U.S. DEPARTMENT OF ENERGY

PNNL-19731

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

American Recovery and Reinvestment Act (ARRA)

FEMP Technical Assistance

United States Pacific Command (PACOM)

Guam

Task 3.3: Building Retuning Training

DD Hatley
RM Underhill

September 2010

Pacific Northwest
NATIONAL LABORATORY

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

Pacific Northwest National Laboratory (PNNL) presented a workshop on building retuning on the island of Guam on August 3-5, 2010. The workshop consisted of 1 day of classroom training and 2 days of hands-on training while actually retuning buildings. The retuning methodology, which identifies low- and no-cost operational ideas, was presented during the class and was well accepted by the attendees. Twenty-four staff members were trained during the workshop.

During the workshop, it became apparent that as site personnel maintain the facilities at Guam, the following retuning efforts and strategies should be prioritized:

- Controlling the mechanical systems' operational hours and zone temperature set points appeared to present the best opportunities for savings
- Zone temperature set points in some buildings are excessively low, especially at night, when the zone temperatures are so cold that they approached the dewpoint.
- Manually-set outside air dampers are providing excessive outside air, especially for spaces that are unoccupied.

Two of the larger schools, one on the Naval Base and one on Anderson AFB, are in need of a significant recommissioning effort. These facilities are relatively new, with direct digital controls (DDC) but are significantly out of balance. The pressure in one school is extremely negative, which is pulling humid air through the facility each time a door is opened. The draft can be felt several feet down the halls. The pressure in the other school is extremely positive relative to the outside, and you can stand 20-feet outside and still feel cool drafts of air exiting the building.

It is recommended that humidity sensors be installed in all new projects and retrofitted into exist facilities. In this humid climate, control of humidity is very important. There are significant periods of time when the mechanical systems in many buildings can be unloaded and dehumidification is not required. The use of CO_2 sensors should also be considered in representative areas. CO_2 sensors determine whether spaces are occupied so that fresh air is only brought into the space when needed. By reducing the amount of outside air brought into the space, the humidity load is also substantially reduced. CO_2 and humidity sensors, combined with outside air sensors, can be used to predict whether conditions are amenable to mold growth and to automatically adjust systems to help prevent mold without using extra energy.

The goal of this training is to give the building operators the knowledge needed to make positive changes in the operation of building systems. As class participants apply this knowledge, building systems will run more efficiently, occupant comfort should improve, while saving energy and reducing greenhouse gas emissions.

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Description of ARRA program

On February 13, 2009, Congress passed the American Recovery and Reinvestment Act (ARRA) of 2009 at the urging of President Obama, who signed it into law four days later. A direct response to the economic crisis, the Recovery Act has three immediate goals:

- Create new jobs and save existing ones
- Spur economic activity and invest in long-term growth
- Foster unprecedented levels of accountability and transparency in government spending.[1]

The U.S. Pacific Command (USPACOM or PACOM) is facing significant energy challenges and has identified the need for a comprehensive and integrated approach to addressing these challenges. In a letter dated March 30, 2009, the PACOM Director of Resources and Assessments requested the support of the Department of Energy Federal Energy Management Program (DOE FEMP) in specific assessment, analysis, and training tasks to work toward the accomplishment of PACOM's energy security strategy. An integrated set of ARRA proposals for FEMP assistance requested national laboratory support for the execution of the identified tasks. The resulting 2009-2010 FEMP PACOM scope of work includes renewable energy and efficiency assessments, energy manager training and development, smart grid and islanding feasibility studies, alternative contracting assistance, and technology demonstrations.

In a competitive grant approach across the services and commands, the national laboratories were awarded over $3,000,000 from DOE FEMP to support PACOM needs. The funds are dedicated to technical assistance projects aimed at bringing the most advanced energy efficiency, renewable power generation, and microgrid assessments and analyses to Department of Defense (DOD) installations in Hawai`i, Alaska, and throughout the Pacific region.

The building retuning training session described in this document represents the Guam-based training session, part of a single task (Task 3.3, FEMP Project 241) within this ARRA-funded energy program. Other building retuning training sessions within this task include two Hawaii-based training sessions and two Alaska-located sessions, to be described in separate reports.

[1] http://www.recovery.gov/

Background

As the United States' oldest combatant command, PACOM has been a force for peace and a committed partner in the Asia-Pacific region for more than 60 years. With an area of responsibility (AOR) that includes more than 3.4 billion people and encompasses about half the Earth's surface, the Command remains a significant stabilizing influence in the world. PACOM is supported by four component commands: U.S. Pacific Fleet, U.S. Pacific Air Forces, U.S. Army Pacific, and U.S. Marine Corps Forces, Pacific. These commands are headquartered in Hawai'i and have forces stationed and deployed throughout the region.

The island of Guam is located in the Pacific Ocean approximately 1,200 miles east of the Philippines and 3,500 miles west of the Hawaii. Guam was first colonized by Spain in 1668 after its discovery by Ferdinand Magellan, and transferred to the United States after the Spanish-American war. The Japanese captured the island in December 1941 and occupied the island until it was liberated by the U.S. 2½ years later. Guam currently has about 140,000 inhabitants, including approximately 7,000 military personnel and their families.

Guam represents a key military asset providing a forward operating base to respond quickly to problems in southern Asia and surrounding regions. The U.S. military occupies roughly 29% of the island - 39,000 acres (160 km^2). Military installations include:

- U.S. Naval Base Guam, U.S. Navy
- U.S. Coast Guard Sector Guam
- Andersen Air Force Base, U.S. Air Force
- Apra Harbor / Orote peninsula
- U.S. Navy Ordinance Annex
- U.S. Naval Air Station, Agana
- Naval Communications Station, Guam
- Joint Force Headquarters-Guam National Guard.

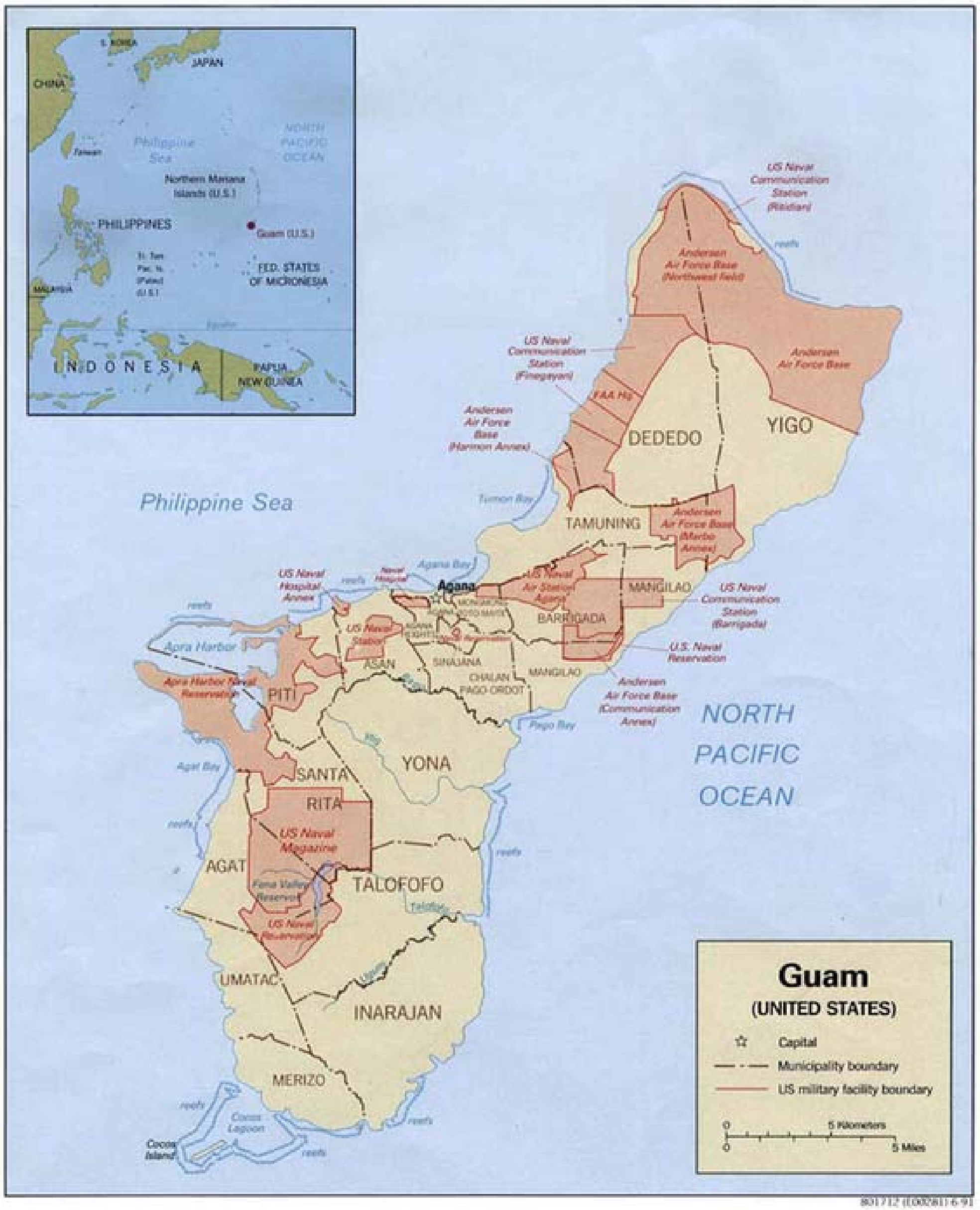

Figure 1. Military Installations on Guam[2]

[2] Source: "American Military Bases on Guam: The US Global Military Basing System" Global Research, August 2, 2010. http://www.globalresearch.ca/index.php?context=va&aid=20405

Task Description: Building Retuning Training

Periodic retuning of building controls and heating, ventilation and air conditioning (HVAC) systems helps eliminate operation faults and improves building efficiency. *Retuning is a systematic, semi-automated process of detecting, diagnosing and correcting operational problems with building systems and their controls*. The process can significantly increase energy efficiency at low or no cost – and the impact is immediate. Unlike the traditional retro-commissioning approach, which has a broader scope, retuning primarily targets HVAC systems and their controls. In addition, retuning uses monitored data to assess building operations even before conducting a building walk through.

Pacific Northwest National Laboratory (PNNL) developed a building retuning and retro-commissioning course for the State of Washington (http://buildingefficiency.labworks.org/lg_bldg_training.stm). Since its development, it has been expanded and customized for other government organizations and private corporations. The course is targeted at operations and maintenance (O&M) staff, HVAC technicians, controls specialists, and energy management staff. After completing the course, the participants are asked to continue the process on their own, retuning additional buildings and reporting the results back to the instructors. The idea is to train the people who can affect real change at an installation rather than always bringing in outside “experts” to retune buildings.

Site Description

The Guam building retuning training (Task 3.3) took place at Camp Covington on the Naval Base. The field training on August 4, 2010 was held on the Naval Base. The field training on August 5, 2010 was held at Andersen AFB. This work is described in further detail below.

General Findings

Cooling and dehumidification are the only HVAC modes that are utilized on Guam. The typical highest outside air temperatures are in the upper 80s, with lows in the mid 70s, so even cooling loads are not very large. Energy prices are extremely high, with rates expected to rise to $0.31/kWh this year. Any savings of energy on Guam will translate into large financial savings. Operational hours and zone temperature set points appeared to present the best opportunities for retuning.

Based on observations taken during the field training, the 24/7 operating mode is the most common mode of operation. There appear to be several reasons for the use of constant operation modes. The most common reasons were based on equipment capabilities and fear of mold growth. Most office areas and classroom zones are not occupied all day. However, many systems did not have the hardware in place to actually perform unoccupied modes or night setbacks. The fear of mold growth is valid because the humidity in Guam is high throughout most of the year. However, building managers may be creating their own problems by not properly controlling the temperatures in each of the zones.

During the training, Pacific Northwest National Laboratory (PNNL) staff found zone temperature set points set very low, sometimes as low as 65ºF. When tenants have control of the thermostat, they often turn it down as far as it will go and leave it there. Because the equipment is not over sized by very much, the zones measure between 65ºF and 70ºF during the day. This is a lower temperature than necessary. In addition, the zones cool down enough at night so that they may approach the dewpoint. This presents the potential for mold issues.

A third major observation was the amount of outside air that is being drawn into the systems. In most cases, a manually set damper controlled the amount of outside air allowed into the system. Because of the humidity issues, excess outside air can contribute significantly to the building's cooling load. As noted above, staff found that in several buildings, tenants get too cold.

Another important observation is that two larger schools, one on each site, are in need of a significant recommissioning effort. These facilities are relatively new and have direct digital controls (DDC), but they are significantly out of balance. The pressure in one school is extremely negative, which is pulling humid air through the facility each time a door is opened. The draft can be felt several feet down the halls. When humid air is pulled through building components, it can lead to mold growth. The pressure in the other school is extremely positive relative to the outside and you can stand 20 feet outside and still feel cool drafts of air exiting the building.

It is recommended that humidity sensor be installed in all new projects and retrofitted into exist facilities. Controlling humidity is very important in this climate.

There are significant periods of time when the mechanical systems in many buildings can be unloaded and dehumidification is not required. The use of CO_2 sensors should also be considered in representative areas. CO_2 sensors determine whether spaces are occupied so that fresh air is only brought into the space when needed. By reducing the amount of outside air brought into the space, the humidity load is also substantially reduced. CO_2 and humidity sensors, combined with outside air sensors, can be used to predict whether conditions are amenable to mold growth and to automatically adjust systems to help prevent mold without using extra energy.

Another option that can be used when mold prevention or night operations are required is to reduce fan speed, reduce outdoor air, and circulate the air. Because no staff are in the facility, this allows for reduced energy usage without impacting areas that may have concentrations of staff. The team found that many air handling units can be turned down to one-half their normal static saving four times the energy usage at night.

Building-Specific Findings

After each classroom day, students and instructors spent the rest of the week in smaller groups, examining individual buildings. Attendees where shown what to look for and how to incorporate simple changes that can both save energy and reduce tenant complaints. Below is a summary of the sites and facilities that were covered during the field exercise.

Naval Base General notes:

- Johnson Control Incorporated (JCI) has an energy savings performance contract (ESPC) and is installing DDC controls on several facilities. One observation that concerned PNNL staff is in several locations JCI has replaced 1 to 2 year old DDC controls on just the air handler portion of a facility and installed their own hardware. This has now segregated the operations of the rest of the building from the air handler operations. There are now two vendors' controls in one facility. This eliminates the ability to integrate the controls system for energy-efficiency routines. It also means maintenance staffs have to know and understand programming on two systems to service one facility. Also the main central work stations will not be able to see the complete facility operations.
- There are a significant number of barracks facilities on the base. The occupied/unoccupied status of each room is somewhat random. An energy saving measure with the newer DDC systems would be to lay out a floor plan map of the rooms with an occupied/unoccupied button that can be set by barracks operation staff. This would allow for energy savings on rooms that are not being used and help control mold by not letting them get to cold.

Building 21 (Chiller Plant)

Wednesday, August 4, 2010 – Chiller Plant (Building 21):

- This facility is currently operated by hand with a full-time operator during the day. There is no automatic control of systems. JCI is currently automating portions of the system like chilled water set points, but not the lead/lag scheduling of chillers or pumps. The design is for a primary/secondary loop system. It appeared that the water flows may be out of balance. The mixing piping system had cold water coming in one side and warm return water in the other end with the pumps drawing from the middle. The pumps nearest the chiller side received colder water than the pumps near the return leg. The operator has manually shut the return water leg to help alleviated this issue, but now the primary loop is over-pressurized and must be hand valved out to balance chillers. Valves appear to be not fully closed and backflow through pumps is common.
- Recommendation for this facility would be to re-pipe the mixing portion of the primary/secondary loop. Install variable frequency drives (VFD) on each secondary pump controlled by differential pressure at the far end of

their respective loops. Change the valves in the facilities to two-way valves. Automate a complete lead/lag and temperature reset system.

MWR Building & Barracks

Wednesday, August 4, 2010 – MWR Building & Barracks:

- Controls have been modified in this facility and the air handlers are now basically a standalone system with no feedback from actual zone controllers. This eliminates the ability to reset conditions based on actual zone conditions. A return air sensor is now used for control.
- The coil drain P-traps are open to the room. This is causing air to suck back into the air handler and maintain a layer of water in the unit. P-traps, which allow water to drain from a coil, are critical in this high humidity environment.
- P-traps on other air handlers were missing altogether (see Figure 2).

Figure 2. P-Trap line with no trap, which allows water to collect in air handler.

- The static pressure sensors in this and other facilities were mounted next to fan and ductwork where the air flow is very turbulent (see Figure 3). The manufacturer's recommendation is for this sensor to be about two-thirds of the way down the main trunk line for best control.
- This and several other facilities had exterior wall pipe and other penetrations that were not completely sealed. These penetrations allow humidity to infiltrate into the facility.

Figure 3. Sensors mounted in improper position.

- Figure 4 shows an air conditioner (A/C) that serves a small solar tank room. The room was cooled to below 70ºF but only has equipment in it. Because this room is quite cool, it appears to be used for staff breaks.

Figure 4. Split A/C unit in mechanical room

McCool School

McCool ES/MS Energy Training Findings, August 4, 2010:

- School was constructed in 2007 for almost $40 million. It has been occupied since 2008.
- Almost all zone thermostats (Alerton) were found to be showing set points of 72º to 73ºF even though the facility was unoccupied except for some maintenance workers.
- CO_2 sensors were observed to be reading excessively high in some fans. This indicates failed sensors and if the control scheme uses CO_2 to bring in additional outside air, this could be causing higher energy costs.
- Building was found to be excessively negative at almost all outside doors. This was observed by warm, moist air being drawn into the building when doors were opened. Significant energy could be saved by using differential pressure sensors on the building and controlling the pressure balance.

- All bathroom exhaust fans operate 24/7 to mitigate mold issues in bathrooms. These exhaust fans also draw in humid air from the outside. Recommend these exhaust fans be coordinated with supply fans, occupancy sensors, and humidity sensors.

- Lights were turned on in all bathrooms and in all hallways even though the facility was basically unoccupied. These lights, particularly bathrooms lights, could be controlled by occupancy sensors.

- Staff observed that some hallways were over lit because of daylight from windows. Daylighting auto-lighting systems would work well in some hall and administration areas.

- The school has a lighting control system that can be used to turn lights on and off. Occupancy sensor could be used to help control energy and lighting better on an as-needed basis.The chiller plant was observed to have both chillers operational at about 60% run load amps (RLA). During the visit, it appeared that one chiller could have easily handled the facility if the air handlers where better balanced for loads.

- The chilled water temperatures were observed to be 38º to 40ºF supply/leaving temperature. This should be reset upwards as required for dehumidification needs.

- The chiller system has a plate/frame heat exchanger to provide for condenser heat transfer to the domestic hot water system. This did appear to be functioning.

Recommendation for this facility is a complete recommisioning of the air balance and operational issue of the air handlers. Installation of humidity and some CO_2 sensors in the zones and advanced humidity/temperature control algorithms should be used. These algorithms can lower air flows and control building balance during unoccupied modes to reduce mold and still control temperatures, resulting in significant energy savings. It is estimated that this investment would have a payback period of 1 to 2 years.

Anderson AFB, Building 25017 (Baracks)
Thursday, August 5, 2010 – Anderson AFB, Building 25017:

- Every room in the barracks has a manual (120 Volt) plug-in de-humidifier.

- Every room has thermostat and variable air volume (VAV) box.

- Supply fan has two-way chilled water valve and VFD-driven fan. VFD was at 100% speed.

- Condensate traps appeared to be working, but trap height was marginal.

- Rooms have thermostats with slider adjustments, but are limited to 4º to 8ºF adjustments. This could be widened at night (or day) when not occupied to gain dead band savings.

- T-8 lights were observed in the air base barracks, but no occupancy sensors in any spaces (dorms or offices).

- Dorm temperatures and set points were observed to be 71º to 72ºF.

- Mechanical room with air handlers was very warm (82ºF) and extremely humid. It was determined that the mechanical room next to the HVAC mechanical room was receiving air ducted from heat exchangers that used outside air in an air-to-water heat compression cycle to make hot water. There are three compressor units. Two of the units were turned off at their disconnects. The fan on the third unit was running, but it had an apparent compressor failure. The fan should be interlocked with the compressor to prevent it from running and pushing warm, moist air into the HVAC mechanical room. This system (heat reclamation) should be connected to the DDC system so it can be monitored and alarmed because this is a critical energy savings system that was not operating correctly and potentially adding more cost by injecting warm, moist air into the adjacent mechanical room. The backup for the air-to-water heat pumps systems and solar hot water systems is generally electric resistance. All of these systems should be connected to alarms so that they are quickly repaired and the use of expensive electric backup is avoided.

- Figure 5 shows a barracks mechanical space with full open outside air grill.

Figure 5. Fully open outside air grill.

- Figure 6 shows the chilled water supply. The low chilled water temperature and very high pump pressures both waste energy.

Figure 6. Chilled water supply gauges

Anderson AFB, Chiller Plant

Thursday, August 5, 2010 – Anderson AFB, Chiller Plant:

- Very old centrifugal chillers were found to be running marginal.

- Three chillers are installed, but only two are operational; 42ºF supply water, 50º to 52ºF return water (8º to 10ºF split). During moderate weather conditions, the supply temperature could be set up to 46ºF to improve efficiency.

- Both chillers were about 65 to 68% loaded. At lower load conditions, using one, rather than two chillers would be more efficient.

- Large water leak at the backflow preventer was observed. The site staff were notified and planned on repairing it soon.

- This chilled water plant is in significant state of disrepair but is slated for a rebuild soon. It is anticipated that the new plant will be fully automated and use advance control algorithms.

Anderson Elementary/Middle School (Anderson Air Force Base)

- Building was found to be excessively positive at most locations. It is recommended that a complete rebalancing of the building be performed along with recommisioning. The addition of a building static pressure sensor integrated with the control systems could save significant energy by balancing the makeup air systems based on the building needs.
- In one mechanical room, balancing damper in the return air duct was found to be mostly closed (50% open). This resulted in more outside air being pulled into the building.
- Two-way chilled water valves were observed on all cooling coils, which usually means that the piping/pumping system is a VFD-design. The chiller plant was observed to be constant volume, not VFD-design. Unless a bypass pipe and/or bypass control valve exists, the chilled water piping system can be prone to over-pressurization issues, which can lead to over-cooling and excess energy consumption.
- The hallway spaces were observed to be 72º to 74ºF (not excessively over-cooled). For a mostly unoccupied facility, these could have been controlled at a higher set point.
- The fans that serve the classroom and hallway spaces were observed to be running at 100% fan speed. This results in excess fan energy at the fan and chiller plant. This is part of the excess building pressurization issues and if the building did not have relief dampers, the doors would be standing open. Rebalance and recommisioning required.
- Chiller plant was using a heat recovery system for the chillers to heat hot water. The system water pump that serves the heat recovery system had a broken coupling so the system was not working.
- Chiller plant had several pieces of equipment that were found to have their "Hand-Off-Auto" switches placed in "Hand". This included one of the cooling towers and several pumps (chilled water and condenser water). This would indicate that the chiller plant is not automated or the automated functions have been bypassed. If the system cannot be run in automatic mode, then the control systems need to be repaired to allow for energy savings.
- Tower was observed to have a drain opened, which leads to excess water consumption and loss of chemical treatment. It appeared that the system may have been in manual bypass mode with a hand-operated water valve. The automatic conductivity meter appears to be non-functional and in bypass mode.

Greenhouse Gas Emissions

The greenhouse gas emissions in building systems are determined by the energy sources used in the building and mix of fuels which produce the electricity used. There is a direct correlation between energy reduction in buildings and reduced greenhouse gas emissions.

The goal of this training is to give the building operators the knowledge needed to make positive changes in the operation of building systems. As class participants apply this knowledge, building systems will run more efficiently, occupant comfort should improve, while saving energy and reducing greenhouse gas emissions.

Recommendations

The workshop retuning activities showed that the site personnel that maintain these facilities should focus their retuning efforts on the following items:

- Controlling the mechanical systems' operational hours and zone temperature set points appeared to present the best opportunities for savings
- Zone temperature set points in some buildings are excessively low, especially at night, when the zone temperatures are so cold that they approached the dewpoint.
- Manuallyset outside air dampers are providing excessive outside air, especially for spaces that are unoccupied.

Two of the larger schools, one on the Naval Base and one on Anderson AFB, are in need of a significant recommissioning effort. These facilities are relatively new, with direct digital controls (DDC), but are significantly out of balance. The pressure in one school is extremely negative, which is pulling humid air through the facility each time a door is opened. The draft can be felt several feet down the halls. The pressure in the other school is extremely positive relative to the outside and you can stand 20 feet outside and still feel cool drafts of air exiting the building.

It is recommended that humidity sensor be installed in all new projects and retrofitted into exist facilities. In this humid climate, control of humidity is very important. There are significant periods of time when the mechanical systems in many buildings can be unloaded and dehumidification is not required. The use of CO_2 sensors should also be considered in representative areas. CO_2 sensors determine whether spaces are occupied so that fresh air is only brought into the space when needed. By reducing the amount of outside air brought into the space, the humidity load is also substantially reduced. CO_2 and humidity sensors, combined with outside air sensors, can be used to predict whether conditions are amenable to mold growth and to automatically adjust systems to help prevent mold without using extra energy.

It is apparent that the recommission process will identify several control systems that are either non-functional or have sensors that have failed and need repair. Several sensors on the control system showed erroneous numbers. Humidity sensors and control of humidity in the control systems would help eliminate building pressure issues and mold issues with a significant reduction of energy. It is estimated that these investments would have a payback period of 1 to 2 years with a significant reduction in energy use.

Contact Information

Contact information for assessment team members and site team from PNNL are:

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Appendix A
Attendees List

Appendix A: Attendees List

Name	Dept/Div Code	Grade/Rank	Job Title
Aguon, Lester	NFM/FEAD	GS-11	Engineering Technician
Baisa, Virgilio	UEM-PW67	GS-12	Project Manager
Borja, Edward	PRA14-HV	WG-10	Air-Conditioning Equipment Mechanic
Briggs, Derek	UEM	GS-11	Energy Manager
Duenas, Frankie	UEM	GS-09	Performance Assessment Representative
Dydasco, Felix	FEAD	GS-12	Engineering Technician
Lemaire, Bryan	DZSP-AC	Contractor	HRAC Mechanic
Mahmud, Zahid	FEAD/EOT	GS-12	FEAD/EOT PAR (Mech)
Manaloto, John	UEM-PW67	Contractor	Resource Efficiency Manager
Melecio, Florante	DZSP-21	Contractor	Resource Efficiency Manager
Padrinas, Vivencio	DZSP-AC	Contractor	HRAC Mechanic
Rivera, Joseph	DZSP-AC	Contractor	HRAC Mechanic
Rivera, Karl	PRA14-HV	WG-10	Air Conditioning Equipment Mechanic
Russell, Patrick	UEM-PW67	GS-11	Energy Manager
Salud, Dennis	PRA14-HV	WG-10	Air Conditioning Equipment Mechanic
San Nicholas, John	PRA14-HV	WG-10	HVAC Foreman
Sinnott, George		GS-11	Engineering Technician
Smith, Al	CI	YD-01	PDC Intern
Tablan, Lino	DZSP-AC	Contractor	HRAC Mechanic
Taitano, Marie	UEM	GS-09	Performance Assessment Representative
Tiong, Jaime	UEM	GS-09	Performance Assessment Representative
Torres, Ben	PRA14-HV	WS-13	Facilities Superintendent
Duklkiewiez, Kasper	DZSP		HVAC Shop
Bay, Edwardo	DZSP		HVAC Shop

Appendix B
Retuned Buildings

Appendix B. Retuned Buildings

The following buildings were retuned as part of this training session:

Naval Base

- Building 21 (Chiller Plant)
- MWR Building & Barracks
- McCool School

Anderson AFB

- Building 25017 (Baracks)
- Chiller Plant
- Anderson Elementary/Middle School

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