Case Study: Efficient Museum Design

The San Francisco Museum of Modern Art (SFMOMA) project consists of a 10-story new addition (with basement and penthouse) to the existing 5-story museum (with basement and penthouse), which was architecturally renovated as well as retrofitted with new central mechanical systems. Program elements for the completed project include art galleries, theater, administrative offices, library, café, event space, retail shop, wood shop, art conservation studios, cafeteria, and cold and cool storage rooms. The completed gross project area is approximately 486,000 square feet. Taylor Engineering provided full mechanical and plumbing design services for the project.

Project Type

New Construction + Retrofit

Services Provided

Plan and Spec Mechanical and Plumbing Design

Completion Date

2016

Innovation

Energy efficient space humidity control using centralized adiabatic humidification

Key Accomplishments

38% reduction in energy use per square foot relative to the pre-retrofit museum

45% annual site energy savings relative to the LEED ASHRAE 90.1 2017 Baseline

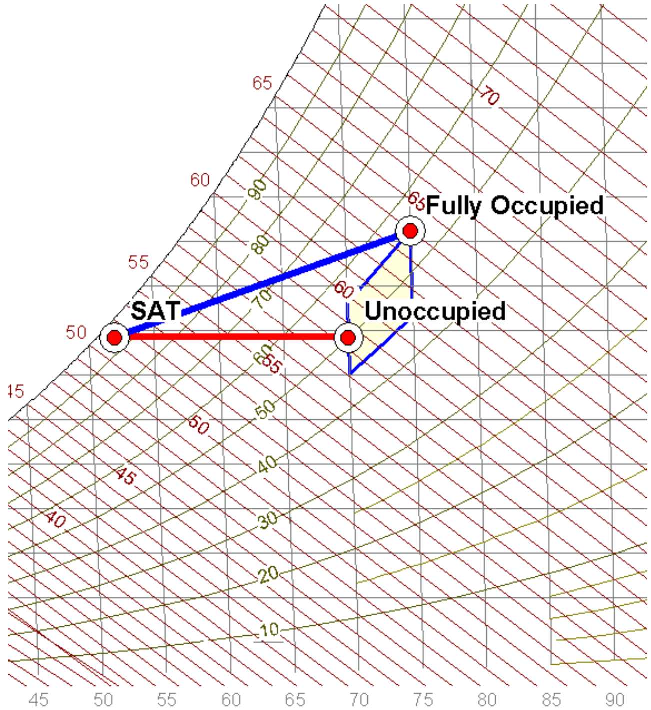
Awards

ASHRAE National Technology Award, 2017

The project is LEED Gold certified, with 45% annual site energy savings compared to the ASHRAE 90.1-2007 baseline and 33% energy cost savings. Currently, the completed project is using on average 38% less electricity/sf than the original museum did (2017 vs 2012 electricity data).

Museums are traditionally large energy users because of the need to provide tight relative humidity control. Taylor Engineering worked closely with SFMOMA conservationists and the project design team to study various published environmental criteria for museums as well as those from major museums across the country. Through this roundtable process, the team concluded that a seasonally adjusted relative humidity setpoint could be used while still maintaining acceptable conditions for artwork and still maintaining a Class A rating according to ASHRAE's 2011 Handbook for HVAC Applications, Chapter 23, Museums, Galleries, Archives and Libraries. This relaxation in humidity control allowed the museum to move to centralized (rather than zonal) humidification, which in turn led to an innovative adiabatic (direct-evaporative) humidifier system described below.

The building (existing and new) is served by three dual-fan/dual-duct systems that have direct evaporative humidifiers in the cooling air handlers and steam humidifiers in the heating air handlers. The direct-evaporative humidifiers provide nearly free humidification (water is evaporated using the energy in return air) and reduced cooling loads. The steam humidifiers on the hot deck provide the additional humidification required due to infiltration of outdoor air at museum entries. The innovative approach to centralized humidity control consists of maintaining a nearly constant supply air condition for a given criteria range: saturated air with a dewpoint temperature just above that at the design space temperature and lowest acceptable relatively humidity, i.e. 70ºF and 45% relative humidity, where RH is adjusted based on time of year as discussed above. For zones that are unoccupied, air is warmed by space loads with no added moisture so the resulting space condition is the “Unoccupied” point in the figure to the right. For spaces that are fully occupied, the room temperature is allowed to rise to 75ºF and, with the moisture added by people, the resulting condition is the “Fully Occupied” point. Thus, with a single supply air condition, all spaces can be maintained in the required temperature and humidity range. The direct-evaporative humidifiers can maintain the desired humidity without any humidity sensors (although dewpoint temperature is monitored) because the supply air is simply always maintained at near-saturated conditions.



The dual-fan/dual-duct system also allows for more effective supply air temperature and pressure resets, and snap-acting dual-duct VAV box logic in non-humidity controlled zones eliminates simultaneous heating and cooling. Gallery zones with humidity control use a dual-duct mixing logic that minimizes simultaneous heating and cooling while allowing for some zone-level humidity control through different dewpoint temperatures in the hot deck (higher) and cold deck (lower). In addition to improving efficiency, dual duct is preferred to hot water reheat because it eliminates piping above galleries, and thus the risk or damage to art should there be a leak.

The air-handlers have design minimum outdoor airflow setpoints 30% higher than ASHRAE 62.1; however, given the mild climate of San Francisco, for the vast majority of the year higher ventilation rates are provided through the use of the airside economizer. Air quality is also improved by eliminating lined ductwork, a potential source of microbial growth given the continuously saturated supply air, made possible in part through the use of quiet and efficient custom fan-array air handlers. The risk of microbial growth on the direct-evaporative humidifiers is mitigated by UV radiation and conductivity control of the water circuit, along with a control sequence where each section of the evaporative media is allowed to fully dry out sequentially once per day.

An 830-ton chilled water plant consisting of two 365-ton existing variable speed centrifugal chillers and a new 100-ton scroll chiller serve the air handlers providing cooling and dehumidification. The chilled water system is primary-only, variable flow/speed using only 2-way valves to increase ΔT and provide self-balancing, which results in both energy savings and first cost-savings. The fact that 10-stories were added to the existing museum, more than doubling the overall square footage, and only an additional 100 ton chiller was added to supplement the existing 730 tons is testament to engineering right-sizing, as well as improved building materials (e.g. better glass) and construction standards (e.g. continuous insulation and air/vapor barriers). Reusing existing chillers and pumps and upgrading with variable frequency drives significantly reduced first costs for the project.

Three new high efficiency cooling towers provide both an open condenser water loop for the chillers as well as a closed-circuit loop for water-source heat pump usage for theater, kitchen, IT and other process loads. Heat rejected to this closed condenser water loop is recovered as preheat for the domestic hot water system. Heating hot water is generated by three 3000 KBH high efficiency condensing boilers with primary-only variable flow with only 2-way valves and oversized heating coils, resulting in high ΔTs and thus low return water temperatures ensuring condensing and high boiler efficiency.

The existing mechanical rooms were a mess of equipment and ductwork, causing consternation with facilities personnel and making routine maintenance difficult. They also were single-fan/dual-duct systems with steam humidifiers, a much less efficient design than dual-fan/dual-duct due to the increased heating and humidifier loads during outdoor air economizer operation and to higher fan energy use due to poor static pressure control. As part of the project, the existing mechanical rooms were redesigned to provide easily accessible maintenance paths and to convert the system to dual-fan/dual-duct with direct-evaporative humidification. Detailed design-phase BIM coordination and careful surveys of existing building ductwork and systems led to a smooth HVAC construction process despite a complex combination of demolition scope, connections of new and existing systems, and a challenging array of program elements with strict aesthetic standards.

The new SFMOMA building is a beautiful space, housing a world-class art collection, which is kept comfortable for both the visitors and the artwork using a very efficient and innovative HVAC system that is cost-effective and easily operated and maintained.

More About Taylor Engineering: Founded in 1995, Taylor Engineering is a nationally recognized engineering firm specializing in mechanical systems design and construction, energy conservation, indoor air quality, controls, and system commissioning. Taylor Engineering specializes in cost-effective and innovative solutions that are designed from the start with construction and operation in mind. Complementing our engineering expertise, Taylor Engineering employees have extensive field experience including mechanical contracting; control system installation and operation; HVAC system monitoring, measurement and evaluation; and site auditing. Our cutting-edge design is informed through our involvement in energy and indoor air quality codes and standards, building science research, and the development of state-of-the-art simulation tools.