OLD CONCEPTS, NEW TOOLS

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Designing a modern commercial office building without a mechanical cooling system might sound like a step backwards in building technology. The “square doughnut” design of The Terry Thomas, a Seattle Class A commercial office building, is actually reminiscent of 1920s architecture.

But, The Terry Thomas could represent the future of energy-efficient buildings in areas with mild climates such as the Northwest. Advanced building simulation tools allowed the building team to design the optimal environment for natural ventilation and daylighting, while maintaining thermal comfort goals and individual control.

The project integrates sustainable strategies from each discipline involved in the building design. In addition to passive strategies, the building incorporates automated controls such as motorized louvered controlled by CO₂ sensors during the heating season and thermostats in the cooling season, and automated external blinds controlled by meteorological conditions.

Designing for Well-Being

One primary project goal aimed to create an environment that enhances occupant well-being by incorporating daylighting, natural ventilation and individual control of the indoor environment. Natural ventilation and daylighting improve the indoor environment and the energy efficiency of the building. Because these goals were set at the beginning, these passive strategies informed the building’s design. For example, a center courtyard enhances natural ventilation and improves daylight, and provides a valuable communal space. This integration made these features more cost effective, and strengthened the case for having them in the design. Each feature was an interdependent piece of a jigsaw puzzle, and the picture required each piece to make sense.

These design considerations led to the concept of using narrow floor plates, prompting a “square doughnut” building design. Shading, daylighting, building form and structure, and other load reduction strategies are critical to the successful implementation of a passive cooling strategy.

Other design features used to make the building more efficient include an easily accessible outdoor staircase in the courtyard, which encourages occupants to use the stairs. A triple net lease agreement in which the tenant agrees to pay expenses usually covered by the owner, such as real estate taxes, building insurance and maintenance expenses, also provided a financial incentive to reduce operational energy use for the building.

The building team used high-end simulation tools to test how various design concepts impact thermal comfort and daylighting. Shading features were designed early in the project to cut off the direct solar gain and keep the internal temperature within the specified comfort range. These features had to work in conjunction with the prescribed glazing area, type of glazing and area of operable windows.

Thermal modeling, which predicts internal space temperatures, was controlled by CO₂ sensors during the heating season and thermostats in the cooling season, and automated external blinds controlled by meteorological conditions.

The site of The Terry Thomas has a rich history. The site’s previous existing building—a light industrial warehouse—was used as a practice space for one of Seattle’s defining bands, Pearl Jam. The previous building would have required nearly a complete rebuild to meet current codes, so it was demolished; 93% of the materials were salvaged (or in the case of the bricks, taken by fans).
used iteratively to inform the design at each stage and to verify that the specifications worked.

**Sustainable Strategies**

**Shading.** In the Pacific Northwest, shading may be used to reduce cooling peak load, and, as in The Terry Thomas, shading can become the basis for the removal of the entire mechanical cooling component from the building. Since solar gain forms the majority of the cooling load in a perimeter dominated building, removing it can make it feasible to keep the internal temperature comfortable without the use of mechanical cooling.

Every floor of each façade orientation (courtyard and exterior) was analyzed separately using thermal modeling to determine the optimum shading strategy to reduce solar gain and glare. Dynamic and fixed external shading to stop the solar heat gain before it enters the space is the primary strategy used to reduce load. Any heat that makes it in is removed using natural ventilation. Dynamic shades were recommended where possible to optimize daylight during cloudy days and when the sun was not directly shining on the façade. The east and west lower sun angles were challenging to shade while also preserving the views and daylight. For these façades, the primary strategy involves fixed exterior glass shades or “sunglasses.” The angle and shading coefficient of these shades are fine-tuned to meet the needs for daylighting, solar reduction and glare reduction. Three-dimensional computer modeling of the sunlight angles at various times of the day and year aided in designing and sizing overhangs and the fixed exterior sun shades.

The various façades require different shading strategies. The east and west external façades have punched screenless windows, with “sunglasses” consisting of custom-designed tinted glass and steel shades. The northeast, some east and west windows, and the south façade facing the courtyard use dynamic external venetian blinds. A rooftop sensor measures the light level and sun angle, and automatically adjusts the blinds as necessary. The

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**Thermal Modeling**

Thermal modeling was conducted during design to determine how passive strategies would affect internal temperatures for all spaces, including the third-floor conference room, as shown in the graph. The primary strategies modeled included shading, daylighting, glass properties, increased operable window area and night purge cooling for better flush out. The conference rooms are the most challenging to cool due to their higher internal load and because they are enclosed for privacy. The architecture firm for the project, also the building’s primary tenant, allows employees to wear shorts on the days when internal temperatures top 80°F.
automated shades reduce solar gain and optimize daylighting during overcast conditions.

Natural Ventilation. Cooling and ventilation for the building is provided passively, and radiant hydronic baseboards provide the heating for the building perimeter. Daylighting reduces the need for artificial lighting, which in turn reduces internal heat gain.

The center courtyard, narrow floor plate and open office plan increase the effectiveness of natural ventilation by enabling cross ventilation. Louvers located near the ceiling of each floor elevation, open ceilings, castellated beams (beams split lengthwise and re-welded, creating hexagonal holes; see photo, p. 26) and operable windows all along the building perimeter are designed to optimize the natural ventilation system.

Motorized louvers allow for night purge and are used in conjunction with occupant-controlled operable windows. Demand control ventilation with CO₂ sensors controls the motorized exterior louvers during heating months to reduce unnecessary ventilation loads.

The building’s completely passive cooling strategy (i.e., natural ventilation without forced air fans) eliminates the cooling system and fan energy consumption for normally occupied spaces in the building. However, reducing the energy consumption is only one benefit of natural ventilation. Since ductwork is not needed, ceilings are higher, enhancing daylighting.

Natural ventilation also eliminates mechanical equipment including chillers, pumps, ductwork, piping

**KEY SUSTAINABLE FEATURES**

**Water Conservation:** Storm water drainage system and holding tank, low-flow fixtures, waterless urinals, dual flush water closets; 54% water use savings according to LEED baseline

**Recycled materials:** Recycled steel, aluminum and fly ash used in construction; 93% of the existing, two-story building was recycled or salvaged; 98.8% of the construction waste was recycled

**Daylighting:** Shallow floor plate depths and high ceilings allow penetration of natural light; daylight sensors are installed on all lighting within 15 ft of the windows

**Individual Controls:** Operable windows, lights

**Design Feature:** Use of stairs is encouraged by a prominent and accessible staircase in the courtyard; the only elevator is past the courtyard

**Passive Cooling:** Operable windows, automated louvers, high ceilings, a shallow floor plate, and shading; a central court acts as a chimney, drawing warmer air through the floors and up through the courtyard

**Other Sustainable Features:** Locally manufactured windows, storefront and metal exterior cladding; minimal use of interior finish materials; castellated beams reduce the quantity of steel and encourage air movement

**THERMAL ANALYSIS: AIR TEMPERATURE**

This daily temperature profile from the thermal analysis shows the performance of the fourth floor open office on a (1% cooling design temperature) typical peak day. Since the solar gain is the largest portion of the cooling load, blocking it and removing internal heat gain via good airflow, cross ventilation and night purge as needed eliminates the need for active cooling.

**A Climate for Natural Ventilation**

The Seattle climate, with few days above 75°F and relatively low wet-bulb temperatures during the cooling season, lends itself to passive cooling. Natural ventilation can achieve indoor conditions that satisfy the adaptive thermal comfort model (ASHRAE Standard 55), which refers to “naturally conditioned spaces.” It is based on a relationship of indoor or acceptable temperature ranges to outdoor climatological characteristics.
and fans. The cost savings were used to pay for various passive strategies required to successfully implement natural ventilation.

One disadvantage of natural ventilation is outside noise. However, the owner and architect (also the building’s anchor tenant) agreed that outdoor sounds were preferred to a mechanical buzz.

In practice, the exterior sounds have been distracting, mostly during meetings. So, the occupants close the windows when necessary. This example illustrates why it is important that users have the ability to control their environment.

Another disadvantage of natural ventilation is the inability to provide heat recovery since no central air intake source exists. CO2 sensors control the louvers to allow for minimum ventilation.

### Building Envelope

<table>
<thead>
<tr>
<th>Component</th>
<th>Type/Description</th>
<th>Reflectivity</th>
<th>Overall R Value</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof</td>
<td>Steel deck, gypsum sheathing</td>
<td>95</td>
<td>R-3.0</td>
<td>Latitude 47.6°</td>
</tr>
<tr>
<td>Walls</td>
<td>Metal framing, gypsum sheathing, batt insulation and corrugated metal cladding</td>
<td>0.4</td>
<td>R-2.1</td>
<td>Courtyard and fourth floor</td>
</tr>
</tbody>
</table>

### Shading

- **External Shades:** Semi-transparent “sunglasses” over top-left and west windows, automated external blinds over northeast windows and select east and west windows
- **Shading Coefficients (SHGC):** 0.52
- **Visual Transmittance:** 68%

### Thermal Analysis

The effect of natural ventilation as a means of passive cooling was underscored using thermal analysis. This iterative analysis conducted early in the design process determined the minimum number of operable windows and areas that would need shading.

- **Hourly temperatures in all spaces were determined using the thermal model.**
- **Trial runs with varying shading, operable windows, flush out times and glass specifications helped establish minimum requirements for the spaces and the added benefit that could be achieved with each strategy.**
- **Design progressed, various permutations and combinations of the design were modeled to determine the most effective package with regards to design, energy and budget.**
The internal courtyard allows for effective cross ventilation in the summer, improved daylighting and a communal space for outdoor activities. The easily accessible external stair encourages occupants to use the stairs.

Advertisement formerly in this space.
performing at least as well as predicted by the energy simulation. Much of the energy savings stem from the natural ventilation system, which eliminates cooling energy and reduces fan energy. In addition, daylighting and efficient lamps reduce lighting energy consumption. Efficient pumps and the heating system’s efficient boilers also contribute to energy savings.

**Daylighting**

The thermal and daylight modeling were done iteratively, informing each other. The design sought to balance two goals: remove glare and solar heat that would impede natural ventilation, and provide ample daylight, especially in the east and west orientations.

The daylighting lab used physical scale models of the building to study different aspect ratios for the courtyard, and the impact of varying ceiling heights, shading devices and sizes of the openings on daylighting. This process also considered the impact of daylighting from the courtyard for each orientation and for various floor heights.

These studies helped refine floor heights to reduce costs as well. The east and west façades use tinted glass as shading devices to provide the required amount of shading while providing the optimum level of daylight in the space.

Theatrical gels were used on the physical scale model to replicate the shading devices’ visible transmittance and determine their impact on the daylight quality and footcandles in the space for overcast days. Since these devices had a dramatic effect on the daylight in the spaces, the studies sought to specify the maximum possible shading coefficient that would also meet the thermal goal.

The courtyard allows each open office space to have uniform daylight. The automated external venetian type blinds on the north, east and south facades have a dual motor so that the daylighting upper portion of the blind can be controlled separately from the viewing portion of the blind.

**Post Occupancy**

After working in The Terry Thomas for a year, the anchor tenant (architecture firm Weber Thompson) was asked to participate in an anonymous survey regarding the building environment and the occupants’ comfort level. A summarized version of the survey, which was initiated by a third party, is available at

**Lessons Learned**

The architect was the primary tenant and negotiated a triple net lease that provided financial motivations that helped push forward some of the energy-saving design concepts.

The cost of the sunshades likely would have been reduced if a mock-up had been produced earlier in the process to allow the contractor to gain familiarity with the design.

Winter heat loss could have been reduced without sacrificing daylight by decreasing the glazing percentage. Replacing the lower 2 ft to 3 ft of glazing on each floor with insulated wall or spandrel also would have mitigated perimeter radiator heat losses.

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**2009 Actual and Modeled Energy Use**

Models have been adjusted by a 0.9 factor since building is 90% occupied.

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All of the survey participants rated the indoor temperature as acceptable or better and said the airflow/circulation was good or excellent. The survey also showed that even though 100% of the occupants knew how to successfully adjust the airflow circulation using operable windows, only 53% were able to adjust the radiant heaters successfully.

The survey showed that 96% of the occupants thought the daylighting was excellent, and 59% thought the glare quality was good or excellent, but 23% thought the glare on their computer screens was poor. The survey indicated that 96% of the occupants were satisfied or very satisfied with overall privacy within the context of an open office floor plan.

The occupants, who were also the architects for the project, have reported anecdotal evidence of fewer flu cases since they have occupied The Terry Thomas. They also state that even though surrounding exterior noise can be a problem, they enjoy the lack of building mechanical noise.

The occupants also reported some problems, such as drafts when the dampers open on cold days in response to CO₂ levels, odor from waterless urinals and glare on computer screens from the windows. These issues are being addressed as the building is fine-tuned.

**ABOUT THE AUTHORS**

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