



## Seeing Double

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We've heard about them, some of us have seen them, and a lot fewer of us have actually worked with them, but that may be about to change. In spite of the adverse economic conditions, double-skin facade (DSF) applications have actually increased as part of the green trend that continues to thrive in the down economy. So what are they, what's the point, and can I expect to see one in my backyard any time soon? Well, it depends a little on where you live, but with recent applications in major metropolitan areas including New York City, Boston, Chicago and Los Angeles, the chances are that there may be one not too far from your doorstep.

DSFs are simply a strategy for improving building envelope performance through the introduction of a second glazed layer, thereby creating an airflow cavity between the two.

The application of the technology in the U.S. has been a long time coming. Although early examples of DSFs exist stateside – the Occidental Chemical Center in Niagara Falls, New York (1980), as but one example – the major development and implementation of the technology took place in Northern Europe through the 1990s and 2000s, with numerous completed works of great variety, driven by legislative mandates for improved energy efficiency in buildings. The impetus for the initial development of DSFs was not only thermal comfort and energy efficiency, but also acoustical performance; mitigating sound transmission through the glazed building envelope. This is still a very good reason for their use, especially as our dense urban environments become increasingly populated with residential dwellings. Nonetheless, thermal performance and natural ventilation have been the more recent drivers of this advanced facade technology.

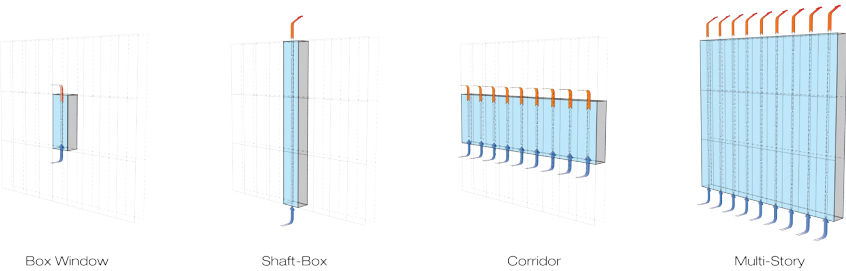
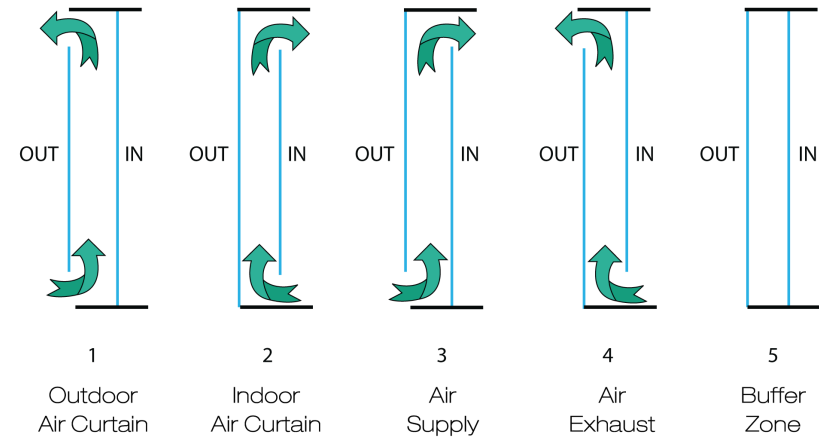




IT'S ALL ABOUT THE CAVITY

The cavity is useful for a few things. First, it acts as a thermal and acoustical buffer between the inside and outside environments. Second, the cavity can be employed in various ways to provide airflow, and even building ventilation. Third, the cavity provides an optimal space for the location of shading devices: outside the inboard skin so that solar radiation is stopped before penetrating into the building, yet shielded from the elements by the outboard skin. If the cavity is deep enough, it can also house mechanical equipment and maintenance platforms. It turns out that cavity depth ranges widely from about 4 in. to 6 ft. (10 cm to 2 m) among the various built DSFs. It should be no surprise, then, that the applications of DSFs are most often categorized by variations in cavity design and behavior. Ventilation type, ventilation mode and cavity partitioning are the most commonly used criteria.

The ventilation type refers to the driver of airflow within the cavity, which can include natural, mechanical and hybrid systems. The ventilation mode refers to the airflow pathway from intake to exhaust. The five common ventilation modes are 1) outdoor air curtain, 2) indoor air curtain, 3) air supply, 4) air exhaust, and 5) buffer zone. The diagrams in Figure 2 trace the pathways characteristic of each mode. Finally, DSFs are most usefully classified by the cavity partitioning strategy employed in any give design. The four primary cavity configurations are box window, shaft-box, story-height (corridor) and multi-story (Figure 3). Each configuration possesses unique attributes of design, performance and application. The multi-story types tend to be the deep cavity systems, while the other configurations typically utilize much shallower cavities.



(top to bottom)  
Figure 1: Internal view of DSF cavity at USC's Eli and Edythe Broad CIRM Center for Regenerative Medicine and Stem Cell Research (Broad Center) by ZGF Architects LLP, and Walters & Wolf (facade contractor/installer) with W&W Glass Inc. (cable system engineer and supplier).

Figure 2: DSF ventilation mode diagrams characterizing the airflow path from entry to exhaust orifices.

Figure 3: DSF cavity configurations with various subdivision of the cavity geometry.



Figure 4: West elevation of DSF with cable net supported outboard skin at the Richard J. Klarchek Information Commons, Loyola University, Chicago, by Solomon Cordwell Buenz (architect) and Enclos (facade design-builder).

TRENDS IN DSF APPLICATIONS

In a recent evaluation of twenty-three existing applications, the most common DSF cavity partition configuration in the United States is the multi-story (70%) and the most common ventilation mode is the outdoor air curtain (74%). The multi-story DSF cavity has no horizontal or vertical divisions, and may encompass an entire elevation of a building facade. Intake air openings are placed at the bottom of the cavity with exhaust openings at the top. Ventilation of the cavity can be naturally induced through the stack effect (as the cavity air warms it rises and is exhausted through the top vent, in turn drawing air into the cavity through the bottom vent) or mechanically assisted as required to prevent overheating of the cavity air. The more advanced designs utilize this cavity behavior to provide ventilation to the building. The Richard J. Klarchek Information Commons at Loyola University in Chicago (Figure 4) utilizes this effect in a west elevation DSF. In this application the stack effect is augmented by offshore winds that act to draw air from the cavity at the top vent.

Multi-story DSFs can provide a unique, highly transparent aesthetic with abundant daylight, a thermal buffer, enhanced acoustical performance, and contribute to building ventilation. Potential disadvantages include flanking sound and odor transmission through the cavity, overheating of the cavity air if ventilation is inadequate, and building code issues with respect to fire-safety because of the lack of fire safing between floors. Design flexibility is greater with the multi-story DSF types than with any other category. Many variations are conceivable, and this DSF type has been applied on educational, museum and healthcare facilities, among other building types. Recent examples of multi-story DSFs include the Eli and Edythe Broad CIRM Center for Regenerative Medicine and Stem Cell Research (2010, Los Angeles) by ZGF (Figure 5), New York Presbyterian Hospital (2010) by Pei Cobb Freed, Cambridge Public Library (2009) by William Wrawn Associates, and the Modern Wing at the Art Institute of Chicago (2009) by Renzo Piano Building Workshop.



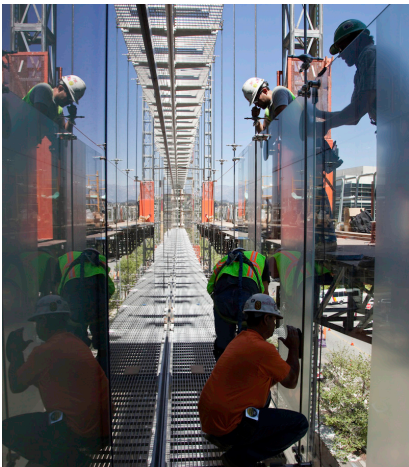


Figure 5: Point-supported exterior glazing installation at the Broad CIRM Center utilizing permanent maintenance platforms during installation to attach glass to tensioned vertical cables.



Figure 6: Workers on swing stages outside and within the cavity, access both sides of the outboard skin of the Loyola Information Commons DSF.

The evolution of DSFs in the U.S. exhibits other emerging trends. An alternative to the multi-story system is the increasingly popular box-window type, with a cavity depth at the shallow end of the spectrum, typically in the range of 4 to 8 inches. This DSF type is easily configured as a modular, prefabricated unitized curtainwall system appropriate for application on high-rise buildings. An early example of this DSF type is the Manulife US Headquarters (2003, Boston) by SOM. The location of mechanized systems, such as shading products within the cavity of the DSF, means that the cavity must be accessible for maintenance purposes, significantly complicating the design of a unitized facade system. The lack of a hermetic seal in the unit means that airborne particulates and moist air can potentially infiltrate the cavity, resulting in dirt and condensation on the inner glass surfaces and further escalating maintenance requirements. Current development efforts are aimed at addressing these issues.

In addition to high-performance unitized curtainwall systems capable of cladding an entire building, box-window configurations can be developed as discrete window or window-wall units, and have been used as a facade component in office, residential, and hospital projects where the floorplan is subdivided into many repeating units (offices, condos or patient rooms). Riverhouse (2008, New York) by Ennead Architects is

an example of a residential development that adopted such an approach.

#### DOUBLE-SKIN DOUBLE INSTALLATION

Assembly and installation issues with DSFs range as widely as the system variations. Unitized double-skin curtainwall systems can be complicated by the need for panel operability to accommodate maintenance needs. Prefabrication may include the installation of shading devices and controllers as part of the unit assembly process. Once the units are assembled, however, installation proceeds much the same as with conventional units, except the units are typically heavier, which may preclude lifting several units simultaneously.

Multi-story DSFs present quite another scenario. Because of the long spans typically involved, these applications will often have exposed structural systems, sometimes requiring architecturally exposed structural steel (AESS) standards. This type of work is often unfamiliar to glazing contractors and steel fabricators alike, and is rightly regarded as a specialty item. In fact, many of the multi-story DSFs referenced above make use of structural glass facade technology, including the use of frameless glass systems as a support strategy for the exterior skin. The interior skin is often a conventional curtainwall or storefront type system. The issue is with the exterior skin, its means of support, and the required

cavity work. The cavity often incorporates maintenance platforms, shading devices, and potentially other mechanical components such as operable vents. These may or may not be included in the facade contractor's scope of work. An issue of particular concern is the cavity depth: the deeper the cavity the easier it is for workmen to operate with all the required equipment. Cavity depths less than 30" begin to seriously constrain ease of movement for the workmen.

A particularly elegant way to support the outboard skin is with the use of a cable net. This presents a new set of challenges to the facade installer relating to the pre-tension requirements that must be applied to the cable system. The magnitude of force is typically high enough that hydraulic jacking equipment is required to achieve the required cable prestress. However, tensioning a cable net is not generally as simple as moving from one cable to the next with a tensioning device. Progressive tensioning tends to alter the previously tensioned cables, resulting from the residual effects to the supporting boundary steel. Cable tensions must be confirmed with the use of an appropriate tension metering device. The installer should request a detailed installation method statement from the facade designer, and carefully consider the cost impacts in the estimate of work.

Access is a consideration on any facade, with little difference here. If there are maintenance

platforms in the cavity and they are installed before the outboard skin, they can be used during installation. If not, temporary platforms may be required within the cavity (see Figure 6). Depending upon the glazing system design, workers may be required on both sides of the skin. In Figure 7, a mast-climber is being used to position men and materials outside the outboard skin of a DSF.

A final consideration for the facade contractor is commissioning. The requirement for system commissioning of advanced facade designs, DSFs among them, is becoming increasingly common, and is something that progressive facade contractors should prepare for. While commissioning requirements will vary between jobs, it is essentially a process of validating that the facade is installed and functioning as intended. With operable and dynamic components integrated into the facade design and critical to the intended function, commissioning processes are vital in assuring the building owner of future performance.



Figure 7: A mast climber (continuous work platform at top of wall) was used to install the outboard skin working from the bottom up at USC's Eli and Edythe Broad CIRM Center, Los Angeles.

#### INFORMAL SURVEY DATA

The Advanced Technology Studio of Enclos, a national provider of curtainwall systems, has been conducting an on-going survey of architects, engineers and facade designers. Among their findings with respect to DSF technology: 50% of respondents are either using, or considering using, a DSF system on a current project, and a whopping 73% regard DSF systems as an important component of future facade technology. Not surprisingly, cost is perceived as the biggest barrier to the diffusion of the technology into the broader building marketplace. Despite a general agreement on the energy saving potential of DSFs, designers and owners remain skeptical of the value provided by the technology in terms of system payback and return-on-investment. Life-cycle costing analysis (LCA) has proven challenging for the industry, partly because of the inherent complexity and partly because of the lack of hard data on the performance of the systems built to date – unfortunately post-occupancy monitor-

ing of buildings is seldom performed. LCA methods are also often compromised by the energy costs used in the models, which fail to reflect the true cost of energy, such as the cost of continued dependency on oil from increasingly volatile foreign sources, and the cost of developing renewable energy sources so that they are ready as the nonrenewable sources are depleted. Higher energy costs and improved LCA methods will have more impact on future applications of DSF technology than any other factors.

Other emerging trends include the application of DSF technology in a broader range of climate zones. The technology was conceived and developed in colder northern climates of the U.S. and Europe, climates dominated by heating degree-days where solar heat gain can be harnessed from the DSF cavity during winter months, and ventilated to the outside during summer months. Presently, DSF technology is receiving heightened consideration in project developments across the U.S., primarily for its perceived attributes of sustain-





ability, including increased energy efficiency, acoustical insulation and access to natural ventilation. Driven by the combined effect of the need for improved energy performance and comfort in buildings, with a continued desire for facade transparency in work and home environments, the DSF continues to evolve in new architectural programs. The result is that DSF designs are now being incorporated into buildings in more moderate climate zones, such as recent applications along the Pacific Coast – from Seattle to Los Angeles. Some designers question the value of DSF designs in these more moderate and warmer climates, uncertain that they represent an effective use of resources. Again, the lack of solid post-occupancy data to measure the performance of DSF applications against initial design targets yields only uncertainty.

Finally, a related trend worth noting is that DSF designs are also diffusing into a broader range of building types. Originating (with

notable exceptions) largely in commercial office buildings, recent applications include institutional, cultural, residential, and health-care projects.

**FUTURE DEVELOPMENTS**

Arguably the most compelling future application of DSF technology is in building retrofits. Realizing energy consumption and carbon emission reduction goals established by various green platforms such as the White House Agenda and the 2030 Challenge initiative will require energy retrofits to a large percentage of the current building stock, many of these programs should include facade retrofits. Many of the early glass curtainwall towers built during the 1960s and 1970s, for example, were originally constructed as single-glazed facades with low visible light transmitting glass (mirror coatings), were poor energy performers from the beginning, and are now approach-

ing something very close to old age. Reuse is a primary tenet of sustainable building practice. Not only should we avoid demolishing our old buildings and replacing them with new ones, we should also make every attempt to renovate the existing facade, reusing as much of the material as possible. The addition of a second skin may prove to be a viable approach in some, if not many of these buildings, providing greater economy, modernizing the appearance, and improving energy performance - all while projecting a positive message of environmental stewardship.

Several buildings which have used a second skin as a strategy for facade retrofit include the 100 Park Avenue and 330 Madison Avenue projects in New York by Moed De Armas & Shannon Architects, and the planned modernization of the Rodino Federal Building in Newark, New Jersey, by Dattner Architects.

CONCLUSIONS

DSFs are a reflection of the escalating demands on the building skin, the most engaging of building systems, which singularly combines attributes of both performance and appearance. DSFs are one strategy of emerging advanced facade technologies that include new glazing materials, improved framing systems, progressive techniques, and novel designs. That unique combination of glass, transparency, and the manner in which it enriches our built environment with daylight and view, assures that glass will remain a predominant material in the building skin. Unfortunately glass, as we well know, is a poor thermal and acoustical insulator, and these negative attributes threaten to limit its use in this same context. It is imperative that we as an industry do not adopt a defensive position in an attempt to protect a vested interest. We must embrace the mandate for improved energy efficiency and reduced carbon emissions in buildings, and deliver

solutions that optimize facade performance and nullify the negative qualities of glass, thus assuring the benefits provided by the unrestricted but appropriate use of glass in the building envelope. The ultimate viability of DSF technology, and the role it will play in future building facades, is unclear. We need to make a more aggressive and sustained effort to better understand how these very interesting experiments in advanced facade design are actually performing.

DSF technology, however, is but one strategy made in response to the challenge presented by facade performance. There are others and there will be many more. The needed solutions will involve an intensifying collaboration between the profession, academia, and industry – one long overdue – and will require ongoing investment in research and development by all stakeholders.

