MULTISTACK®

Moore Hall at University of Hawaii Improves Comfort, Achieves $150,000 Annual Energy Savings

About the University of Hawaii

Founded in 1907, the 320 acre campus of the University of Hawaii at Mānoa is the flagship campus of the University of Hawaii system. Students and faculty come from across the nation and the world to take advantage of UH Mānoa's unique research opportunities, diverse community, nationally-ranked Division I athletics program, and beautiful landscape. Consistently ranked a "best value" among U.S. colleges and universities, University of Hawaii students get a great education and have a unique multicultural global experience in a Hawaiian place of learning—truly like no place else on earth.

- The University of Hawaii offers:
- Bachelor's degrees in 92 fields
- Master's degrees in 84 fields
- Doctoral degrees in 51 fields
- Professional degrees in three fields

The University of Hawaii is accredited by the Accrediting Commission for Senior Colleges and Universities of the Western Association of Schools and Colleges (WASC). Full-time faculty includes 1,209 instructors and professors of which more than 85 percent have doctoral degrees. The student-faculty ratio is 14.1 to one and it is one of only 32 institutions nationwide to hold the distinction of being a land-, sea-, and space-grant research institution. Classified by the Carnegie Foundation as having "very high research activity," UH Mānoa is known for its pioneering research in such fields as oceanography, astronomy, Pacific Islands and Asian area studies, linguistics, cancer research, and genetics.

Blake Araki, PE, MPA, is the Engineering Manager in the Mechanical Division at the University of Hawaii. It's a big, important job—Araki manages 527 buildings totaling more than 6.1 million square feet of facility space. Araki said, "Our goal is to keep the campus operating efficiently, comfortably and safely to provide an environment conducive to productive teaching, learning and research. We serve the needs of the academic community. We treat them as our clients and clearly understand that they are the reason we are here and not the reverse."

In determining what projects to undertake, Araki considers whether existing equipment or systems are at or beyond life expectancy; does the equipment require excessive maintenance and repairs; are health, safety or code compliance issues involved; are operating costs excessive due to inefficient or outdated equipment, and whether new or updated equipment would provide multiple benefits.

Moore Hall was a building that needed attention. Built in 1969, the nine-story, 111,000 square-feet classroom and faculty office building houses the University of Hawaii's Linguistics Department. When Araki decided to move ahead with improvements to HVAC systems at Moore Hall, he retained the design services of Randolph H. Murayama and Associates (RMA). Creatively, Araki directed the engineers to provide for a performance based design and specifications that would focus on providing an optimal performance and efficient chiller plant and system. Araki wanted, not only an energy-efficient and comfortable performance-based design, but also the ability to document system performance. To accomplish this expectation, long time associate PSIG-Hawai'i was retained to handle the load and efficiency measurement of the HVAC system, develop the measurement and verification protocol for the design, equipment selection methodology development, design duties and post-measurement and commissioning of the

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>
> – Les Taniyama, PSIG-Hawaii

completed, installed system. Since 1993 cumulative annual energy savings of all PSIG-Hawaii energy-efficient projects total more than 32 million kWh per year while avoiding more than 30,000 tons of annual CO2 emissions.

Moore Hall Design Criteria Included

- Improving operation, performance, efficiency, reliability, flexibility, serviceability of the mechanical equipment or system being replaced or repaired
- Sustainable, environmentally-friendly design consideration (e.g. refrigerant selection, energy efficient lighting where replaced, ice thermal storage, heat recovery, etc.)
- Maximize existing mechanical system enhancements to allow future expansion and new technologies. (E.g. maintaining the existing chilled water loops, VFD's for variable volume systems, installing premium efficient motors, etc.).
- Address and/or improve indoors environmental conditions (temperature/humidity)
- New Energy Management and Control System (EMCS), to control central plant, roof equipment, air handlers (with VFD's) and VAV terminal units.
- EMCS allows for the scheduling of all mechanical equipment.

Project Challenges

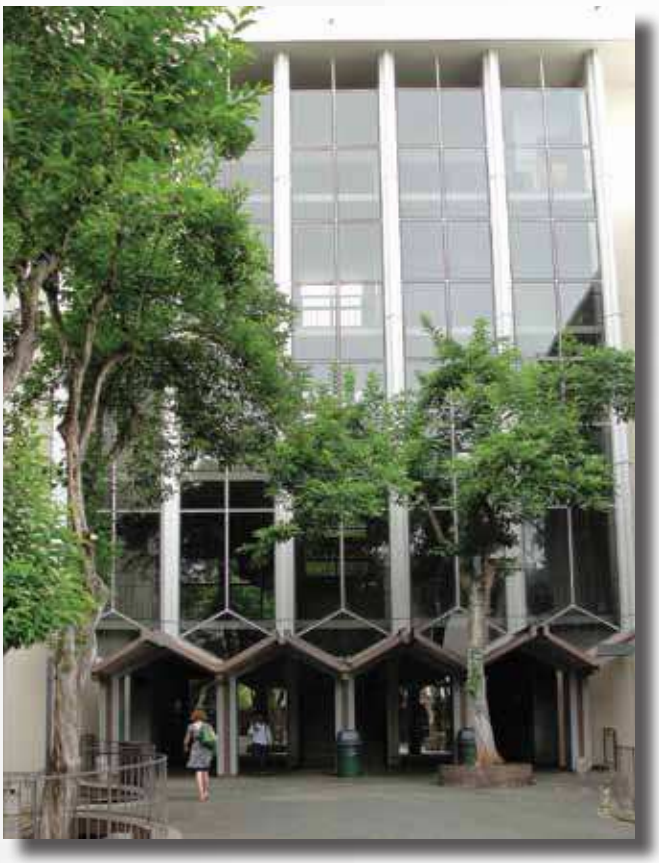
Among the challenges that Araki and RMA faced on the Moore Hall project was limited time for existing system evaluation and redesign. All work had to be scheduled so as not to disrupt students and faculty. The fact that Moore Hall was an active, occupied building generated access issues plus logistical constraints such as construction parking and materials staging. All work had to be accomplished within code requirements related to access for disabled persons, storm water control and hazmat issues.

Finally, the building itself was a challenge. Over the years, the electrical power supply to the building did not grow to accommodate additional demand. The existing design of the building envelope and ventilation system did not allow for creative on-demand designs.

Performance Design Approach

Araki notes that while University projects are funded with public money, system purchases do not have to be based solely on low first cost. Purchasing considerations include overall installed cost, life-cycle costs and whether the new equipment truly meets the University's requirements for building comfort control, efficiency, reliability and future serviceability. The reason that Araki worked with RMA and PSIG on the Moore Hall project (and others) is that they use a Performance Design Approach to their projects. RMA/PSIG's Performance Design Approach establishes baseline energy use and cooling load measurements that are used in developing the basis of the design. It provides for measurement and verification methodology to document before and after energy use, performance and efficiency—documenting energy savings.

The design process includes extensive measurement of an existing building's performance, providing an accurate picture of how a building is actually operating and what changes are needed to optimize operation for best efficiency and comfort. Very importantly, the Performance Design Approach creates an extended post-project commissioning period to sustain system performance and energy savings and includes user training to maximize sustainable energy efficiency and savings. Araki has always maintained that providing an efficient design is only as good as sustaining that efficiency from year to year.



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Moore Hall is equipped with two 160-ton Multistack chillers with the MagLev™ bearing system for high efficiency, high reliability and low maintenance.

Les Taniyama, PSIG-Hawaii, said, "We installed various types of meters on the existing chillers and HVAC equipment throughout the building. This allowed us to carefully define the building's actual needs and cooling load. We measured not only the kW and kWh of the chillers and overall chiller plant, but all other HVAC components. We learned that the cooling capacity of the existing chiller plant (320 tons) was more than twice the actual cooling load (150 tons) because the Moore Hall chiller plant also serves a chilled water loop that includes other campus buildings. As a result, Moore Hall was often significantly over-cooled, resulting in comfort complaints from students and faculty."

In addition to setting up extensive instrumentation to study the building, the RMA design team did a walk-through of the building. Tatiyama said, "We counted 68 sweaters on the backs of classroom and office chairs—plus a couple of floor heaters tucked under desks in the offices! This building had some serious comfort issues!

Fifty percent of the energy use in buildings such as Moore Hall is for HVAC. And half of that energy use is for the chillers. Twenty-five percent of total building energy use is a big number. Araki knew that by establishing the best operating environment for the chillers and condensers, he could achieve the best energy efficiency.

A Tough Environment

Another challenge facing the Moore Hall project team was that the wet bulb temperature in Hawaii is always very high. RMA's performance designs attempt to provide for a very stable operating equipment condition under variable ambient weather conditions. The team discovered that centrifugal chillers don't like rapid changes in operating conditions such as water flow rates or condensing temperatures. In fact, some chillers are just 'too smart'—their controls are so advanced that they 'remember' previous operating conditions and are always adjusting the equipment controls to allow for changes, like rapidly changing condenser water temperatures due to passing rain showers on a sunny day.

Eric Nakagawa, RMA, said, "ASHRAE standards call for being able to operate at 50 percent load capacity at 65-degree condensing water temperature. You literally cannot get to those conditions in Hawaii. However, Multistack provided the systems engineering and product applications support to give us the confidence that the Multistack chillers would perform well in Hawaii. These Multistack chillers can successfully operate at as little as 20-percent load with 70–75-degree condenser water temperature!"

The system was designed to accommodate operation of one or both chillers while operating both cooling towers in either mode. The condenser water pump VFD's automatically change condenser

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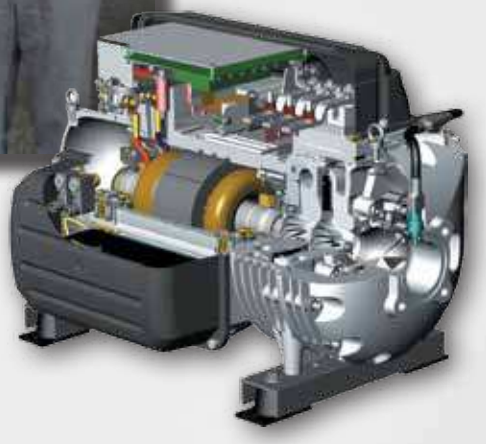
Left: (left to right) Les Taniyama, Vice President of PSIG Hawaii; Blake Araki, PE, MPA, Engineering Manager, Mechanical Division, University of Hawaii at Mānoa; Eric Nakagawa, Associate of Randolph Murayama & Associates; Herman Siu, Trane Sales Engineer. All are graduates of University of Hawaii

Below: MagLev Compressor



water flow rate per chiller for single or dual chiller operation. This provides proper flow rate through the cooling towers and chiller in all operating modes. Herman Siu at Trane Hawaii provided selections of Evapco cooling towers, paying attention to details like cooling tower cell minimum flow rates and condenser water flow rates to optimize performance.

During the post-project commissioning process the project team also adjusted air handler VFDs to minimize or eliminate rapid changes in airside operating conditions, thereby stabilizing chilled water flow and chiller performance. The design allows Moore Hall operators to operate the new Multistack chillers in either series or parallel configuration to achieve best efficiency for conditions—series configuration is usually most efficient. The plant is also configurable to allow for building-only cooling or to include the loop (either in series or in parallel connection).

New Multistack Chillers Installed

Blake Araki developed a budget that included new chillers, adjusting the airside systems and integrating air handlers and VFDs into an optimized, efficient system. The entire energy management system plus all the thermostats and VAV terminals throughout Moore Hall were replaced.

Araki agreed with RMA to install two 160-ton Multistack chillers with the MagLev™ compressors and flooded evaporator because the project required optimum capacity to be able to serve the building and the four-building loop. Eric Nakagawa, senior designer at Randolph H. Murayama & Associates mechanical engineers, said, "The Multistack chillers have just the right size and cooling capacity. These chillers fit university-type buildings very well and their performance makes them an excellent choice." RMA's Lance Suzuki, P.E. assisted in designing the HVAC system upgrades.

The MagLev™ compressors provide efficiency, reliability and redundancy advantages. The magnetic bearings nearly eliminate rotational friction, require no oil and since the chiller has multiple compressors, the building automation system can very closely match chiller output to actual load conditions. If one compressor were to fail, the other compressor provides redundancy.

Another factor in favor of the Multistack chillers is the compact design. Although other makes of chillers would have fit into Moore Hall's basement equipment room, those chillers were too long relative to future serviceability such as heat exchanger tube cleaning or replacement. Multistack was flexible and worked with PSIG and the University to provide heat exchanger shells of the necessary length.

Another advantage of the Multistack chillers is the FlexSys™ controls that provide unmatched controllability to adapt and fine-tune overall chiller and individual module/compressor operation for redundancy and to achieve optimized performance throughout the broad spectrum of operating environments at Moore Hall. In addition to on-site control, the Moore Hall

FlexSys controller can be accessed in real time, anytime and from anywhere in the world via laptop, iPad, or Smart Phone.

FlexSys control flexibility allows end users to field connect devices that allow it to either respond to BAS commands, send the BAS information, or control auxiliary devices such as isolation valves, pumps, cooling tower fans, temperature reset, load limit, etc.

In addition to water-cooled flooded chillers like those installed at Moore Hall, FlexSys controllers can also be applied to water-cooled DX chillers, air-cooled flooded chillers, air-cooled DX chillers, built-up DX systems, modular chillers, dedicated heat recovery chillers and a host of innovative applications never before possible.

New EMS System

The University of Hawaii is not only saving significant energy costs at Moore Hall, but comfort is greatly improved while maintenance time and costs are sharply reduced. The improved energy management and control system makes the HVAC system virtually self-correcting—or it notifies operators of an issue requiring corrective action. The new EMS allows operators to better see and understand the entire building.

Kenneth Richardson, President of Island Controls, collaborated with RMA and PSIG-Hawaii to create custom programming for the Automated Logic Corp. "Web Ctrl" EMS and control system. Integrating graphics with custom programming lets operators visualize building performance at a glance. Richardson said, "These custom dashboards provide real-time status by switching from screen to screen. The custom control and reporting schemes required for this performance project were accommodated by Automated Logic's open object oriented protocol."

Taniyama said, "If you can't see what's happening in the building, you can't understand it and make good operating decisions. We are also documenting in real time, as part of our measurement and verification protocol, the energy use of the building, the air conditioning equipment and each chiller, as well as the building cooling load. This is critical to sustaining our energy use and efficiency—so much so that the EMS alerts operators if energy use exceeds set limits.

"For example, we learned that previously the Moore Hall chillers ran 24/7/365 because they had to be manually started and shut off. Rather than send someone over to shut off and then restart the chillers twice daily, they would just let them run. Previously, if Moore Hall needed after-hours cooling, they had to operate the HVAC on at least three of the building's nine floors to meet minimum load requirements of the old chillers. Now, with the EMS and Multistack chillers, they can operate as little as only three or four air handling units on a single floor of the building!"

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The Moore Hall Team

Blake Araki, Engineering Manager, Mechanical Division
– University of Hawaii at Mānoa

Randolph H. Murayama & Associates
– Mechanical Engineer/Lead

Power & Systems Inspection Group (PSIG-Hawaii)
– Energy Engineer/Designer

Island Controls
– EMS and Controls Engineer

H&O III, Inc.
– Electrical engineer

Kai Hawaii, Inc.
– Structural engineer

Island Controls, Inc.
– Energy management and controls provider/consultant

Multistack LLC
– Chiller provider

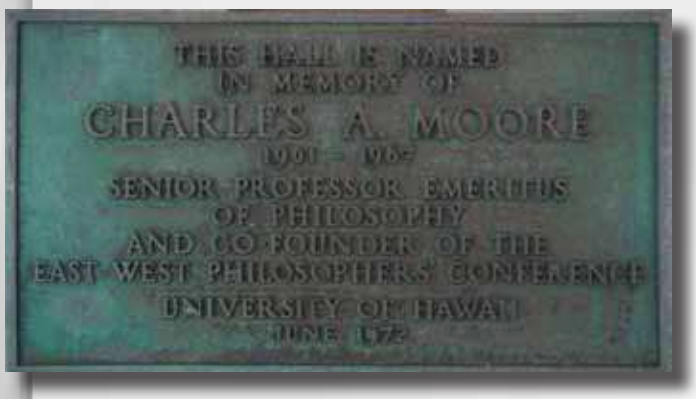
Results

Moore Hall went from an average chiller efficiency of 0.68 kW per ton, to 0.38 kW per ton. Taniyama notes that three years ago the University installed VFDs on all of the air handling units and the design team initially didn't think that they would be able to save much energy at Moore Hall. However, in January, 2010, the first full month of operation with the new chillers, cooling tower and systems adjustments, chiller plant energy use at Moore Hall decreased by 74 percent compared to February, 2009. The new system is saving significantly more energy than originally projected.

Average office/classroom Energy Use Index (EUI) was 22.8 kWh/square foot/year. In 2009, following installation of VFDs on the Moore Hall air handlers, the Moore Hall Energy Use Index was 19.8 kWh/square foot/year or 13 percent less than the average building EUI. In 2010, after installation of the new Multistack chillers, cooling tower and energy management system, the Moore Hall EUI was 11.6 kWh/square foot/year—49 percent less than 2009!

> "The energy savings numbers speak for themselves plus the system is more stable and operates much more reliably and efficiently. Comfort levels are definitely better. The Multistack chillers have met all of our performance requirements at Moore Hall."
>
> – Blake Araki, University of Hawaii

Although projected annual energy savings were calculated at 275,000 kWh, in 2010 the measured annual energy savings totaled 621,000 kWh. At $0.25/kWh, that's $155,250 savings per year—and more as energy costs increase.



Blake Araki said, "The energy savings numbers speak for themselves plus the system is more stable and operates much more reliably and efficiently. Comfort levels are definitely better. The Multistack chillers have met all of our performance requirements at Moore Hall."

"Multistack has really gone to bat for us on this project," said Eric Nakagawa. "Their support is excellent. As a designer I measure the quality of a manufacturer and their products by how well they handle problems. There were times when we called Multistack when it was eight o'clock in the evening at their headquarters in Wisconsin. The Multistack team has never walked away from any problems." ☐

MULTISTACK®

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