IMEG

BREATHING NEW LIFE INTO HISTORIC MARSTON HALL

A SUCCESS STORY OF REUSE AND RENOVATION

A 60,000-sf renovation of Marston Hall, one of the oldest structures on Iowa State University's (ISU) campus and home to the College of Engineering, breathed new life into the building's historic halls.

The original building first opened in 1903 as the Division of Engineering and was renamed in 1947 for the College of Engineering's first dean, Anson Marston. Over the past century the building was modified piecemeal, resulting in a warren of small, mostly administrative spaces replacing the original classroom learning areas and laboratories. Sections of the building were unused, many other sections underused, and even portions of the original 1903 mechanical systems were still in use.

> **In 2016 ISU completed the first comprehensive renovation of Marston Hall, creating a 21st century learning environment within the 19th century structure to give the building another 100 years of life. The renovation is simultaneously respectful of the building's history and forward-looking—embracing both the college's past accomplishments while facilitating future innovations.**

Seventy-five percent of the original interior structure was removed in this unique renovation that preserved the building's history while providing updated classrooms, an auditorium, student interaction spaces, offices, and a welcome center. During the renovation, the north and south wings of the building were completely restructured and a new, highly efficient, primarily hydronic mechanical system utilizing active chilled beams was installed.

This whitepaper discusses the challenges and successes the IMEG design team encountered while meeting and exceeding the owner's goals, including achieving LEED Gold certification.

Fitting the new into the old

A key challenge in the renovation of the facility was physically integrating 21st century systems within a facility that was not intended to house them—and still retain as much of the original building architecture as possible. The building structure (Figure 1) was characterized by low floor-to-floor heights and an original masonry system that integrated air supply and relief shafts within thick corridor walls. A hot deck/cold deck tunnel (split top/bottom) ran under the ground floor central corridor that fed a series of vertical masonry shafts in corridor walls that served individual upper spaces. The original mechanical design was a pneumatically controlled multizone system distributed in the structural walls of the building.

To build the new systems into Marston Hall, a similar utility distribution strategy was employed. The hot deck/cold deck tunnel below the ground floor hallway was cleared out to create a walkable service/utility corridor. A majority of the MEP ducts, pipes, and associated services (which originate from central mechanical rooms in the basement) are distributed in this lower level to multiple vertical chase locations throughout the floor plate (Figure 2). This allowed the horizontal distribution on each occupied floor to be minimized and contained within small zones on each floor. This then allowed ceiling heights to remain higher than if large utilities were piped and ducted across the floor plate on each occupied level.

The ventilation load was minimized by using a dedicated outside air system (DOAS), a direct ventilation system that removes any doubt that each space is receiving the code-required outside air. In addition to the energy benefits, providing only the code-required ventilation rate via the DOAS system also allowed the ventilation and exhaust duct mains to be as small as possible, easing routing through the building. However, in some cases the code-minimum ventilation air provided to certain zones was not enough to meet the chilled beam activation minimum air flow rate. For this reason, parallel fan-powered VAV boxes were used on the DOAS system. Ventilation air is provided via the VAV air valve through the chilled beams to the occupied spaces. When the chilled beams have a call for cooling, the parallel fan energizes, boosting the air flow to the chilled beams to the rate required for proper activation and cooling. This allowed the primary ventilation ducts to remain as small as possible to ease space constraints.

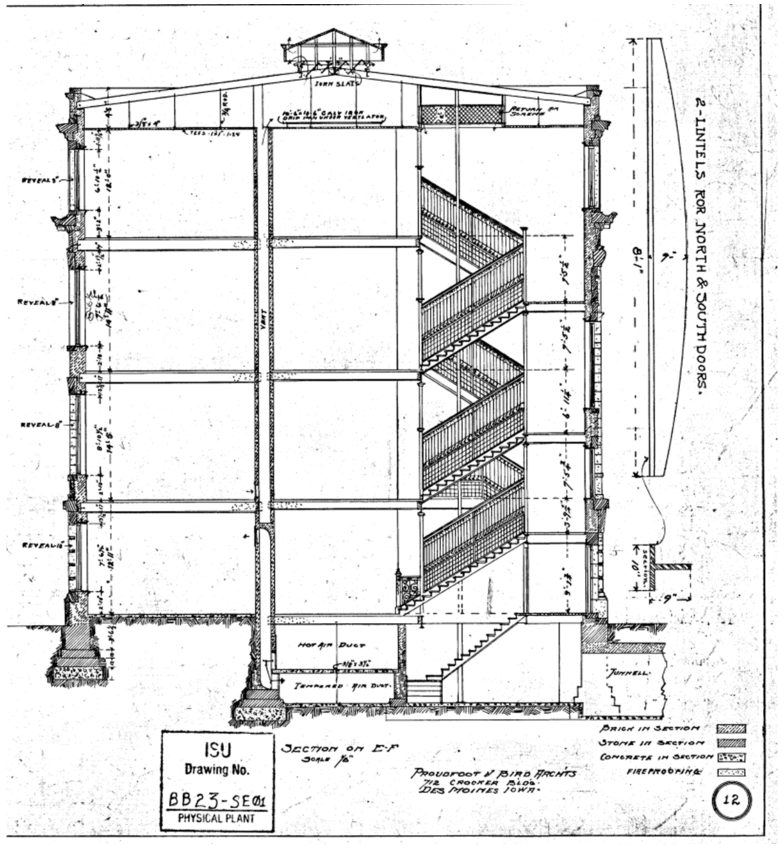

Figure 1

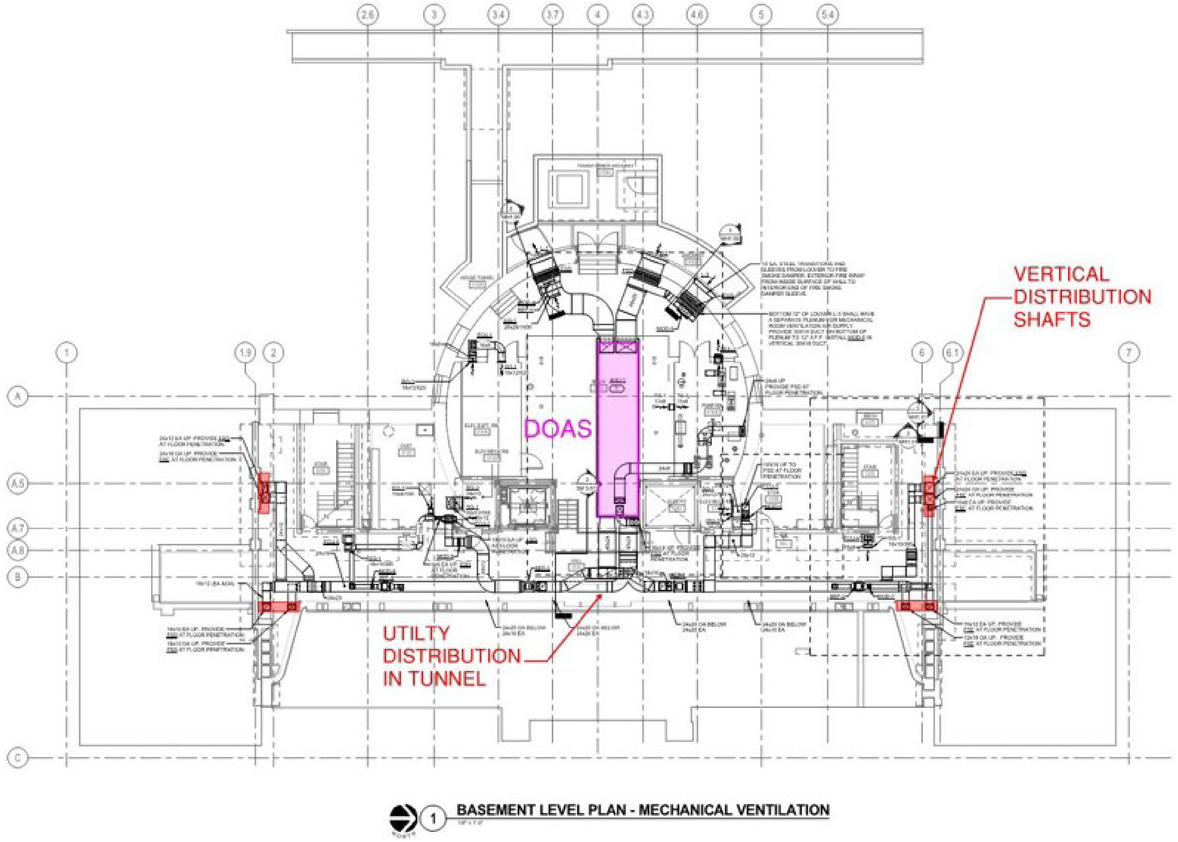

Figure 2

Energy-efficient mechanical systems for optimal occupant comfort

Marston Hall's new HVAC system—which would be served by the campus chilled water and steam supply—not only needed to fit within the physical limitations of the existing building, but it also needed to provide individual room-by-room zoning for temperature control and achieve ISU's energy efficiency and LEED Gold certification goals.

Because the building is served by ISU's central power and cogeneration plant, opportunities were not available to improve upon the production of heating and cooling efficiency within the building. Nor were opportunities available for on-site renewable energy. However, the following strategies were employed within the building to optimize its energy-efficient operation:

- **Increased insulation.** The envelope loads were minimized by adding insulation to the exterior walls. The original masonry building structure did not include exterior wall insulation, and the original exterior wall R-Value was calculated as 2.7. New insulation increased the exterior wall R-Value to 15. The building's operable windows had been replaced just before the renovation, and are modern double pane insulated units. Occupants in office and administrative spaces are also able to control natural space ventilation through the operable windows. Windows in spaces without permanent occupants, such as classrooms, are locked closed.

- **Code-minimum ventilation air.** The DOAS ventilation system was used to minimize the ventilation energy load. The unit supplies 10,000 CFM of outside air filtered to MERV 13, which is an average of 0.16 CFM/SF over the entire building. Ventilation is one of the largest loads that must be accommodated in facilities in Climate Zone 5A due to extreme winter and summer conditions, so the use of a DOAS ventilation system allowed the amount of ventilation air provided to the building to be the minimum required by ASHRAE 62.1-2010. In office and classroom spaces, the air is introduced via the active chilled beams to provide a zone air distribution effectiveness of Ez = 1.0. In the auditorium space, which has higher ceilings than practical for using chilled beams, ventilation air and cooling supply are both introduced through an underfloor air plenum, using displacement ventilation to cool and ventilate the space, and are controlled by carbon dioxide sensing. The space is served with a high return, providing a zone air distribution effectiveness of Ez = 1.2.

- **Energy recovery.** With the amount of ventilation air minimized, the peak heating and cooling loads associated with the ventilation air were then further reduced by energy recovery wheels in the DOAS air handling unit. Fan-powered VAV boxes were used for meeting the chilled beam's minimum activation air when the minimum ventilation rate did not. Additionally, ventilation air reheat and dehumidification were accommodated by using a desiccant dehumidification and energy recovery wheel in the DOAS unit. No steam energy is used for reheating ventilation air, and hydronic heating and cooling via active chilled beams and perimeter convectors were employed throughout most of the building to minimize air-based heating and cooling.

In providing optimal thermal comfort for occupants, the design not only complied with ASHRAE 55-2010 but also achieved LEED Credit IEQ 7.1 for thermal comfort. The owner desired temperatures of 75°F/50% RH in the summer and 72°F/20% RH in the winter without the building being actively humidified. The design assumed Clo levels (a measure of clothing and thermal insulation) would be 0.66 in the spring and summer and 0.70 in the fall and winter and that metabolic rates in offices and conference rooms would be 1.1 and 1.0 for classrooms. Design air speed for all spaces is below 40 fpm. There have not been significant comfort complaints.

Reliable radiant cooling in a humid climate

This project demonstrates that using a chilled beam system for cooling in an older building in a humid climate can be successful if handled properly from design, operation, and occupant education standpoints.

The existing building lacked a vapor barrier to inhibit moisture transfer and it has operable windows, a combination that could create condensation and dripping if a space becomes too humid. Analysis was conducted early in design to determine the peak space latent loads, and to determine which source (permeation, infiltration, or occupants) was the dominant load. By far, moisture from

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ENERGY PERFORMANCE ANALYSIS

Marston Hall's energy use intensity (EUI) had been 146 kBtu/SF/year average for the two years prior to the 2016 renovation. LEED energy modeling analysis using Trane Trace showed that the building would consume approximately 53 kBtu/SF/year after renovation—a 64% reduction.* After 12 months of operation post renovation, however, the first year of data showed the building was operating at 71 kBtu/SF/year—still a reduction, but much higher than what had been predicted (Figure 1).

ISU and the design team then executed the LEED Measurement and Verification (M&V) analysis credit to determine causes of the higher-than-anticipated energy consumption. Multiple issues were identified, the most notable being a DOAS unit steam valve commanded open 100% at all times (Figure 2). This was negating energy recovery benefits, using unnecessary steam, and causing increased chilled water use. The issue was quickly and simply corrected, saving the university as much as $24,000 a year in energy costs.

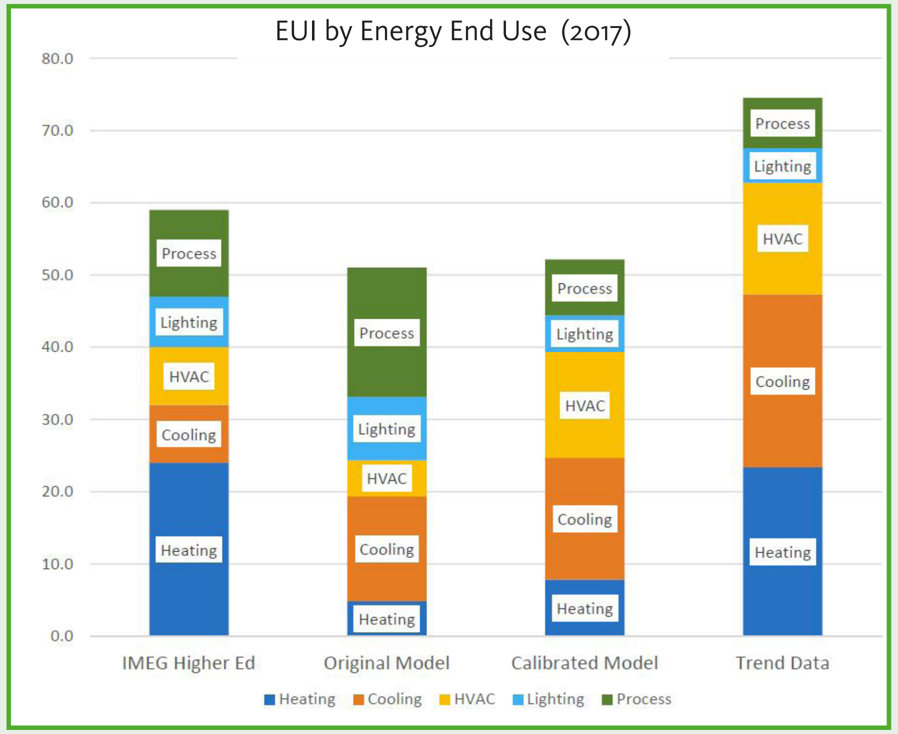

Figure 1

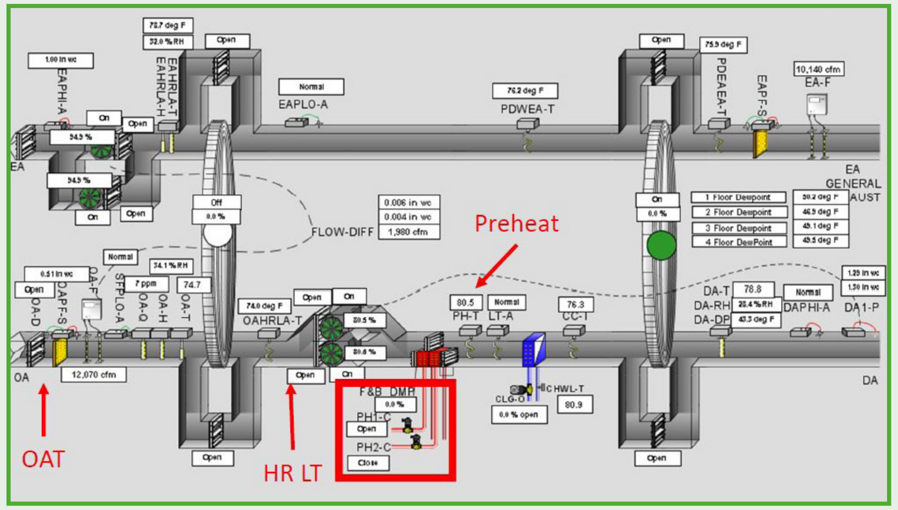

Figure 2

An updated energy model based on actual use and occupancy (both higher than what the original model assumed) showed an EUI of 65 kBtu/SF/year, with the building operating within 10% of the new benchmark.

** The original modeled energy use was also a 33.5% reduction over the code-allowable 86 kBtu/Sf/year—and $38,850/year less in energy costs than what the new code minimum would allow.*

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occupants was shown to be the dominant source of space latent load. To combat the risk of condensation on the chilled beams, the following strategies were employed:

- The DOAS system with passive dehumidification wheel provides ventilation air to the building at the following conditions: 60°F db/51.2°F wb/44 grains/lb of moisture/44°F dew point. Typical 55°F saturated supply air (as may be used in a traditional VAV system) has a moisture content of 60-65 grains/lb with a dew point of 54-55°F. This dry ventilation air is required to absorb space latent loads and ensure the space dewpoint remains below 55°F, which is below the chilled beam loop set point temperature of 57°F.
- The mechanical control system includes dew point sensors in each space that lock out the chilled beam cooling when a space's dew point reaches 57°F.
- To ensure duct leakage was minimized and the dry ventilation air was supplied to the spaces, the DOAS supply ducts and associated VAV boxes were sealed to meet SMACNA Class A, plus sealed with heavy backed adhesive tape (UL 181A-P compliant) at all joints. The VAV box construction seams were all taped to reduce leakage, as these VAV boxes leak considerably as made.
- Occupants and building operators were educated by the design team and university staff on the mechanical system operation, helping them to understand the potential issues caused by leaving windows open at the wrong times.

The DOAS and chilled beam system has operated successfully since the building opened in the summer of 2016.

Ease of operation and maintenance

Engineers selected a mechanical system comprised of equipment that is familiar to Iowa State facilities staff and only requires simple regular maintenance. The DOAS air handler, main mechanical pumps, and heat exchangers are located in an accessible mechanical space in the basement. Exterior access and interior elevator and stair access is provided to this mechanical space. Adequate space is provided for coil pulls, filter changes, and regular maintenance. The air handler serving the auditorium is located in a mechanical room adjacent to the space, on floor level off a central corridor.

Fan-powered VAV boxes are located above accessible ceilings for filter changes. Chilled beams and perimeter radiant convectors only require periodic cleaning and are accessible throughout the building. During the construction of the project, the design team, contractors, and owner worked together to place and map isolation valves and control valves for optimized access and clearance. The isolation, control, and drain valves serving the perimeter heating system in the auditorium are located behind an access panel at floor level, as opposed to above the high auditorium ceiling.

1st place ASHRAE Technology Award

The renovation of Marston Hall provided an innovative and energy-efficient design within a 19th century building. Marston Hall currently uses 50% less energy than it had prior to renovations, even though its use and occupancy have increased significantly, with opportunities for greater improvement available through measurement and verification analysis. Because of these improvements, Marston Hall received a 2022 1st Place ASHRAE Technology Award, which recognizes outstanding achievement in the design and operation of energy-efficient buildings. Reuse and renovation of the historic building provides the College of Engineering with a new home that continues to be connected to its roots.

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