness.
- LIST considerations for the use of advanced glazing technologies and in particular fire-rated glass, fenestration, and interior partitions.
- COMPARE the qualitative and quantitative performance considerations for building interior spaces in terms of wellness, energy usage, or other operations impacts.

A memorable political punchline last year for building teams involved how windows would shrink to tiny sizes and perhaps even disappear should the wrong candidates be elected. The joke was lost on most professionals. The fact is, more than ever, openness and copious daylight remain among the most desirable characteristics for end-users in a range of building types. This means applying bigger openings, jumbo sizes, and more glass everywhere—including in ways that help improve energy performance, life safety and wellness, and overall quality of experience.

Recent studies show why these investments in expanding glazing can be so valuable. In one

ROEHNER + RYAN, COURTESY STUDIO MA

For the headquarters of a law firm in Phoenix, interior glazed partitions and interior windows allow daylight from operable skylights and windows to cool and illuminate the net-zero ready facility.

survey published in the journal *Human Factors* (bit.ly/2INwy0G), office occupants "that have more open and natural views rated their room satisfaction more highly." A study in *Building and Environment* shows offices with access to daylight and views measurably improve cognitive performance and satisfaction while also reducing eyestrain. Our understanding of these dynamics is better, yet the latest research findings are nothing new. For a long-range perspective, a U.S. National Bureau of Standards study from 1975 (bit.ly/2IO8rPp) addresses "the windowless situation" then affecting schools, factories, housing, offices, and hospitals seeking to reduce first costs or save energy, yet also raising psychological issues. In the wake of the oil embargo, the authors wrote, "The current need for energy conservation has forced some fundamental re-evaluation of building design."

Thanks to data and analytics used routinely today to model and predict building performance, new and remarkably subtle approaches are being used to create façades and interior glass assemblies that allow more visible light transmission (VT) while reducing undesirable heating by direct sunlight, measured as solar heat gain coefficient (SHGC), or energy losses caused by radiating energy (emissivity) and direct conduction. Key measures of glass system performance include:

- **U-factor,** the rate of conduction of non-solar heat flow by building enclosure elements including curtain wall, windows, and skylights.
- **Air leakage,** the rate of air movement around a glazed opening such as a window, door or storefront subjected to a specific pressure difference.
- **Light-to-solar-gain (LSG) ratios,** which compare SHGC and VT as a measure of the relative efficiency of glazing materials in transmitting daylight while blocking heat gain.

A proliferation of in-house-developed and third-party simulation software tools are supporting building team efforts to better evaluate and design glazed assemblies with finely tuned control of all these variables. One team of sustainable design researchers at Harvard's Graduate School of Design developed an early base system called DIVA-for-Rhino around 2009 that more recently advanced to studies by a group of 14 architecture firms, engineering firms, and façade manufacturers. The resulting simulation software (solemma.com/ClimateStudio.html) can relatively quickly determine annual illuminance, glare, and thermal comfort distributions in building spaces designed for using daylight and artificial illumination.

Software like this can also automate reporting for certifications such as daylight requirements or credits in Living Building, LEEDv4, and other widely used eco-standards. Building teams can test and archive design ideas as well: At a conference on tech-driven, bioclimatic architecture, cutting-edge simulation tools were demonstrated as part of the drive for a greener, more resilient future. Presenting on her own headquarters design, AIA COTE Award juror Christiana Moss, FAIA, discussed how daylighting and thermal performance modeling

"help create highly sustainable, forward-looking environments that inspire culture, communities, and transformation at scale." Moss also showed how extensive use of glass on projects was consistent with highly efficient and net-zero energy designs for both institutional and commercial applications.

BIGGER OPENINGS, JUMBO SIZES

This tendency is growing among the most influential today, as building teams innovate with new, larger monolithic glass panel sizes and more operable openings. The new Santa Monica City Hall East building in California, for example—a first municipal building nationally to achieve Living Building Challenge status—is wrapped completely in glass with large openings and 209 operable windows. The building team led by constructor Hathaway Dinwiddie, architect Frederick Fisher & Partners, and engineer and Living Building consultant Buro Happold, employs clever cooling and heat-control strategies to help ensure net-zero building operations for the 50,200-sf facility. Critical to achieving these lofty goals, according to Amber Richane, project manager for the City of Santa Monica, was the use of adaptive envelope design, integral shading, and high-performance glass.

For larger expanses, such as in the city hall extension, new technologies for glass finishing and coating expand capacity for larger panel sizes. One recent example in Wichita Falls by Vitro Architectural Glass (bit.ly/36LXvK5), a jumbo coater for MSVD on varied glass substrates and panel thicknesses, expands capabilities for not only larger coated glass sizes but also novel platforms for low-emissivity (low-e) coating development for solar control, and "to accelerate development of advanced, high-performance coatings that maintain their neutral appearance when viewed from any angle."

New output like this everywhere from China to Chile increases availability of low-e glass, often at lower costs, helping facilitate more jumbo glass sizes in projects at all levels, from the budget-minded to the decidedly high end.

One low-income housing development, the 86,000-sf Dr. Muriel Petioni Plaza Senior Apartments, is a mixed-use facility for seniors and the first locally—in New York City's Harlem—to achieve LEED, thanks to its ample unit windows, high-performance mechanical systems, rainwater harvesting, and green roof.

COURTESY SAFTI FIRST

For a cleanroom facility dedicated to nanobioelectronics work, a fire-rated glass partition system allows for visibility to key operations areas while meeting all life safety requirements at the Joint School of Nanoscience & Nanoengineering in Gateway University Research Park, Greensboro, N.C.

Distinguished from other affordable works for seniors, the building offers ample roof terrace space, amenity spaces, and distinctive façades with south-facing sunshades to cut solar heat gain, all adding more interconnections between residents and community while still meeting stringent jurisdictional standards.

Developed by Jonathan Rose Cos. with owner Harlem Congregations for Community Improvement or HCCI and with architecture by Body Lawson Associates Architects and Planners (BLA) and building led by contractor Lasberg Construction, the $24 million project reflects a movement toward using more glass within the context of passive-design principles.

"For our affordable housing developments under way now, passive design is the key to reducing operating costs, using enclosures with a thick blanket of insulation and better-performing glass specs," says BLA principal Victor Body-Lawson, AIA. "Along with those highly insulated envelopes, fenestration can modulate sunlight coming in so occupants operate smaller heating and cooling systems, and MEP systems have smaller air blowers and other components, all further reducing environmental impact."

The eight-story building, according to HCCI, with a two-bedroom super's unit serves 63 one-bedroom units for low-income seniors over the age of 62 years earning no more than 50%

of area median income, or AMI, a key measure used in the apportionment of affordable housing funds in many U.S. cities.

In other urban projects, selective uses of larger glass openings are seen as encouraging public engagement and interaction, including in many "attainable housing" offerings in infill lots. For example, the design for a new rental and retail building called The 955 in San Francisco, led by Unisource Development, is "intended to break down barriers to promote community among residents as well as the neighborhood," says architect Lada Kocherovsky, AIA, the principal of Page & Turnbull and incoming president of CREW San Francisco. "Nestled in the historic district, the 955 Post multifamily residential project takes design cues directly from the rhythms of the neighborhood architecture and interprets them in a contemporary visual vocabulary, emulating forms, materials and textures."

COURTESY CETRARUDDY

Using earth-toned bronze glass specified for optimal efficiency and daylight transmission, the tower One Madison in New York City offers full-height curtain wall with operable panels for wellness-oriented openness essential to market-rate multifamily buildings.

With a sixth-floor setback and large punched-out windows using low-e glass panels and thermally broken frames above a high-efficiency storefront system at street level, the prominent mixed-use residential project in the city's downtown Lower Nob Hill district will accommodate 69 new housing units on eight stories, including 17 on-site affordable apartments and ground-level retail spaces.

FROM HIGH-END TO HISTORIC

For the adaptive reuse or preservation of historic buildings, selective uses of high-performance glazing benefits historic environments. Examples include windows and daylighting for the 1930s Hooper Community Center at the Webb Schools in Claremont, Calif., with new, energy-saving glass in historic frames, replaced windows and complementary light shelves along with a new cupola with clerestory. For the Carson Block Building, a landmark structure in Eureka, Calif., reimagined as a cornerstone of the community's cultural and commercial life, the Roman-inspired arched windows and terra cotta carvings are matched by completely rebuilt tall glass storefronts.

"In historic buildings, any glazed openings were typically designed to bring in natural ventilation and provide daylight/views," says architect John D. Lesak, AIA, FAPT, principal with Page & Turnbull, Los Angeles. "Windows tend to define the historic character of building." Depending upon the era of construction and use of the building, the ratio of glass-to-wall can vary widely, he says, and treatment of historic windows should be approached in a hierarchical manner:

- First, preserve and retain the window.
- Second, repair the window as needed to make it function as intended.
- Third, upgrade the window in a way that retains the historic character.

The last step often includes such steps as replacing the glazing, adding high-performance film to the existing glass, installing weatherstripping, and adding supplemental glazing, such as a storm window. "Only as a last resort, if repair is infeasible, do we replace windows. Ideally, windows are replaced 'in-kind,' but if that is not an option, select the highest-performing systems that match the character of the original in terms of operation, layout, glass color, and VT, as well as profile and shape of frame elements, position in the wall, and the like," he says, pointing to the Greek Theatre in Los Angeles, where repair and in-kind replacement were infeasible.

At the high end, an expected turn toward more punched-out openings is instead evolving into more health-oriented reasons to incorporate even greater glazing expanses. According to the WELL Building Standard (standard.wellcertified.com/light/right-light), "Exposure to adequate levels of sunlight is critical for health and well-being, for effects ranging from visual comfort to potential psychological and neurological gains." Additionally, measurable physiological benefits accrue from "the quality of light provided by the sun," not to mention literally glowing reviews by building occupants—and

premiums in rents and sale prices for multifamily buildings.

"What we consider to be luxury living is changing rapidly and decisively during the challenges of COVID-19," says architect John Cetra, FAIA, Founding Principal of CetraRuddy. "Living environments that respond to a newly emerging definition of luxe include multifamily interiors for 'inside-out living' in open, floor-to-ceiling glass homes with wraparound terraces." Cetra cites examples including the 35-story 200East59 in Manhattan, developed by Macklowe and Centurion and constructed by Gilbane, where 67 residences offer the fully wrapping terraces and a sense of seamless indoor/outdoor living space. High-efficiency, low-e glazing modulates interior LSG and VT.

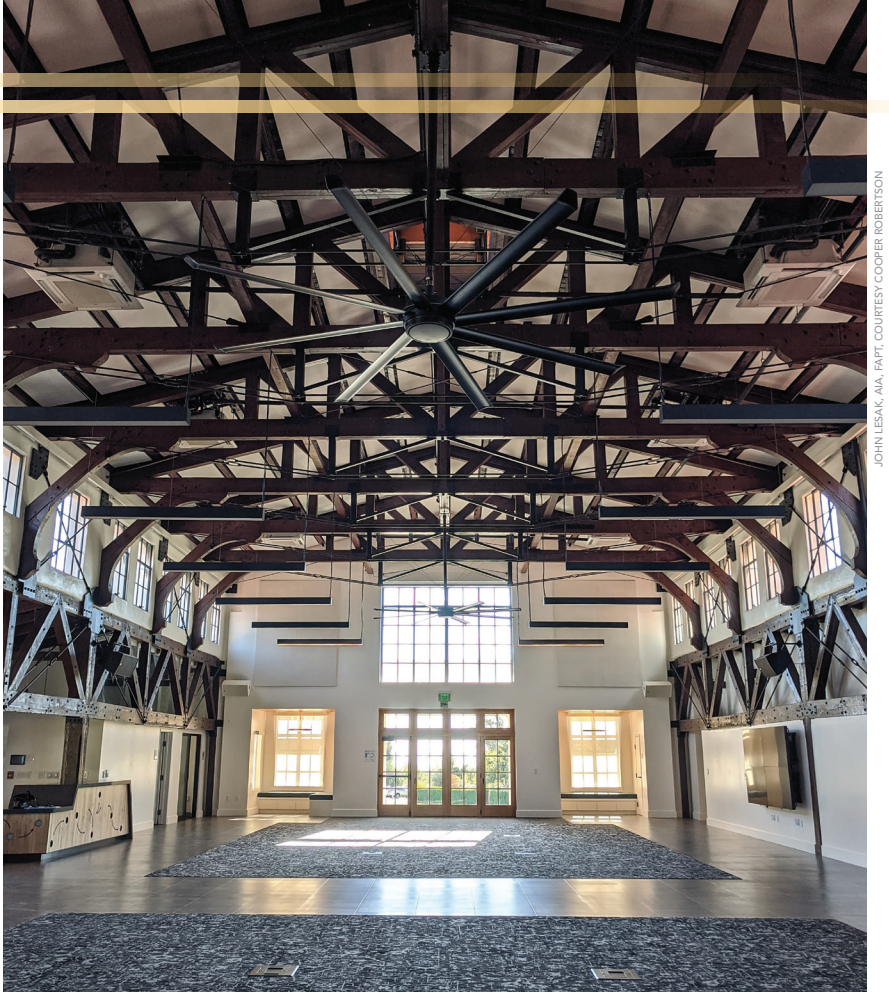
FIRE-RATED GLAZING

Larger fenestration sizes are also increasingly used in applications traditionally reserved for opaque walls, thanks to glazing technologies engineered for protection against fire as well as its dangerous radiant heat. These fire-rated glass panels and assemblies allow for larger glass areas and opening sizes but with significant limitations depending on opening size, glazing material performance, and the intended occupancies and function. For example, glass ceramics and other fire-protective glazing such as specialty tempered and wired products are subject to restrictions in areas and application types outlined in the descriptive tables in the International Building Code's seventh chapter. Glazings that do not block radiant heat may not be used in certain assemblies, even if the enclosures adequately block smoke and flames.

According to code experts and manufacturers, including SAFTI FIRST (safti.com/articles/limitations), building teams apply fire-protective glass products only as large as the maximum sizes tested and meeting a number of specific restrictions. For example, interior separations may use 20- to 45-minute fire-protection-rated glazing only where permitted in fire barriers rated to 1 hour, for use in "incidental use areas or mixed occupancy separations, or in fire partitions." These applications are limited to 25% of the wall area. Another common application, in the transoms and sidelights of fire door assemblies, incurs a limitation of a maximum 45-minute rating.

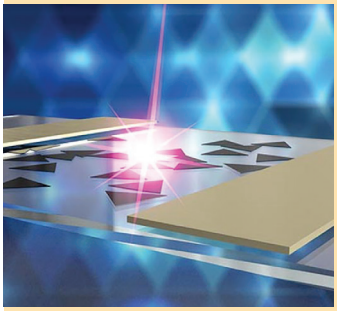
For building façades and exterior walls, 20-minute to 90-minute ratings are possible for fire-protective glazing in fire windows, defined as "a window constructed to resist a fire of known standard intensity for a specified time." The fire ratings depend, however, on the fire separation distance and occupancy type as given in section 705 of the International Building Code (IBC). A final consideration for fire-protection-rated glass usage is for fire door vision panels or lites, limited 100 square inches in size for fire-protection ratings of 60, 90, or 180 minutes. Alternatively, fire resistive glazing obviates the IBC size and application limitations for fire protective materials, because they meet ASTM E-119 testing for blocking radiant heat, allowing uses up to the maximum size tested for all 60-minute to 120-minute applications, including stairwell walls, façades, and interiors.

Applied properly, the fire-protective and fire-resistive glazings open wide the doors to design. In one reconstruction project, a team including Corgan and the specialty contractor Infinite Glass and Metal created a new observation deck experience as part of a $165 million redevelopment of the Empire State Building. A glass elevator brings visitors to the 102nd floor



JOHN LESAK, AIA, FAPT, COURTESY COOPER ROBERTSON

For historic structures such as the Hooper Student Center at the Webb Schools in Claremont, Calif., the building team combined new efficient glass in historic frames with new windows, light shelves, and a cupola with clerestory windows.



SMART GLASS FOR SMARTER BUILDINGS

The category of glazings collectively termed "smart glass" are adding to the interior and enclosure applications. New techniques developed for smart glass include thin films (bit.ly/35F3alP) that can display augmented reality (AR) information in compatible devices or convert solar energy into electricity, or both. Similarly, ultra-thin photodetectors—used in many smartphones—hold promise for glazings with automated sensing properties (optics.org/news/11/11/17), according to Corning, which collaborated with Penn State's Materials Research Institute on a novel way to integrate the light detectors with the manufacturer's chemically strengthened Gorilla Glass.

While glazings with instant smarts will one day grace building façades and interior partitions, current commercial applications are focused on optimizing daylight, according to Brad Pfahler, Project Manager with Studio Ma.

"We are working on residential and institutional projects exploring very high-performance solutions such as net-zero energy and water, and advanced techniques are necessary to get to net zero, and one of the options is electrochromic glass," says Pfahler.

through a glass shaft, opening to panoramic views of Manhattan's skylines. Constructed with a curtain wall using fire-rated frames and glazing, the historic high-rise's elevator surround demonstrates the potential of transparency, visibility, and even energy efficiency in a memorable public space experience designed for fire and life safety. The glazing is a close-to-colorless low-iron float glass in panels with clear intumescent interlayers, with visual qualities similar to typical float glass. Narrow-profiled curtain wall mullions and corners clad with stainless steel carefully hew to the interior aesthetic and the classic architecture.

ENERGY EFFICIENT INTERIORS

With a motto of "glass everywhere," building teams influenced by projects like the observatory have created interior experiences that not only open up vistas and communication but also share daylight and, in some cases, controlled heat to reduce energy consumption.

The approach has shown promise even in extreme desert environments. For a Phoenix-based law firm seeking to adaptively reuse an existing commercial structure, for example, a building team including Caliente Construction, engineers Pangolin Structural and Peterson Associates, and architect Studio Ma maximized both envelope openings and interior glazed partitions in converting a 6,100-sf structure. With skylights, openable windows, and workspaces demarcated by custom glass walls and doors as well as interior windows, The Phoenix Law Group also enjoys a workplace with much greater energy efficiency than comparable buildings in the climate zone.

"The reimagined building needed to feel and operate as one large open office with strong visual connections among staff members, while also accommodating private offices where the firm's lawyers conduct sensitive, confidential work," says Christopher Alt, RA, Studio Ma's Co-founder and Principal. Using energy and daylight modeling to inform their design outcomes, the architects also studied the detailing of black-framed glass partitions to carefully controlled acoustics while allowing daylight and openness indoors and views to the outside. A set of operable skylights illuminates the spaces and circulates fresh air by means of stack effect, a technique that draws ventilation air and circulates cooler air toward work areas, where needed, and flushes hot air out of the roof. The façade's large glass openings are protected by a continuous exterior assembly of modern wood louvers.

Workplace building teams have developed these ideas for a range of climate zones and occupancies, according to Elisabeth Post-Marner, LEED AP, WELL AP, Principal with design firm Spacesmith. "Today we are able to build effective open interior spaces where the end-users actually benefit. This user-focused approach now often starts with planning of adjacencies to ensure that workstations and collaboration areas such as huddles receive natural light," says Post-Marner, who is also past president of the IIDA's New York chapter.

Other recent projects reflecting these ideas include the headquarters for MarketAxess and

for another law firm, Boies Schiller Flexne, designed by Schiller Projects, an interiors specialist, collaborating with Spacesmith as architect for the project. Built by contractor Structure Tone to plans created with the engineer Silman (structures) and AMA (mechanical and electrical) with the HDLC Architectural Lighting, the law firm in an urban office building centers on glass-enclosed partner offices with glazed partitions demarcating well-illuminated conference rooms placed in strategic locations. Drawn from research on the best way to support the law firm, the result maximizes glass-wrapped offices and primary meeting rooms with sleek glass partitions lending daylight to huddle areas, smaller rooms, break areas, and open work zones.

For these open interiors, the building teams employ glass materials such as switchable glazings, decorated glass panels, and fritted or film-applied applications that benefit interior occupancies by enhancing communication, tuning available illumination, and offering responsiveness to changing environmental conditions.

The same holds true for the exterior glazing selection process, says John Ivanoff, Associate Principal in façade consulting with strategy and engineering firm Buro Happold, while the potential for energy impact is significantly more momentous. "For energy conservation, it is important to study thermal and solar transfer, optimized window-to-wall ratios or WWRs, and opportunities to integrate photovoltaic systems," says Ivanoff, whose recent projects include the glass-topped adaptive reuse of the historic Tammany Hall building. "In some projects with very energy-intensive occupancies such as laboratories, Buro Happold finds that façade design has limited impact on overall energy use. However, facade design and glass selection can have a very significant impact on peak cooling loads in these situations, as well as occupant comfort."

Just as one might have suspected in 1975.+