Energy and Water Efficient Operations and Maintenance Guidelines: Military Health System

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1. INTRODUCTION

1.1 PURPOSE

The purpose of this Tricare Management Activity (TMA) document is to provide Military Departments' facilities managers with standardized, user-friendly guidelines that drive the energy efficient operation and maintenance (O&M) of military medical treatment facilities (MTFs) throughout the Department of Defense (DoD) inventory.

1.2 AUTHORITY

DoDD 5136.12, May 31, 2001 established TMA as a DoD Field Activity operating under the authority, direction, and control of the Assistant Secretary of Defense for Health Affairs. TMA exercises authority, direction, and control over all DoD medical and dental facilities, program funding, and other resources within the Department of Defense. The TMA Portfolio Planning and Management Division (PPMD) serves as the focal point for all issues pertaining to the acquisition, sustainment, renewal, and modernization of the full range of facilities within the Department of Defense (DoD) TRICARE Military Health System (MHS).

1.3 INTENT

The guidelines offered in this document are intended to assist the Facility Manager in making uniform, standardized O&M decisions for facilities that are consistent with sister service facilities across the DoD MHS. The strategies and recommendations are intended to provide the Facility Manager with a consistent decision-making framework for operating and maintaining energy efficient, cost-effective facilities across the MHS in a manner that supports the medical mission and is consistent with legislative and DoD directives and mandates.

1.4 LEGISLATIVE AND EXECUTIVE ORDER REQUIREMENTS

All DoD Components must comply with the facilities performance and reporting mandates and requirements in the legislation, Executive Order, and DoD Policies listed below, as well as in any subsequent or updated mandates. Key sections of these requirements are summarized in Appendix D.

- Executive Order 13423: Strengthening Federal Environmental, Energy and Transportation Management - January 2007 (EO 13423)
- Executive Order 13514: Federal Leadership in Environmental, Energy and Economic Performance - October 2009 (EO 13514)
- Energy Independence and Security Act of 2007 (EISA)
- Energy Policy Act of 2005 (EPAct)
- National Defense Authorization Act of 2007 (NDAA 2007)
- DoD Strategic Sustainability Performance Plan - August 2010 (SSPP)

MHS is committed to meeting or exceeding all Federal and Departmental energy management mandates in a manner that promotes and supports the primary healthcare mission by operating and maintaining world-class healthcare facilities.

1.5 DoD REQUIREMENTS

All DoD Components are encouraged to implement the recommendations presented in this document, consistent with all other applicable DoD and Federal medical facility procedures and parameters, including but not limited to the following:

- The Joint Commission’s Environment of Care Standards
- Unified Facilities Criteria (UFC) 4-510-01, Design: Medical Military Facilities
- UFC 4-010-01, DoD Minimum Antiterrorism Standards
- DoD Directive 5136.12 TRICARE Management Activity (TMA)
- All other applicable UFC documents
- All Occupational Safety and Health Administration (OSHA) Regulations and Standards
- All National Fire Protection Association (NFPA) Regulations and Standards
- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) Codes and Standards

The information provided throughout this Guide references numerous codes and standards. This information is intended to provide a consolidated reference and give readers a summary of requirements in the referenced standards. MHS recognizes that these reference standards will be updated and the information cited herein will become outdated. It is facility managers’ responsibility to ensure compliance with the latest version of all codes and standards. A list of all referenced codes and standards is presented in Appendix F.

1.6 APPLICATION

MTF O&M personnel typically devote significant time and resources to troubleshooting and often postpone preventive maintenance and optimization of ongoing system operations. Large medical facilities offer additional challenges, such as maintaining:

- Facilities to meet the health care mission
- Round-the-clock operations
- Sterilization and infection control
- Sophisticated medical equipment
- Diverse space uses and occupants within one facility

UNIFIED FACILITY CRITERIA

The Unified Facility Criteria (UFC) 4-510-01, Design: Medical Military Facilities provides requirements for new construction and major renovations of MTFs. As explained in this UFC document, in section 1-2 titled "Applicability of UFC 4-510-01," the UFC sets forth DoD policy, procedures, and technical criteria for the design and construction of facilities in the Department of Defense Medical (DoDM) Military Construction (MILCON) program as well as other medical design and construction projects over the UMC (Unspecified Minor Construction) threshold. The UFC further notes that, "when considered feasible and economical by the services, the technical criteria in this document shall be the basis of design for Operations and Maintenance (O&M) or Repair and Maintenance (R&M) work…"

This Energy Efficient O&M Guide was developed to provide more specific guidance for operations and maintenance of military medical facilities where the UFC standards are not feasible. This document was developed to help MTF personnel incorporate energy efficiency into everyday building O&M in a manner that provides the best possible environment while minimizing energy use and associated cost. It was developed with input from the Health Facilities Steering Committee (HFSC) energy subcommittee and MTF facility energy managers. This guidance identifies opportunities to enhance system efficiency and operations, areas for additional investment, and best practices. Appendices include resources, abbreviations and acronyms, a glossary of terms, a legislative summary, maintenance checklists for key energy-consuming equipment, and a list of referenced codes and standards.

HEALTH & SAFETY CONSIDERATIONS

As noted above, the purpose of this guidance is to provide for optimal, energy-efficient O&M while supporting the primary medical mission. Recommended strategies should only be implemented after consideration of impacts on clinical requirements, such as ventilation rate and pressurization relationships. As with any change in O&M procedures, energy efficiency measures should be vetted to avoid negative safety impacts. If not already in place, the facility manager should establish a procedure for reviewing changes with appropriate stakeholders (e.g., administrators, clinical staff, etc.).

2. OPERATIONS & MAINTENANCE PROGRAM

SECTION SUMMARY

This chapter showcases how Facility Managers should develop a robust, all-encompassing O&M program that will improve energy efficiency and occupant comfort. Effective facility management must utilize metrics to assess, monitor, and maintain the facility's systems. Benchmarking, metering, scheduling, and auditing are critical to attaining this desired outcome.

This chapter offers proven approaches for realizing energy efficiency gains while utilizing technology that is typically already in place. This chapter also suggests awareness programs and training opportunities, including avenues for improvement beyond building system modifications. Facility Managers can accomplish many of these methods, programs, and recommendations at little or no cost to building owners.

Hospitals have well-defined departments. It is essential to include department managers in scheduling and comfort-related decisions. Actively involving department managers in decision-making aids the overall effort and can help Facility Managers avoid unforeseen problems.

TAKEAWAYS

After reading this chapter, Facility Managers will have learned to quantify energy efficiency progress in their buildings and establish an O&M program to continuously monitor and improve those facilities.

QUICK WINS

- Utilize past utility bills to benchmark a facility in ENERGY STAR's Portfolio Manager
- Determine if advanced metering is appropriate for the facility
- Review past audit and re-commissioning reports
- Review Building Information Modeling (BIM) data for preventive maintenance information and upcoming maintenance milestones
- Raise building occupant awareness of energy conservation efforts by utilizing Federal Energy Management Program (FEMP) resources

MEASURES OF SUCCESS

- Conduct a building occupant survey and analyze results to ensure optimal comfort
- Realize quantifiable monthly energy cost savings through reduced energy consumption
- Progress towards mandated energy reduction goals for existing Federal buildings (e.g., EISA Section 432)

2.1 BUILDING OPERATING PLANS

BUILDING OPERATING PLAN OVERVIEW

MHS recommends that all MTFs develop and implement building operating plans. Facility O&M staff should use building operating plans to clarify how to optimize building energy efficiency and occupant comfort. A building operating plan can also be used for quality assurance purposes to monitor and observe building performance and the O&M contractor's performance (if applicable).

In developing a building operating plan, Facility Managers often start by collecting information that informs the plan. Possible sources of information include:

- Building Information Modeling (BIM), when available
- Current energy profiles from utility bills and metering data (if available)
- As-built drawings documenting design intent
- Current operating parameters through review of control system sequences of operations
- Interviews with building occupants and operations and maintenance staff

Often, a computerized maintenance management system (CMMS) or building automation system (BAS) implements the operating plan and targets particular heating, ventilation, and air conditioning (HVAC) systems and equipment for potential energy savings.[1]

In general, the plan will identify equipment schedules (hourly, weekly, or seasonal), temperature and humidity setpoints, and equipment setpoints. Facility Managers should establish a procedure to check occupant requirements and re-evaluate equipment operating schedules. All Building Operating Plans should include specifications and operating parameters for the following:

- Electrical and mechanical systems and all applicable components
- Medical equipment
- Control systems
- Vertical and horizontal transportation
- Environmental systems and equipment
- Fire suppression
- Fire alarms
- Compressed air
- Other appropriate systems

[1] Better Bricks. *Building Operations: Tools and Technical Advice*, http://www.betterbricks.com/DetailPage.aspx?ID=492

BUILDING INFORMATION MODELING OVERVIEW

MTFs should utilize Building Information Models (BIM), if they exist for a facility, to inform building operating plans. MHS recommends that requirements for ongoing preventative maintenance as well as any updates made to the equipment or operating plan during O&M are recorded in the BIM model.

Although BIM models may not exist for older facilities, UFC 4-510-01 Chapter 20 requires all new construction and major renovation projects to use BIM during the design and construction phase as of February 2011.[2] BIM has been included in DoD MHS contracts since 2005, and all construction projects over $5M are utilizing BIM to varying degrees.[3]

DESCRIPTION OF BUILDING INFORMATION MODELING

The process of Building Information Modeling utilizes multi-faceted computer software to not only document the design but to also simulate the construction and operation of a new or retrofitted facility.[4] The result is an object-based representation of the physical and functional characteristics of a facility, called a Building Information Model (BIM). The BIM is defined as 3-D graphics that include facility data. The 3-D graphics represent the geometry of the facility. In addition, information used by other building analysis applications, such as cost estimation, energy simulation, daylighting, computational fluid dynamics (CFD), and building code compliance, is also included. As a result, the BIM can carry an extensive amount of data about the building's assemblies, finishes, and equipment.

The BIM serves as a shared knowledge resource for information about the facility, forming a reliable basis for O&M decisions throughout the facility lifecycle. If a BIM model exists for a facility, a complete inventory of the equipment including warranties and maintenance schedules as well as information on building operating plans including proposed operating schedules may be available in the model data. As this information becomes more readily available, facility managers will be able to use this tool to create a database for ongoing preventive maintenance, such as for HVAC and safety systems that require regular inspections and upkeep.

BUILDING OPERATING PLANS AND BUILDING INFORMATION MODELING RESOURCES

Better Bricks
    http://www.betterbricks.com/DetailPage.aspx?ID=492#DevelopingABuildingSystemOperationsMap

Whole Building Design Guide
    http://www.wbdg.org/om/om_manual.php

Tricare MHS BIM Objectives
    www.tricare.mil/ocfo/_docs/MHS%20BIM%20Objectives.pdf

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[2] *http://www.tricare.mil/ocfo/_docs/BIM-UFC-RequirementDetails.pdf*

[3] *http://www.tricare.mil/ocfo/_docs/BIM-MHS-Overview_Ecobuild2010_101130.pdf*

[4] *Adapted from: http://www.gsa.gov/graphics/pbs/GSA_BIM_Guide_v0_60_Series01_Overview_05_14_07.pdf*

Tricare MHS Facility Life Cycle Management (FLCM) Building Information Modeling (BIM) Minimum Requirements
http://www.tricare.mil/ocfo/_docs/BIM-UFC-RequirementDetails.pdf

GSA
http://www.gsa.gov/portal/content/102276

2.2 BENCHMARKING

BENCHMARKING OVERVIEW

Benchmarking is the process of comparing a facility's energy performance to a baseline and/or other, similar facilities to help assess performance and inform decision-making. It is a vital function of any effective O&M program and is mandated for covered facilities, per EISA Section 432.[5] This strategy encourages individual facilities to track progress over time and compare data with facilities of similar type and function within the service, MHS, and beyond. Additionally, benchmarking can assist in estimating the greenhouse gas (GHG) emissions of a facility, identifying investment priorities, and verifying and tracking progress of improvements over time.

MHS recommends that all MTFs are benchmarked using the ENERGY STAR Portfolio Manager[6] tool to the greatest extent possible. Benchmarking can also be conducted through the Labs21 benchmarking tool or another tool approved by the service medical command energy program manager. Benchmarking data should be shared with the service medical command (MEDCOM, BUMED, AFMSA) and MHS (OSD (HA)/PPMD) through Portfolio Manager's read-only sharing capability or other agreed-upon means.

EISA Section 432 requires benchmarking for each metered building that is (or is part of) a covered facility. Although complete benchmarking requires data for all energy sources (e.g., electricity, natural gas, steam), MHS recommends that MTFs enter available data in the benchmarking tool as it is available. This will show progress made towards benchmarking goals, and partial data may be useful for some analyses.

BENCHMARKING BEST PRACTICES

To the greatest extent possible, actual energy consumption data should be used because it is difficult to reliably benchmark a facility that estimates utility usage. Benchmarking requires input of current and historical utility bills; this activity alone increases awareness of energy use, which can potentially lead to energy savings if corrective actions are taken. Once utility data are captured and synthesized, it is good practice to share it with maintenance staff and building occupants. This will engage and educate the facility's energy consumers.

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[5] U.S. DOE, FEMP. *Building Energy Use Benchmarking Guidance*, http://www1.eere.energy.gov/femp/pdfs/eisa432_guidance.pdf

[6] ENERGY STAR Portfolio Manager, http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

ENERGY STAR Portfolio Manager is one of the most commonly used benchmarking tools for commercial buildings, including medical offices and hospitals, and is already widely used across MHS. Facilities are compared among peers and energy usage is normalized for weather variances. Benchmarking data can be used to set goals and monitor performance. Metrics used frequently include energy cost per square foot, energy consumption per square foot, or energy consumption per building occupant. Other metrics may include energy use per bed or patient. ENERGY STAR Portfolio Manager combines energy usage data with building, site, and occupant information to characterize a facility's energy performance on a scale from 1 to 100. Facilities with an ENERGY STAR Score of 75 or higher may seek recognition as an ENERGY STAR Building and can publicize this achievement by displaying an ENERGY STAR plaque on the building. MHS recognizes that Portfolio Manager has some limitations with regard to benchmarking MTFs. For example, military hospitals tend to be larger than the commercial facilities in the ENERGY STAR model. Likewise, military clinics are more energy intensive than the medical office buildings against which they are compared. However, as noted above, Portfolio Manager is a well-established standard and is useful when comparing peers within the MHS facility inventory (e.g., comparing the energy performance of multiple military health clinics).

In 2006, the American Society for Healthcare Engineering (ASHE) and Environmental Protection Agency (EPA) collaborated on the creation of ASHE's Energy Efficiency Commitment (E2C). Facility Managers have the option of participating. This program is built on the past successes of energy benchmarking through ENERGY STAR Portfolio Manager and the publication of ASHE's Healthcare Energy Guidebook. The guidebook profiles the U.S. healthcare market on size and energy-related characteristics and provides energy benchmarking data that can be used to compare healthcare facilities. The intent of the guidebook is to provide assessment of practices, methodologies, and technologies being applied for the purpose of improving energy efficiency in hospitals. The E2C program recognizes healthcare facilities that significantly improve their Energy Star score, regardless of whether they achieve a score of 75 or higher.

BENCHMARKING RESOURCES

ENERGY STAR Portfolio Manager

http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

ASHE Healthcare Energy Guidebook

http://www.ashe.org/e2c/resources.html

Laboratories for the 21st Century

http://www.labs21century.gov/

2.3 METERING

METERING OVERVIEW

Metering provides Facility Managers with information about a facility's energy consumption, which can be used to create a baseline and analyze trends. Metering by itself does not save energy, but it informs decisions and allows managers to track the impacts of O&M improvements and investments.

The Metering Financing Hierarchy*

"No Cost" Options:
Policy-directed approaches
- Include in construction and renovation projects
- Assess tenant fees
- Reinvest energy savings

Utility provided (for time-based rate customers)
Appropriations Options
- Line-item appropriations
- Locally managed appropriations

Alternative Financing
- Utility company financing
- Energy savings performance contracts (ESPC)

* FEMP O&M Best Practices Guide to Achieving Operational Efficiency: www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

MHS includes appropriate metering in MILCON new construction and major renovations. Installation of metering equipment at existing MTFs is at the discretion of the host installation and service.

EPAct Section 103 requires each agency to use electric advanced metering to the maximum practical extent by October 1, 2012. EISA Section 434(b) requires natural gas and steam advanced metering to the maximum extent practicable by October 1, 2016. At a minimum, advanced meters provide the capability to measure and record hourly interval data and communicate the data to a remote location daily so that they may be integrated into an advanced metering system.

METERING BEST PRACTICES

A basic working knowledge of how utility consumption data are measured and recorded is an excellent energy management best practice. Utility meters provide a cost-effective means for tracking facilities' utility consumption. Electric and natural gas have historically been metered for the entire military installation. Recently, though, advanced metering of individual buildings has progressed, and a MTF may have access to real-time utility consumption information.

The equation below, developed by the Department of Energy (DOE), can assist in deciding whether a meter should be installed on an unmetered (estimated) utility service.

$$\frac{\left[\left(\frac{\text{Installed Cost}}{\text{Desired Simple Payback}}\right) + \text{Annual Cost}\right]}{\text{\% Annual Savings}} = \text{Minimum Annual Electric Bill}$$

Example:

$$\frac{\left[\left(\frac{\$5{,}000}{10\,years}\right) + \$300\right]}{0.02} = \$40{,}000$$

In this example, it is economically feasible to meter any building that has an annual estimated bill over $40,000 to achieve a 10-year simple payback with an installed cost of $5,000 and annual cost of $300. The threshold for annual building electrical costs to justify cost-effective metering applications will vary by site, based on metering costs and anticipated energy savings.

The anticipated annual energy savings varies according to the attention paid to the metering data. Metering provides the information that, when analyzed, allows the building staff to make informed decisions on how best to operate building systems and equipment. Effective use of metering data will allow a facility to verify utility bills, optimize equipment performance, diagnose equipment and systems operations, and manage energy use.[7] Industry averages report an estimated 2-5% energy savings from application of data collection, cost allocation software, and the resulting corrective activities. Combining advanced meters with a building tune-up (re-commissioning), industry average savings range from 5-15%, and, by adding a continual operational analysis and ongoing building commissioning, a facility could realize savings of 15-45%.[8]

When utilities are not metered, reasonable consumption estimates must be developed. Although not always accurate, estimating by square footage is one of the most common methodologies. Many installations use an estimate based on square footage to bill the MTF for utility consumption. MTFs may choose to develop other metrics and measures to more accurately benchmark and track their energy use over time. Estimating energy consumption by looking at similar facilities, using temporary metering, or conducting an engineering analysis are acceptable alternative methods.

METERING RESOURCES

FEMP's Guidance for Electric Metering in Federal Buildings
    http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf

DoD Energy Manager's Handbook
    http://www.wbdg.org/ccb/DOD/DOD4/dodemhb.pdf

2.4 BUILDING SCHEDULING

MTFs have diverse schedules. Some MTFs operate 24 hours per day, while others are occupied only 8 hours per day, and many large, complex MTFs have multiple uses and schedules within one building. Developing strategies to minimize hours of equipment operation, while maintaining building comfort levels and adequate lighting, can reduce energy consumption. As described in Section 2.1 above, MHS recommends that building operating plans establish a procedure to check occupant requirements and re-evaluate equipment operating schedules. Typically, this should be performed biannually (at the beginning of the heating and cooling seasons), and staff should consider the following best practices:

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[7] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

[8] U.S. DOE, FEMP. *Guidance for Electric Metering in Federal Buildings*. February 2006.

- If the facility receives utility bills (as opposed to paying the installation based on a formula), analyze demand charges and identify opportunities to schedule equipment in a manner that minimizes peak demand. Strategies may include staggering equipment start up or shifting non-essential loads to off-peak hours. Note that this does not reduce total energy consumption but can reduce costs by avoiding demand charges.
- Identify facility equipment with the flexibility to reduce output or be turned off for part of the day
- Consider reducing the minimum number of air changes per hour (where allowable) and modifying temperature control setpoints (higher in the cooling season and lower in the heating season)
- Limit the number of HVAC zones that serve areas requiring 24 hours per day, 7 days per week (24/7) support. Manual override controls may be provided for the medical staff to quickly return to previous space conditions. Flow parameters, air pressure differentials, etc., must be considered for isolation areas to prevent contamination of adjacent clean areas. Where possible, provide dedicated HVAC systems for smaller spaces operating on a 24/7 schedule if that schedule is different from the building's general schedule. Any changes to the AHU scheduling must consider the overall building pressurization requirement in order to prevent infiltration and mold.
- Reduce light levels at night while maintaining minimum safety requirements

BUILDING SCHEDULE STRATEGIES

TURN OFF HEATING SYSTEMS DURING SUMMER

Most buildings do not require heating during the summer. When the heating system is on, the hot water or steam often leaks through control valves, causes thermal comfort problems, and consumes excessive cooling and heating energy. To improve building comfort and decrease heating and cooling energy consumption, the following actions may be appropriate:

- Turn off boilers or heat exchangers if the entire building does not need heating
- Manually valve off heating and preheating coils if the heating system has to be on for other systems. If implementing this measure, ensure proper protocol is in place to avoid system failure due to human error.
- Reset differential pressure of the hot water loop to a lower value to prevent excessive pressure on control valves during the summer
- Troubleshoot individual zones or systems that have excessive cold complaints
- Investigate heat recovery systems as a technology to supply needed heating to enable boiler shut-off in summer (boilers operating at low part-load in the summer are highly inefficient). A small, high-efficiency modular boiler may also be an attractive option to enable large boiler shut-off in summer.
- Implement an outside air reset to adjust the hot water temperature setpoint for the boiler
- Consider the following measure in constant air volume systems in dry climates: When the reheat system is shut off, maintain room comfort by increasing supply air temperature. This measure is not suitable for

other climates where the cooling coil leaving air temperature has to be controlled below 57°F to control room humidity level.

TURN OFF SYSTEMS DURING UNOCCUPIED HOURS

If a building is not occupied at night or on weekends, the HVAC system may be turned down or completely turned off during these periods. However, local circumstances, such as building pressurization requirements or the need for humidity control or freeze protection, may impact appropriate setpoints. With a properly designed warm-up/cool-down, comfort can be properly maintained with significant energy savings, specifically in outpatient and administrative areas. In more extreme climates, it is important to carefully evaluate optimal start and stop times to prevent compromising building operations. Temperature requirements for medical equipment operation, calibration, and pressurization to avoid moisture infiltration must also be evaluated. Typical night setback conditions of 55°F in heating mode and 85°F in cooling mode should be applied where practical. Otherwise, specific use requirements will dictate temperature range parameters.

In a commercial or institutional building, office equipment and lighting comprise a large portion (50% or more) of the electrical system requirements. Turning off these systems during unoccupied hours can save energy without degrading occupant comfort. The following actions can help O&M staff reduce energy consumption:

- Scheduling lights to turn off and setting back room thermostats after zones are vacated each day
- Scheduling Air Handling Units (AHUs) to turn off at night and on weekends. A schedule needs to be developed for each zone or AHU.

  > ***Note:*** *Turning off the system too early in the evening or turning the system on too late in the morning may cause comfort problems. Conversely, turning off a system too late in the evening and turning the system on too early in the morning may reduce savings. It is important to achieve a balance between maximizing energy savings and providing a comfortable environment during all occupied hours, while ensuring all spaces reach setpoints prior to occupancy.*

- Scheduling the boiler hot water pump to turn off at night during the summer when AHUs are turned off
- Scheduling chillers and chilled water pumps to turn off when free cooling is available or when AHUs are turned off
- Installing occupancy sensors and timer controls where occupancy patterns are not predicable

Building occupants can assist in reducing energy consumption by turning off office equipment and lighting. Facility Managers should ensure occupants are well informed and understand the implications of their actions. A well-designed awareness program, as discussed later in this document, should provide this information to educate building occupants.

SLOW DOWN SYSTEMS DURING UNOCCUPIED/LIGHTLY OCCUPIED HOURS

Most large buildings are never completely unoccupied. It is not uncommon to find a few people working regardless of the time of day. The zones that may be used during the weekends or at night are also unpredictable. System shut downs often result in complaints, but substantial savings can be achieved while maintaining comfortable conditions by an appropriate combination of the following actions:

- Reset outside air intake to a lower level (0.05 cfm/ft^2) during these hours in hot summer and cold winter weather. Outside air can be reduced when there are very few people in the building. Check outside and exhaust air balance to maintain positive building pressure.
- Install occupancy and CO_2 sensors to control lighting, exhaust fans, and HVAC equipment, where appropriate
- Reset the minimum airflow to a lower value for variable air volume (VAV) terminal boxes
- Program constant volume terminal boxes as VAV boxes, and reset the minimum flow from the maximum to a lower value (possibly zero) during unoccupied hours
- Reset AHU static pressure and water loop differential pressure to lower values
- Set supply air fan at lower speed

LIMIT FAN SPEED DURING WARM-UP AND COOL-DOWN PERIODS

When nighttime shut down or setback is implemented, seasonal warm-up or cool-down periods are necessary. During warm-up and cool-down periods, fan systems are often run at maximum speed because all terminal boxes require maximum heating or cooling. Establishing an appropriate fan speed limit can reduce fan power significantly. This principle may also be applied to other systems, such as pumps. The following actions can help achieve fan energy savings:

- Determine the optimal start-up time using 80% (adjustable) fan capacity if automatic optimal start up is used
- Set the fan speed limit at 80% (adjustable) manually and extend the warm-up or cool-down period by 25%
    - If the speed limit is set at another value, determine the new warm-up period by multiplying the existing warm-up period by the old fan speed limit, and then divide by the new fan speed limit

Example as stated:

$$T_{new} = \frac{T_{existing} \times X_{existing}}{X_{new}} = \frac{(100RPM) \times 1Hour}{0.8Hour} = 125RPM$$

- Keep outside air damper closed during warm-up and cool-down periods

  Note: *If the outside air damper cannot be closed tightly, extra thermal energy may be required to cool or warm outside air that leaks through the damper. This factor should be considered when this strategy is implemented.*

BUILDING SCHEDULING RESOURCES

Whole Building Design Guide

http://www.wbdg.org/resources/hvac.php?r=optimize_om

http://www.wbdg.org/resources/electriclighting.php?r=optimize_om

Better Bricks

http://www.betterbricks.com/DetailPage.aspx?ID=492

2.5 ENERGY AUDITS

ENERGY AUDIT OVERVIEW

An energy audit is a study that identifies opportunities within a facility that could be addressed to reduce energy consumption and operating cost. The audit results should be presented along with all information needed by the owner/operator to decide if an energy conservation measure (ECM) should be implemented.

EISA Section 432 requires comprehensive energy and water evaluations of covered facilities. Each year, 25% of covered facilities should be evaluated, ensuring each facility is audited at least once every four years. For DoD, covered facilities are defined as installations (as opposed to individual buildings on an installation), and audits are scheduled and conducted by the host installation and service. MHS recommends that each MTF over 5,000 ft^2 receives a level I audit once every four years. For buildings over 100,000 square feet, a more detailed level II audit is recommended. A copy of the audit report should be provided to the medical command and MHS, and results for MTFs should be entered in FEMP's EISA 432 Compliance Tracking System (CTS). MHS encourages MTF energy managers to work with installation leadership to schedule audits. Facility Managers may be able to conduct audits using other resources such as in-house personnel or performance contracts.

ENERGY AUDIT DEFINITIONS

Facility surveys and audits may be accomplished in conjunction with environmental assessments and other regularly scheduled plant or safety inspections, independently conducted by qualified DoD personnel or contractors, or through an energy savings performance contract (ESPC) or utility energy services contract (UESC), or through a utility program. DOE guidelines for EISA Section 432 base the audit report format on the ESPC Preliminary Assessment (PA) level audits. A PA-level audit contains the documented findings of a walkthrough survey and may include an evaluation of energy cost savings and energy unit savings potential, building conditions, energy consuming equipment, and hours of use or occupancy, which can be used to develop preliminary technical and price proposals.[9]

[9] U.S. DOE, *Facility Energy Management Guidelines and Criteria for Energy and Water Evaluations in Covered Facilities*. November 2008.

ASHRAE has established three standard levels of energy audits. The levels provide general categories used to define the type of information and results expected. The energy audit level determines the depth of information analyzed, the ECMs evaluated, the confidence in the calculations, and the cost of the study.

LEVEL I – WALK-THROUGH ASSESSMENT

This level of audit involves assessing a building's energy cost and efficiency by analyzing energy bills and briefly surveying the building while accompanied by the building operator. This study provides savings and cost analysis of low/no-cost measures and lists potential capital improvements that merit further consideration. Walk-through Assessments are ideal when there is doubt or uncertainty about the energy savings potential.

LEVEL II – ENERGY SURVEY AND ANALYSIS

This level of audit expands on a Walk-through Assessment by including a breakdown of energy use in the building as well as a more detailed building survey and energy analysis. The findings presented should include the savings and cost analysis of all ECMs that meet the owner's/operator's constraints or that are potentially capital intensive and require further study, along with a discussion of any effect on operation and maintenance procedures. Level II energy audits are adequate for most buildings and ECMs.

LEVEL III – DETAILED ANALYSIS OF CAPITAL-INTENSIVE MODIFICATIONS

This level of audit focuses on capital-intensive ECMs identified during a Level II audit and provides more detailed field data collection and engineering analysis. The findings provide detailed project cost and savings information with a level of confidence high enough for major capital investment decisions.

ENERGY AUDIT BEST PRACTICES

It is helpful to accurately determine actual energy consumption prior to initiating an energy audit. Estimated consumption based on facility size or other parameters may lead to costly inaccuracies. If reliable data are unavailable, the best interests of all parties will be served by installing basic metering. Collecting data for several months will establish an accurate energy consumption baseline. Consider sub-metering to isolate areas where the usage patterns vary significantly from the building main meter. The baseline established in this phase will be critical to the evaluation of ECMs and activities.

At a minimum, energy surveys and audits will be required to capture the following information:

- Name of electric, natural gas, and other energy utilities servicing the facility; account numbers; and meter numbers, if possible
- Background energy (all utility types) and water demand and consumption data for each building on site, including FY2003 (energy) or FY2007 (water) baseline year, if possible
- Facility locations, descriptions, year of construction, type, gross square footage, and major energy-consuming systems (types and brief descriptions)
- The number of regular building occupants and general occupant hours

- Identification of energy and water waste and potential ECMs, and estimates of energy and cost savings for each
- Identification of any previous facility energy and/or water audits
- Identification of major facility activities, including upcoming decommissioning, recent or planned facility upgrades, renovations, or major building equipment/system replacement

ENERGY AUDIT RESOURCES

DoD Energy Manager's Handbook
http://www.wbdg.org/ccb/DOD/DOD4/dodemhb.pdf

2007 ASHRAE Handbook: HVAC Applications

DOE FEMP: Facility Energy Management Guidelines and Criteria for Energy and Water Evaluations in Covered Facilities
http://www1.eere.energy.gov/femp/regulations/guidance.html#cf

2.6 ENERGY CONSERVATION MEASURES

Audit reports will identify numerous ECMs that will provide energy, water, and cost savings for the facility. Some ECMs will be no/low-cost suggestions, others will be O&M strategies, and others will require some level of capital investment. While capital investment is largely outside the scope of this document, this section does outline considerations for implementing upgrades and retrofits in existing buildings. Determining which ECMs are implemented depends largely on the owner's priorities, available resources, investment criteria, and budget. ECMs prioritization should consider capital cost, cost effectiveness, effects on indoor environment, and resource availability. Other important factors include payback, alignment with other sustainability and greenhouse gas (GHG) goals, life of the measure, maintenance costs, measurement and verification requirements, and changes in building operation.

Under EISA Section 432, energy managers may implement ECMs within two years of completing each evaluation. For each measure implemented, energy managers shall ensure that equipment is fully commissioned to be operating at design specifications, an O&M and repair plan is in place and followed, equipment and system performance are measured during the equipment's life, and energy and water savings are measured and verified.

Risk should always be considered and understood when evaluating ECMs. To reduce the risk of failure, energy managers can research and evaluate documented performance of ECMs in similar situations. Through HA/PPMD, MHS will provide best practices and technical information and facilitate the sharing of lessons learned across the MHS to support energy managers. A common issue is the overestimation of energy consumption for individual end uses, and estimated savings are not achieved. When doubt exists about energy consumption, temporary measurements should be taken and evaluated.[10]

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[10] ASHRAE. *2007 ASHRAE Handbook: HVAC Applications*. 2007.

ENERGY RETROFIT PROJECT DELIVERY TEAM

The Facility Manager or designee should head the project delivery team. The energy consultant, energy service company, utility, equipment vendors, installing contractors, commissioning agents, etc., should all be members of this team. Each member will play a key role in the system's successful implementation and commissioning. Each member should remain engaged with the project until its successful completion and delivery.

ENGINEERING DESIGN ANALYSIS

For capital investment in retrofit projects, the investment grade (Level III) audit should be used as the basis for the engineering design analysis. Energy engineering consultants should develop design criteria to provide the most energy efficient system operation while maintaining medical facility standards, reliability, and user comfort. The facility staff should participate in the design process to ensure that all projects facilitate and promote improved operations, maintenance, and life-cycle costs.

EQUIPMENT AND CONTRACTOR SELECTION

Where possible, make new equipment selections that are compatible with existing building systems for consistency in operations, maintenance, and inventory. Communicate with owners and visit sites that have utilized proposed equipment in a similar setting and application. Select lighting, HVAC, control contractors, etc., that have substantial energy retrofit experience and include them on the energy retrofit delivery team.

SYSTEM COMMISSIONING

The role of system commissioning in the energy retrofit process is to ensure that all system components are installed as designed and operating per specification. During this process the Facility Manager and staff should receive operational instruction, training, and support documentation that ensures a thorough level of understanding of all aspects of the system.

PROJECT PERFORMANCE MONITORING AND VERIFICATION

Accurate measurement and determination of energy savings is the single most important issue for the ultimate success of the energy retrofit project. The development of an accurate baseline followed by consistent measurement and verification will minimize or eliminate disputes over actual energy and dollar savings for the project. The measurement strategy should follow the International Performance Measurement and Verification Protocol (IPMVP).

ENERGY CONSERVATION MEASURE RESOURCES

DoD Energy Manager's Handbook

http://www.wbdg.org/ccb/DOD/DOD4/dodemhb.pdf

FEMP Facility Energy Checklist

http://www1.eere.energy.gov/femp/services/energy_aware_fec.html

International Performance Measurement and Verification Protocol (IPMVP)
http://www.evo-world.org/index.php?option=com_content&view=article&id=272&Itemid=397&lang=en

2.7 BUILDING COMMISSIONING

MHS includes commissioning requirements in all MILCON projects. MHS encourages the re-commissioning and retro-commissioning of existing buildings by service medical commands and energy managers. Through HA/PPMD, MHS will provide best practices, lessons learned, and other technical resources to support commissioning.

COMMISSIONING DEFINITIONS

COMMISSIONING

Commissioning is the systematic process of assuring by verification and documentation that all facility systems perform interactively in accordance with the design documentation, its intent, and the owner's operational needs, including preparation of O&M personnel. Because many building systems are integrated, one system's deficiency can result in suboptimal operation and performance of other building systems. Commissioning will address these deficiencies. The General Services Administration (GSA) estimates that, on average, the operating cost of a commissioned building range from 8-20% below that of a non-commissioned building.[11] Commissioning can result in a variety of benefits, including:

- Improved building occupant productivity
- Lower utility bills through energy savings
- Increased occupant and owner satisfaction
- Enhanced environmental/health conditions and occupant comfort
- Improved system and equipment function
- Improved building operation and maintenance
- Increased occupant safety
- Better building documentation
- Shortened occupancy transition period
- Significant extension of equipment/systems life cycle

[11] General Services Administration. The Building Commissioning Guide. 2005.

RE-COMMISSIONING

Re-commissioning refers to commissioning of a building that was already commissioned at some point in its life. Once a building has been commissioned as part of new construction, periodic re-commissioning ensures that the results continue, since most buildings, even if previously commissioned, will drift away from optimal performance over time. Therefore, re-commissioning is a periodic event that keeps the building operating according to its design or current operating needs.

Optimally, re-commissioning becomes part of a facility's continuing O&M program. Typically, re-commissioning occurs every 3 to 5 years. However, facilities should base the frequency of re-commissioning on the complexity of the systems involved and the dynamic needs of the occupants. If there are frequent build-outs or changes in building use, re-commissioning should be completed more often.[12]

RETRO-COMMISSIONING

Retro-commissioning is the first-time commissioning of an existing building. Many of the components of retro-commissioning are similar to those of commissioning. Retro-commissioning, however, occurs after construction, as an independent process, and its focus is usually on energy-using equipment such as mechanical equipment, lighting, and related controls. Retro-commissioning may emphasize bringing the building back to its original intended design, but the original design documentation may no longer be relevant or even in existence.

REAL-TIME COMMISSIONING

Real-time commissioning is an ongoing and proactive process utilized to resolve operating problems, improve comfort, optimize energy use, and identify retrofit opportunities. Real-time commissioning involves actively monitoring building systems to determine when further commissioning activities and corrections are needed. As a system drifts away from optimal operation over time, real-time commissioning activities focus on optimizing controls and building sequences to meet current facility demands and addressing operational changes with a focus on reducing energy consumption while optimizing occupant comfort.

COMMISSIONING AGENT

Commissioning activities are best handled by an independent party that can provide an objective evaluation because it is not familiar with past or present building activities and will therefore objectively question and examine all operating conditions.

For more complex commissioning projects, including most real-time commissioning projects, the commissioning agent should meet the following minimum qualifications:[13]

[12] U.S. DOE. *Building Commissioning: The Key to Quality Assurance*. 1999.

[13] Portland Energy Conservation (PECI). *Building Commissioning Guideline*s, for Pacific Gas & Electric. 2002.

- Experience in design, specification, or installation of commercial and medical building mechanical control systems and other systems being commissioned
- History of responsiveness and proper references
- Ability to meet liability requirements
- Experience working with project teams, managing projects, conducting scoping meetings, and communicating skillfully
- Experience commissioning at least two projects of similar size and of similar equipment to the current project. This experience should include writing functional performance test plans.

BUILDING COMMISSIONING RESOURCES

Whole Building Design Guide (WBDG)
http://www.wbdg.org

The WBDG provides a variety of commissioning resources and references, some of which are listed below:

- GSA's Commissioning Guide Book, available through WBDG
- *A Practical Guide for Commissioning Existing Buildings* by Tudi Haasl of Portland Energy Conservation Inc. and Terry Sharp of Oak Ridge National Laboratory. April 1999. Available through WBDG
- FEMP Operations & Maintenance Best Practices
  http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf
- The Building Commissioning Association
  www.bcxa.org

2.8 AWARENESS

AWARENESS OVERVIEW

Energy awareness programs publicize energy conservation goals, disseminate information on energy matters and energy conservation techniques, and emphasize energy conservation to all building occupant and command levels. Awareness programs empower building occupants to eliminate waste by changing attitudes and behaviors. An effective awareness program targets specific audiences, involves as many energy users as possible, is widely publicized, and clearly defines energy saving actions and goals.[14]

[14] U.S. DoD, Office of Deputy Under Secretary of Defense. Installations and Environment. *Department of Defense Energy Manager's Handbook*. August 2005.

Effective tools to increase awareness include websites, speaking opportunities, targeted emails, displays, reports, newsletters, awards and guidance. Awareness programs provide information on how to achieve specific goals or results and help maintain energy savings over time.

FEMP develops outreach materials to serve as "Resource Reminders" for Federal agencies. This information will assist in communicating the importance of using energy wisely. FEMP provides posters, bookmarks, calendars, and other material to be placed and distributed in high-traffic areas. To request materials or information, contact:

Outreach Program
US Department of Energy, Federal Energy Management Program
202-586-4536
or visit: http://www1.eere.energy.gov/femp/services/outreach.html

AWARENESS RESOURCES

FEMP Campaign Materials
http://www1.eere.energy.gov/femp/services/yhtp/campaign_materials.html

Department of Defense Energy Manager's Handbook
http://www.wbdg.org/ccb/DOD/DOD4/dodemhb.pdf

See also service specific materials, for example:

- Army Knowledge On-Line- www.us.army.mil
- Navy- https://energy.navy.mil

2.9 TRAINING

TRAINING OVERVIEW

High-quality training programs are key to changing the behavior of the wide range of people involved in a facility's operations and maintenance.[15] If the training is successful, participants will take the information and put it into action—incorporating energy efficient and sustainable concepts into everyday choices. Training resources are available from the government, private organizations specializing in training, industry, universities, and professional associations. The most effective training has the backing of top management and is delivered periodically to continually reinforce high-priority ideas.[8] Training can occur in numerous different forms, including either commercially available or in-house generated books, videos, on-line training, software, webinars, training manuals, certifications, and classroom training.

[15] U.S. DOE, FEMP. *Greening Federal Facilities*. May 2001.

Large buildings with modern systems are sufficiently complex to encourage individual staff members to become in-house experts in different areas. A staff with good basic skills and diverse, advanced technical skills is invaluable in maintaining and operating a complex building and will reduce reliance on outside contractors.[16]

Medical commands and Facility Managers are responsible for developing and executing training plans that ensure appropriate training, and for incorporating training completion and the application of results into performance assessments.

Take advantage of resources developed by the following professional organizations:

- Air Conditioning Contractors Association (ACCA)
- American Institute of Architects (AIA)
- American Society of Healthcare Engineers (ASHE)
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)
- American Trainco
- Association of Energy Engineers (AEE)
- Building Owners and Managers Association (BOMA)
- Building Owners and Managers Institute International (BOMI)
- Federal Energy Management Program (FEMP)
- International Facility Management Association (IFMA)
- Refrigeration Service Engineers Society (RSES)

Facilities staff may elect to attend GovEnergy, the annual energy workshop co-sponsored by DoD, DOE, GSA, and other Federal agencies. The workshop brings together Federal energy managers and representatives from the commercial sector for quality training and networking opportunities. Additional information is available from www.govenergy.gov.

TRAINING RESOURCES

Defense Logistics Agency (navigate to About DLA Energy / Training Opportunities)

http://www.desc.dla.mil/

FEMP Training

http://apps1.eere.energy.gov/femp/training/

[16] Better Bricks. *Best Practice O&M: Assess Staff Training*, http://www.betterbricks.com/DetailPage.aspx?ID=489

2.10 WATER CONSERVATION

WATER CONSERVATION OVERVIEW

MHS strives to meet or exceed all Federal and departmental mandates for water management, where life-cycle cost effective, while maintaining complete support to the primary healthcare mission.

Federal agencies are required by EO 13514 Section 2(d) to reduce their potable water consumption intensity by 2% annually through FY2020 (relative to a FY2007 baseline) and to reduce industrial, landscaping, and agricultural water consumption intensity by 2% annually through FY2020 (relative to a FY2010 baseline). Additionally, processing potable water (treating, heating and pumping) is energy intensive and contributes to air emissions associated with fossil fuel energy generation. Note that ENERGY STAR's Portfolio Manager provides a means to track water consumption and verify water savings. When water consumption data are available, the Facility Manager should include it with energy benchmark data in Portfolio Manager.

WATER CONSERVATION BEST PRACTICES

Below is a list of actions that will assist in reducing potable water usage, sewage discharge, and associated costs.

- Meter make-up water for cooling towers, boilers, and irrigation. Most utilities allow users to deduct cooling tower make-up. Sewer discharge is rarely metered separately. Instead, sewer bills are usually a pre-determined percentage of water consumption. Documenting the amount of cooling tower make-up water may not reduce water consumption, but it can potentially reduce the sewer bill.
- Sterilizers use substantial water and energy to provide steam. Recycle steam condensate and non-contact cooling water from sterilizers to make-up water in cooling towers or boilers.
- Retrofit water faucets with laminar flow restrictors to control water spray and minimize cleaning.
- Use low-flow toilets and waterless urinals in high-use areas. Retrofit kits are available for some older toilets and urinals. Experiment with a mock-up to ensure satisfactory operation and perform life-cycle cost analysis to weigh water savings versus maintenance costs. Also, be advised that before retrofitting low-flow toilets in an existing facility, the existing sanitary piping must be evaluated as the slope provided for higher-flow fixtures may be insufficient for low-flow fixtures and can hinder proper drainage.
- Properly size medical air compressors to improve efficiency and minimize maintenance. Retrofits are typically very cost effective and save water, energy, and maintenance costs. Use an oil-less, self-contained, air-cooled medical air compressor to eliminate water cooling.
- Optimize and revisit humidification settings. Ensure humidification is only used during the proper season and setpoints are appropriate for the facility's climate and space-use.
- Reclaim potable grey water from drains, cooling coil condensate, and/or captured rainwater for filtration, treatment, and use in non-potable process water needs such as landscaping, process cooling (sterilizers) or cooling tower make up.

- Utilize captured rainwater or grey water or on-site treated wastewater for irrigation and watering of green spaces. Using reclaimed water for selected applications can reduce costs and preserve potable water supplies.

WATER CONSERVATION RESOURCES

DoD Energy Manager's Handbook
http://www.wbdg.org/ccb/DOD/DOD4/dodemhb.pdf

U.S. EPA WaterSense Program
http://www.epa.gov/watersense

FEMP Water Efficiency Best Management Practices
http://www1.eere.energy.gov/femp/program/waterefficiency_bmp.html

3. HVAC OPTIMIZATION

SECTION SUMMARY

This chapter details several aspects of optimal HVAC operations in MTFs. It discusses conditions that affect energy consumption and efficiency and offers solutions for improvement. Best practices gathered from DOE, Better Bricks, and ASHRAE provide Facility Managers with comprehensive suggestions to significantly impact building conditions and occupant comfort.

TAKEAWAY

After reading this chapter, Facility Managers will be able to review and utilize a range of best practices to implement in their buildings that will result in more energy-efficient HVAC systems.

QUICK WINS

- Implement maintenance schedules detailed for major HVAC equipment
- Adjust building to operate at detailed temperature setpoints and ventilation requirements

MEASURES OF SUCCESS

- Reduced energy consumption realized in quantifiable monthly energy bill savings as compared to the same month in previous years
- Improved indoor air quality realized through a building occupant survey or environmental testing
- Improved preventive and predictive maintenance should yield greater energy efficiency and longer life for HVAC equipment

3.1 OPTIMIZATION OF HVAC SYSTEMS

HVAC OVERVIEW

MHS recognizes that HVAC systems provide indoor environments that provide occupant comfort and support infection control. MHS also recognizes that HVAC systems are major energy consumers in MTFs. Facilities should operate and maintain HVAC systems in a manner that meets all applicable standards and addresses optimization in the building operating plan. It is important to evaluate and implement best practices for energy efficient HVAC O&M documented here to the greatest extent possible without compromising safety.

The primary purpose of a HVAC system is to control the properties of the air inside a defined, enclosed space. The HVAC system controls:

- Temperature – The system adds or removes heat as required to maintain the desired air temperature

- Humidity – The system removes excess humidity from the space or adds humidity to a space to maintain the comfort level or meet the required humidity level
- Outside Air – The system brings in outside air to replace the air exhausted from the building and to slightly pressurize the building to reduce infiltration. The amount of outside air introduced is designed to provide the required air changes per hour. The outside air is filtered and conditioned (heated and cooled) before it goes into the space.
- Infection Control – The system serves the critical function of infection control in MTFs by providing adequate amounts of cleansed air. Cleansing of air is achieved through filtration, dilution, air changes, and temperature and humidity control.

HVAC systems are designed to meet internal and external loads on the system. Internal loads include people, lights, equipment, and powered displays such as computers, televisions, etc. Conditions outside the space include the outdoor weather (sunlight, temperature, humidity, wind, etc.), the heat transfer properties of the building enclosures (walls, windows, and roof, etc.), and the amount of outside air entering the space through cracks and doors.

TYPES OF HVAC SYSTEMS

HVAC systems can be categorized based on the type and location of their key components. The type of system found in a building typically depends on the size and age of the building. The following are the HVAC system types typically found in healthcare buildings:

Unitary systems are factory assembled, available as single-packaged or split-system units, and may take the form of a heat pump (providing both heating and cooling) or an air conditioner. Unitary systems include an evaporator, blower, compressor, and condenser. Some unitary air conditioners also include an electric resistance or gas heater section. The systems are typically cabinet or ski-mounted for easy installation. Compared to central chiller plants, unitary systems do not last as long (median lifetime of 15 years) and are less efficient.[17] Unitary systems are generally used in buildings up to three stories that have smaller cooling loads, and are not typically found in MTFs. When used at MTFs, it is important to mitigate the additional risks of condensation and mold that are associated with this technology.

Packaged systems, also called single-packaged units or rooftop units, have all the system components in one unit, which is located outside the building on the ground or the roof, and conditioned air is supplied to various areas of the building through ducts. The main components of the cooling system include the compressor, condenser, expansion unit, and evaporator or cooling coil. The main heating components, if present, include an electric coil or a gas-fired furnace (the furnace could also utilize oil or biomass).

Split systems have two main sections – the condenser unit and the air handling unit. The condenser unit is typically located outside and contains the compressor, condenser, and expansion valve or coil. The air handling units are located inside close to the delivery points and contain the evaporator or cooling coils and supply fans. If a heating

[17] http://www.energystar.gov/index.cfm?c=business.EPA_BUM_CH9_HVAC#S_9_4

system is present, it is located in the air handling unit and may be either gas-fired or electric. Conditioned air is supplied through short ducts from the air handling units. Split systems are more efficient than packaged systems.

Central heating and cooling systems have the main heating and cooling components housed in one central location and circulate water to air handling units located in the building zones. These are large capacity systems found in larger buildings where the split and packaged systems run into physical limitations of duct lengths and refrigeration pipe runs, or where building operators may desire central systems for centralized infection control and maintenance. These systems require at least one room to house the equipment. Circulating hot water, or steam heated by a boiler and cold water cooled by a chiller, typically provides heating/cooling in these larger systems. Other main components include the air handling units, circulating pumps, and cooling towers. Central heating and cooling systems are the most common type of system utilized in large MTFs, and their O&M energy-related issues are discussed in depth in the following sections.

HVAC EFFICIENCY

Duct leakage can be a significant waste of energy and, especially in older systems, prevent proper service to areas of a facility. Building operators often increase fan speed to compensate for duct leakage, but increased fan speeds fail to accomplish the anticipated increase in airflow when the ducts are leaking. Warmer- or cooler-than-expected spaces in non-conditioned areas around ducting are signs of potentially significant leakage. To address these problems, repair all obvious leaks, seal duct seams, access panels, and test ports.

General HVAC system properties that may affect energy consumption and efficiency include:

- Increasing fan speeds and not cleaning the coils leads to inadequate airflow and possible indoor air quality concerns. Consider pre-filters and UV filters at the coils.
- Installation of variable frequency drives (VFD) on fans when the service area dictates. Anticipate a one- to three-year payback for systems that operate on a 24/7 schedule.
- Fans should deliver the minimum pressure required to satisfy all zones. Typically, the one zone with the highest pressure requirements governs the pressure for the entire system. Poorly installed ductwork, excessive flex duct, and partially closed dampers are often the source of the problem. Always attempt to improve the air flow path before increasing the system pressure.
- Confirm proper operation of all dampers. Excess outside air requires additional energy to condition. Insufficient outside air can create indoor air quality concerns. Control economizer dampers when possible to maintain supply-air temperatures and save energy.
- Prevent simultaneous heating and cooling and wasted pump energy. Heating and cooling valves must close completely. Install VFDs on pumps and close coil bypasses.

OPERATIONAL EFFICIENCY MEASURES FOR AHU SYSTEMS

Air handling systems condition and distribute air inside buildings. Typical AHU systems consist of some combination of heating and cooling coils, supply and return air fans, filters, a mixing box section, humidifiers, dampers, ductwork, terminal boxes, and associated safety and control devices, and may include an economizer. As the building load changes, AHUs change one or more of the following parameters to maintain building comfort: outside air intake, total airflow, static pressure, supply air temperature, and humidity. Both operating schedules and initial system set up impact building energy consumption and comfort. As many of the following measures as appropriate should be used to optimize AHU operation and control schedules:

1. ADJUST TOTAL AIRFLOW AND FAN HEAD FOR CONSTANT AIR VOLUME SYSTEMS

Airflow rates are often significantly higher than required, primarily due to system over-sizing. The excessive airflow often causes excessive fan energy consumption, excessive heating and cooling energy consumption, humidity control problems, and excessive noise.

2. SET MINIMUM OUTSIDE AIR INTAKE CORRECTLY

Outside air intake rates are often higher than design values in existing buildings due to a lack of accurate measurements, incorrect design calculation and balancing, and operation and maintenance problems. Excessive outside air intake may be caused by one of the following:

- The mixed air chamber pressure is lower than the design value
- Significant outside air leakage through the maximum outside air damper on systems with an economizer
- The minimum outside air intake is set to use minimum total airflow for a VAV system
- Lower than expected/designed occupancy

3. IMPROVE STATIC PRESSURE SETPOINT AND SCHEDULE

Building operators sometimes use the supply air static pressure to control fan speed and ensure adequate airflow to each zone. If the static pressure setpoint is lower than required, some zones may experience comfort problems due to a lack of airflow. If the static pressure setpoint is too high, fan power will be excessive. Most existing terminal boxes use proportional controllers to maintain the airflow setpoint.

When the static pressure is too high, the actual airflow is higher than its setpoint. The additional airflow depends on the setting of the control band. Excessive airflow can also occur when terminal box controllers are malfunctioning. For pressure dependent terminal boxes, high static pressure causes excessive airflow. Consequently, high static pressure often causes unnecessary heating and cooling. A higher than necessary static pressure setpoint also causes noise problems.

4. OPTIMIZE SUPPLY AIR TEMPERATURES

Supply air temperatures (cooling coil discharge air temperature for single duct systems; cold deck and hot deck temperatures for dual duct systems) are the most important operation and control parameters for AHUs. If the cold air supply temperature is too low, the AHU may remove too much moisture during the summer using mechanical cooling. The terminal boxes must then warm the over-cooled air before sending it to each individual diffuser for a single-duct AHU. Dual-duct air handlers require more hot air. The reduced air temperature requires input of additional thermal energy for both systems.

If the cold air supply temperature is too high, the building may lose comfort control. The fan must supply more air to the building during the cooling season, so fan power will be higher than necessary. The goal of optimal supply air temperature schedules is to minimize combined fan power and thermal energy consumption. Although developing optimal reset schedules requires a comprehensive engineering analysis, Facility Managers can develop improved (near-optimal) schedules based on several simple rules. The next section, *Improve Economizer Operation and Control*, provides guidelines for developing improved supply air temperature reset schedules for four major types of AHU systems.

5. IMPROVE ECONOMIZER OPERATION AND CONTROL

An economizer is designed to eliminate mechanical cooling when the outside air temperature is lower than the supply air temperature setpoint and decrease mechanical cooling when the outside air temperature is between the cold deck temperature and a high temperature limit. Economizer control is often implemented to control mixed air temperature at the cold deck temperature (or simply 55°F). This control algorithm is not usually optimal and may increase energy consumption. Economizer operation can be improved using the following steps:

- Integrate economizer control with optimal cold deck temperature reset. Building operators often ignore cold deck reset when the economizer is operating because the cooling is free. However, cold deck reset normally saves significant heating costs.
- For a draw-through AHU, set the mixed air temperature 1°F lower than the cold deck temperature setpoint. For a blow-through unit, set the mixed air temperature at least 2°F lower than the supply air temperature setpoint. This will eliminate chilled water valve hunting and unnecessary mechanical cooling.
- For a dual-duct AHU, the economizer should be disabled if the hot air flow is higher than the cold air flow because the heating energy penalty is typically higher than cooling energy savings.
- Set the economizer operating range as wide as possible. For dry climates, the economizer may be activated when the outside air temperature is between 30°F and 75°F, between 30°F and 65°F for normal climates, or between 30°F and 60°F for humid climates. When proper return and outside air mixing can be achieved, the economizer can activate even when the outside air temperature is below 30°F.
- An enthalpy economizer should be used because it measures the total heat content of air.
- Measure the true mixed air temperature. Most mixing chambers do not achieve complete mixing of the return air and outside air before reaching the cooling coil. It is particularly important that mixed air temperature is measured accurately when an economizer is being used. Use an averaging temperature sensor for the mixed air temperature measurement.

6. IMPROVE COUPLED CONTROL AHU OPERATION

Coupled control is often used in single-zone single-duct, constant volume systems. Conceptually, this system provides cooling or heating as needed to maintain the setpoint temperature in the zone and uses simultaneous heating and cooling only when the humidistat indicates that additional cooling (followed by reheat) is needed to provide humidity control. To control relative humidity levels, the control signals or spring ranges are overlapped;

therefore, simultaneous heating and cooling occurs almost all the time. Eliminating excess airflows, minimizing valve leakages, and modulating airflows with a zone-sensible load can reduce thermal energy consumption.[18]

7. VALVE OFF HOT AIRFLOW FOR DUAL DUCT AHUS DURING SUMMER

During the summer, most commercial buildings do not need heating. Theoretically, there should be no hot air in dual-duct VAV systems. However, hot air leakage through terminal boxes is often significant due to excessive static pressure on the hot air damper. For constant air volume systems, hot airflow is often up to 30% of the total airflow. During summer months, hot air temperatures as high as 140°F are possible due to hot water leakage through valves. The high hot air temperature often results in occupant discomfort. Eliminating this hot airflow can improve building thermal comfort and reduce fan power, cooling consumption, and heating consumption.

In certain climates, it is similarly unnecessary to provide cooling in winter for the same reasons as for heating in summer. The better solution is to eliminate simultaneous heating and cooling when possible.

8. INSTALL VFD ON CONSTANT AIR VOLUME SYSTEMS

The building heating and cooling load varies significantly with both weather and internal occupancy conditions. Constant air volume systems consume a significant amount of energy to meet humidity control requirements. Most of this energy waste can be avoided by installing a VFD on the fan. Guidelines for VFD installation are separately presented for dual-duct, multi-zone, and single-duct systems.

- For a single-fan dual-duct constant air volume system, a VFD and two static pressure sensors should be installed.
    1. During normal operating hours, the fan speed should maintain the static pressure setpoint in both ducts. When the building thermal load is less than the design value, both ducts carry airflow. The pressure loss through the main duct is significantly less than the design value. Using a VFD can avoid this reduced duct loss showing up as additional pressure loss at the terminal boxes, which saves fan power. More importantly, it significantly decreases over-pressurization of the terminal box dampers and associated leakage and noise.
    2. During weekends or at night, the VFD can easily reduce flow. Compared with running the fan at full speed, a reduced flow saves fan power and heating and cooling energy.
- For multi-zone systems, the VFD can be controlled using zone dampers. During the cooling season, the VFD should maintain at least one zone cooling damper at 95% open (or another appropriate value). During the heating season, the VFD should maintain at least one zone heating damper 95% (or some other chosen value) open. The installation of the VFD combined with the proper control achieves true VAV operation for multi-zone systems. Ideally, the VFD supplies cooling only to at least one zone during summer and heating only to at least one zone during winter. The airflow to each zone changes proportionally with the zone load (assuming constant supply air temperature). Use a minimum fan speed

[18] University of Nebraska, Energy Systems Laboratory. Energy Performance Analysis of Coupled-Control Units with Both Thermostat and Humidistat. February 2005.

to prevent air circulation problems in the zones during the swing seasons. In general, the minimum fan speed should be no less than about 50% (may vary depending on the type of diffusers).

- For a single-duct constant air volume system, the VFD should be installed if nighttime shut down cannot be implemented. The VFD can be used to reduce flow at night and on weekends.
- For a single-zone constant air volume system, VFD installation may be feasible if the system operates for at least 5,000 hours per year.

9. AIRFLOW CONTROL FOR VAV SYSTEMS

An airflow control method should ensure sufficient airflow to each space or zone, control outside air intake properly, and maintain a positive building pressure. These goals can be achieved using the variable speed drive volume tracking (VSDVT) method.

The VSDVT method reduces the fan energy by using the improved static pressure reset and decoupling the outside and return air dampers. It implements the volumetric tracking using the VSD speeds and the fan heads and uses CO_2 demand control to minimize outside air intake. This method can result in significant building pressurization control improvement and significant energy savings. For more information about the VSDVT method, see FEMP's *Continuous Commissioning Guidebook*.[19]

10. IMPROVE TERMINAL BOX OPERATION

The terminal box is the AHU system's end device. It directly controls room temperature and airflow. Improving the set up and operation are critical for room comfort and energy efficiency. The following measures can improve terminal box operation:

- Set minimum air damper position properly for pressure dependent terminal boxes
- Use VAV control algorithm for constant air volume terminal boxes
- Use airflow reset
- Integrate lighting and terminal box control, so that air flows when the lights are on
- Integrate airflow and temperature reset

11. MINIMIZE SYSTEM RESISTANCE

Numerous factors contribute to the increase in air and water flow requirements at MTFs. Air change standards have increased, and additional heat loads (e.g., new medical equipment) have appeared, requiring more cooling. Building operators typically address these increased requirements by increasing fan power and pumping capacity. However, the initial approach should be optimizing existing equipment and related system operation:

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[19] *http://www1.eere.energy.gov/femp/program/om_guidebook.html*

- Eliminate all possible system resistance
- Properly size ductwork, piping, dampers, valves, etc., to minimize system resistance
- Repair all air and water leaks to optimize flow characteristics

Do not increase supply air and water pressures when settings have been adequate in the past and there has not been a change of use. Identify and remove any added air-side or water-side system resistance that may be limiting air or water flow. Consider inspecting the following areas:

- Clean or replace filters as required
- Reduce dust build up within ducts, inlets, outlets, and on cooling and heating coils. Proper dust control increases system efficiency and improves indoor air quality. Ensure all duct cleanings and coil cleanings are completed in compliance with Joint Commission standards.
- Reduce fan energy consumption and filter maintenance by achieving optimal filter performance
- Reduce the frequency of air filter changes and save energy by reducing the fan discharge pressure. Consider replacing 2 in. deep pleated filters with 4 in. deep filters.
- Increase system capacity by reducing the air filter pressure drop (remove excess filters)
- Do not install excess air filters. Do not use low-efficiency, pleated filters as pre-filters for high-efficiency bag filters. A higher efficiency pleated filter may be all that is required in non-patient care areas. This can reduce fan energy and filter costs and heat exchangers will stay cleaner, improving system efficiency and reducing maintenance. At all times, confirm that filtration meets requirements for infection control.
- Do not make filter decisions solely on first cost. Consider the life-cycle cost and performance. For example, a rigid final filter with better seals will limit bypassed particulates. This filter costs more than a conventional bag filter but lasts longer and has more consistent capture efficiency.
- Select a knowledgeable filter vendor to optimize air filter applications
- Repair any obvious air and water leaks
- Check air dampers and air and water valves for proper settings
- Inspect, clean, ensure proper operation of, or remove flow control devices if they do not serve a purpose (even though unnecessary, automatic flow control devices often remain after variable speed pump and fan retrofits)
- Clean water strainers as a first step to troubleshooting flow problems, as anything trapped by the strainers will add resistance. Clean water strainers again after flow problems have been corrected, as newly freed particulates may be trapped.

SYSTEM OPERATION

In buildings with more than one AHU, do not deactivate all the AHUs at once if they serve areas occupied at different times. Have each unit turn on about one hour before the space it serves is occupied.

If there is no means to have the equipment turned off automatically, time clocks should be installed. Properly set time clocks can reduce energy consumption by as much as 20%. Allowable temperature ranges in critical care areas such as operating rooms, patient rooms, intensive care units, etc., will prevent turning off air handling equipment.

Air filters should be changed regularly every 30 to 60 days. Dirty filters restrict air flow causing equipment to run longer to provide the needed cooling or heating.

At least every six months, review the HVAC equipment start/stop schedules to assist in reducing utility consumption and cost.

OPTIMIZATION OF HVAC SYSTEMS RESOURCES

Better Bricks
http://www.betterbricks.com/DetailPage.aspx?ID=544

ASHRAE Advanced Energy Design Guide for Small Healthcare
http://www.ashrae.org/publications/page/1604

FEMP Continuous Commissioning Guidebook
http://www1.eere.energy.gov/femp/program/om_guidebook.html

3.2 BOILERS

Boilers are typically fueled by oil, natural gas, or electricity, but may also be fueled by alternative sources such as biomass. Electricity is the least cost-effective fuel source and condensing natural gas boilers are generally the most efficient. It is impossible to change efficiency without changing the safety of the operation and the resultant life of the equipment, which in turn, affects maintenance costs.[20] However, proper O&M ensures that efficiency does not degrade over time. Best practices associated with boiler O&M include:

- **Reducing excess air**: The most important parameter affecting combustion efficiency is the air-fuel ratio. The boiler should have sufficient excess air to operate safely, but no more than is required by the manufacturer.
- **Installing waste heat recovery**: The stack loss of combustion is the heat that travels up the stack without doing any useful work. Use a modern combustion analyzer to measure and calculate the boiler's stack temperature along with combustion air ambient temperature, the percentage of excess air, and combustion efficiency. Stack losses vary between 12-18%, depending on fuel type.[21]

[20] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.
[21] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

- **Periodically measuring efficiency:** Combustion efficiency should be measured and recorded at least once a month during the heating season. Combustion efficiency can be measured through flue gas analysis. Typical combustion efficiencies for standard boilers range from 70-85%, depending on the firing rating of the boiler. Efficiency usually drops at lower firing rates. The efficiency for condensing boilers should be around 95%.
- **Stopping dynamic operation and operating boilers at peak efficiency**: Plants with two or more boilers can save energy by load management by operating each boiler to obtain combined peak efficiency. For boilers that operate on and off, it may be possible to reduce the firing rate by changing burner tips.
- **Considering whether more boilers are being used then necessary:** Redundancy enhances reliability so that duplication is unnecessary. For example, a modular system (e.g., modular boilers and VFD chillers) can provide reliability and enhance efficiency by utilizing a staged equipment approach that allows systems to operate most efficiently at or near design capacity.[22]
- **Considering implementation of an outside air reset:** For hot water heating systems, an outside air reset adjusts the required water temperature from the boiler to better match the heat loss from the facility based on the outside air temperature. Outside air resets can reduce boiler fuel consumption, reduce fluctuations in circulating water needs, and improve thermal comfort within a facility.
- **Consider combined heat and power (CHP) system alternatives:** Combined heat and power systems (cogeneration systems) generate both electricity and heat. They convert waste heat from electrical generation into energy that can be used for heating and cooling. CHP system's cost effectiveness should be evaluated based on: 1) utility incentives and rate structures; 2) "black start" capability (ability to come online without relying on the grid); and 3) prime mover type (equipment that best fits the hospital's thermal and electric loads and power quality requirements).[23]
- **Perform routine maintenance:** Predictive, preventive maintenance should be performed on schedule. This includes checks for leaks and damaged or missing insulation, and inspecting furnaces (checking for leaks/proper flame color), sensors, gas connection, flue blockage, scale and soot deposits, etc., per manufacturer's guidelines and the recommendations in Appendix E.

BOILER RESOURCES

FEMP Operations & Maintenance Best Practices
http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

ASHRAE Advanced Energy Design Guide for Small Healthcare
http://www.ashrae.org/publications/page/1604

[22] U.S. DOE Commercial Building Initiative, *CHP Fact Sheet*, May 2010.

[23] U.S. DOE, Commercial Building Initiative. *CHP Fact Sheet,* May 2010.

3.3 CHILLERS

Building chillers are the largest energy users in most commercial facilities, sometimes accounting for as much as 50% of electricity used.[24] As such, chillers present MTFs with some of the best opportunities for improving energy efficiency— and for realizing the major cost savings and environmental benefits that come with it.

Variable-speed chillers are much more efficient than constant speed equipment. Variable-speed drives can reduce cooling delivery system energy use by 30-50%, depending on the load profile.[25]

Table 1: Variable-Speed Drives Save Energy[26]

Chiller (kW/ton) Percentage Savings per Degree (°F) of Reset		
	Fixed-Speed Drives	Variable Speed Drives
Chilled Water Reset	0.5% - 0.75%	2.0% -3.0%
Condenser Water Reset	0.75% - 1.25%	1.5% - 2.0%

Chiller retrofits with variable-speed drives can be cost effective where system controls offer the opportunity to increase temperature splits and optimize the use of chilled water. Eliminating piping flow restrictions or system limitations further enhances the opportunity.

CHILLER BEST PRACTICES

To optimize chillers, utilize these strategies or other best practices identified by the Facility Manager as appropriate. Best practices associated with chillers include:

- **Considering variable-speed chillers in parallel**: Variable-speed chiller efficiency improves at lower loads. It is often more efficient to operate two chillers at lower loads than one chiller at a larger partial load. Optimal system efficiency is accomplished with variable-speed chilled water pumps piped in parallel. Magnetic-bearing centrifugal chillers are especially efficient at partial loading.
- **Optimizing the condenser-water temperatures:** Raising the chilled water temperature reset by 1°F can reduce the chiller's energy usage by about 2%.[27] Relative humidity levels should be regulated to meet requirements as chilled water temperatures rise. Lowering the temperature of the condenser water can also reduce the chiller's energy usage.[28] It should be noted that adjusting temperature resets could cause

[24] *Facilities Net Article. http://www.facilitiesnet.com/hvac/article/5-Threats-to-Chiller-Efficiency--1893*

[25] *Science Stage. http://sciencestage.com/d/3808842/power-quality-and-lineconsiderations-for-variable-speed-ac-drives.html*

[26] *Lawrence Berkeley National Laboratory. "Chiller Controls-related Energy Saving Opportunities," January 2003.*

[27] Better Bricks, http://www.betterbricks.com/DetailPage.aspx?Id=584

[28] Better Bricks, http://www.betterbricks.com/DetailPage.aspx?Id=539

additional energy use elsewhere and could reduce the equipment's ability to meet demand. Maintaining the manufacturer's setpoint is the safest course.

- **Low-delta T:** This condition occurs when the chilled water system does not produce a temperature change that matches the chiller's design during off-peak conditions. This may occur if the running chillers are not fully loaded and the next chiller is commanded to start (manually or by an automated system). At times, this condition causes the secondary flow to be larger than the primary, and warm water from the return mixes with the cold water from the chillers. This condition may be addressed by eliminating three-way and bypass valves when possible, and implementing VFDs, properly sized control valves, and other operational changes (proper setpoint, chilled water reset, economizer cycle and control calibration).
- **Varying the flow-through evaporator:** Consider varying the flow through the evaporator and removing decoupling equipment where possible. Control chilled water flow to maintain a temperature differential greater than 14°F. Repair leaking valves and eliminate water bypassing the cooling coils to facilitate this process.
- **Operational flexibility:** All chillers and pumps should be piped in a header configuration so any chiller and any pump can be operated in any combination to address all loads.
- **Performing routine maintenance:** Ensure efficient operation of equipment by ensuring all components of the chiller are operating as expected. Perform complete maintenance activities as recommended in Appendix E.

CHILLER RESOURCES

FEMP Operations & Maintenance Best Practices
http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

Better Bricks
http://www.betterbricks.com/DetailPage.aspx?ID=539

3.4 COOLING TOWERS

Internal loads in medical centers typically require chilled water year round, allowing cooling towers to periodically cool condenser water temperatures well below the design range. An improperly maintained cooling tower will produce warmer cooling water, resulting in higher condenser temperatures. The higher condenser temperatures reduce the efficiency of the chiller and waste energy. Chillers typically consume 3% more energy for each degree increase in the condenser temperature.[29]

Variable-speed chillers permit a much wider evaporator and condenser water temperature range as opposed to conventional chillers. With variable-speed chillers, cooling tower capacity improvements are magnified as colder

[29] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

condenser water temperatures result in enhanced variable-speed chiller performance. Colder condenser water helps justify water-side economizers because a large amount of water is evaporated as the cooling tower reduces condenser temperatures.

COOLING TOWER BEST PRACTICES

Cooling tower operational efficiency improvement opportunities are as follows:

- **Upgrade fan blades**: High efficiency plastic propeller fan blades reduce fan energy consumption by 20-30%. With no increase in fan energy, tower capacity can often be increased by as much as 15%.[30]
- **Optimize controls**: Provide VFDs for fan and pump motors. Consider operating two pumps or two fans at 50% of the total required flow. Energy consumption may be half of that consumed by operating one pump or fan at full flow.
- **Increase system flexibility**: Pipe all cooling towers in parallel in a header configuration so any tower may operate with any chiller.
- **Provide optimal water conditions**: Evaluate water conditions and different water treatment options. Scale deposits may act as a barrier to heat transfer. Algae and sediments that get into the cooling water can clog the spray nozzles, causing uneven air flow and reduced heat transfer surface area. Chemical-free water treatment may reduce water treatment costs and mineral build up.
- **Utilize free cooling**: Consider providing a heat exchanger between the condenser water and chilled water to provide a water-side economizer for free cooling. This application is often cost effective for cooling towers that operate 8,760 hours per year (i.e., year round).
- **Implement condenser water reset**: The temperature setpoint of the water leaving the cooling tower should be at least 5ºF higher than the ambient wet-bulb temperature. If the direct digital control (DDC) system has a wet-bulb temperature sensor, this can be set automatically; otherwise, the operator should consider manual, seasonal adjustments.
- **Perform routine maintenance**: Implement a preventative maintenance program as detailed in Appendix E.

COOLING TOWER RESOURCES

FEMP Operations & Maintenance Best Practices
    http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

Better Bricks
    http://www.betterbricks.com/DetailPage.aspx?ID=538

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[30] U.S. DoD. *Operation and Maintenance Guide to Energy Efficiency in Air Force Medical Facilities*. October 2003.

3.5 COMPRESSED AIR

Many medical facilities use compressed air for HVAC controls, laundry equipment, laboratory equipment, and maintenance shops. The use of compressed air is energy intensive and often overlooked as a potential source for energy savings. Even small leaks can waste significant energy – use ultrasonic detection to identify inaudible leaks. Consider VFDs and soft start controls to reduce peak demand caused from compressor start-up. Systems should be checked for leaks at least annually, and facilities should implement all applicable, cost-effective best practices.

COMPRESSED AIR BEST PRACTICES

Some of the most cost-effective energy savings strategies are presented below:

- **Optimize storage**: Produce and store air at the lowest required pressure to reduce compressor energy consumption and leakage. Many locations that require less than 50 psi generate and store 100 psi, which wastes energy. Every 10 psi increase above what is required in pressure requires about 5% more power to produce.[31]
- **Filter maintenance**: Change filters per manufacturer's recommendation or when they become clogged. The additional pressure drops due to improperly maintained filters throughout a system increase the initial pressure required for the system to operate effectively.
- **Reconfigure system**: Survey compressed air consumption and develop a compressed air energy conservation plan. Where possible, reduce the production pressure and dedicate small compressors to small high-pressure loads.
- **Heat recovery**: Heat generated by air compressors can be used for waste heat recovery. This waste heat can be utilized for space heating or process pre-heating. The energy savings and low cost often result in a short payback period.
- **Relocate air intake**: Much less energy is required to compress cool air versus warmer air. If the compressor and air intake are located in a mechanical room, temperatures may be much higher than other areas of

Air Compressor Retrofit Case Study*

The Health Science Center (HSC) is a building in a complex that makes up the largest hospital in Manitoba, Canada. An energy audit of the centrifugal compressor showed that while the compressed air demand of the hospital was variable, the power consumption of the compressor was flat. The baseline established indicated energy consumption was over 1,400 MWh – costing $68,500 per year. It was determined the best solution would be to purchase an air-cooled variable speed drive lubricant-free compressor and cycling-style refrigerated air dryers that were better able to track the varying loads of the facility. Originally, these modifications resulted in savings of $39,500 per year, until the system was retrofitted with heat recovery, which resulted in total savings of $51,500 per year in operating costs.

* http://compressedairchallenge.org

[31] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

the facility. Reducing the air intake temperature by moving the intake to a cooler room or to a shaded, covered area outside may lower the energy required for compression.

- **Optimize production**: Make incremental pressure reductions until operational concerns arise. Once boundaries are established the pressure may be gradually increased to fine tune control. A new actual operating pressure will be established at minimal cost with immediate savings.

  Note: Air compressors may be designed for a minimum pressure that exceeds facility requirements. Higher storage air pressure may be used to reduce the size and cost of the storage tank. A larger storage tank may be an option. Seek guidance from the air compressor manufacturer before making significant pressure reductions.

- **Perform routine maintenance**: Check regularly for leaks in the compressed air delivery system. Maintain and inspect air compressors according to recommendations made in Appendix E.

COMPRESSED AIR RESOURCES

FEMP Operations & Maintenance Best Practices
http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

Compressed Air Challenge
http://www.compressedairchallenge.org/

U.S. DOE's AIRMASTER+
http://www1.eere.energy.gov/industry/bestpractices/software_airmaster.html

3.6 MOTORS AND PUMPS

EPAct requires Federal agencies to purchase only ENERGY STAR® or FEMP-designated products in all product categories for which they are available, with limited exemptions. Included among these products are requirements for the purchase and use of high-efficiency electric motors. All new and replacement motors should be compliant unless a Facility Manager demonstrates that it is not cost effective.

Premium efficiency motors produce more power and are more efficient than lower-cost models because they reduce waste heat through the use of higher quality components, including using steel with better magnetic qualities, larger diameter wire, and better bearings. These features contribute to an increase in the operating life and performance of the motors. The higher quality construction also means they tend to operate more quietly and perform more reliably. Typically, premium efficiency motors will decrease expenses when run at full load because they are approximately 2- 4% more efficient than standard efficiency motors. The example in the chart below demonstrates the importance of right-sizing fans and installing energy efficient motors. The example below is based on the purchase of an 1,800 RPM, totally enclosed, fan-cooled motor operating 8,000 hours per year at 75% load, and it assumes an electricity rate of $0.05/kWh.[32]

Table 2: Premium Efficiency Motors Save Energy

Horsepower (hp)	Full-Load Motor Efficiency (%)		Annual Savings from Use of a NEMA Premium Motor	
	Energy-Efficient Motor	NEMA Premium Efficiency Motor	Annual Energy Savings, kWh	Dollar Savings ($/yr)
10	89.5%	91.7%	1,200	$60
25	92.4%	93.6%	1,553	$78
50	93.0%	94.5%	3,820	$191
100	94.5%	95.4%	4,470	$223
200	95.0%	96.2%	11,755	$588

Based on purchase of a 1,800 rpm totally enclosed fan-cooled motor with 8,000 hours per year of operation, 75% load, and an electric rate of $0.05/kWh

Proper maintenance is also vital to achieving top efficiency and expected life. Additionally, because motors and pumps are components of many HVAC and process applications, their efficiency directly affects the efficiency of other system components.

MOTOR AND PUMP BEST PRACTICES

The following will help reduce energy consumption and O&M costs:

- **Turn off unneeded motors**: Locate motors that operate needlessly, even for a portion of the time they are on, and turn them off. For example, there may be multiple HVAC circulation pumps operating when demand falls, cooling tower fans operating when target temperatures are met, ceiling fans running in unoccupied spaces, exhaust fans operating after ventilation needs are met, and escalators operating after closing.
- **Proper sizing**: Do not assume an existing motor is properly sized for its load. Typically, motors operate most efficiently at 75- 85% of full load rating; under- or over-sizing reduces efficiency. For larger motors

[32] U.S. DOE. *EnergySmart Hospitals Energy Management Training*

and pumps, Facility Managers may benefit from seeking professional help in determining the proper size and actual loading of existing components.[33]

- **Optimize impellers**: Trim or change pump impellers if head is larger than necessary.
- **Optimize Speed:** VFDs can be used to more accurately match motor output with demand by modifying the speed of the motor. VFDs can result in substantial energy savings, especially for varying loads. Specify rotor grounding in controlled electronic motors. Also, consider adjusting the speed of a motor for the most efficient match of horsepower to output, on more consistent loads. A 20% reduction in fan speed can reduce energy consumption by nearly 50%.[34]
- **Create an inventory**: Beginning with the largest motors and those with the longest runtimes. This information will help the Facility Manager make informed decisions about motor replacement and plan preventative maintenance.
- **Perform routine maintenance**: Perform preventative and predictive maintenance as detailed in Appendix E. Utilize ultrasonic and vibration analysis to identify changes in equipment condition and performance. These changes are often a precursor to component degradation and failure.

As a general rule, it is most cost effective to leave existing motors in service until they fail. The primary exception is motors that are significantly oversized (e.g., operating at about 25% load). When an old, inefficient motor fails, replace it with a premium efficiency motor. However, if an existing motor is NEMA premium efficiency it may be most sensible to rewind it. Consider using laser alignments to pumps to lower coupler resistance, thereby lowering power used. A typical rewind costs about 60% of a new motor, but motor efficiency typically drops after a rewind. For motors smaller than 10 HP, a new motor is generally less expensive than a rewind.[35]

MOTOR AND PUMP RESOURCES

The National Electrical Manufacturers Association (NEMA)

http://www.nema.org/gov/energy/efficieny/premium

DOE's Motor Master Software:

http://www1.eere.energy.gov/industry/bestpractices/software.html

FEMP Operations & Maintenance Best Practices

http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

[33] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

[34] *FEMP. FEMP Designated Product: Electric Motors. http://www1.eere.energy.gov/femp/pdfs/electric-motors-draft-2.pdf*

[35] Association of Energy Engineers. *Certified Energy Manager Training Program*

3.7 STEAM SYSTEMS

STEAM SYSTEM OVERVIEW

Steam systems serve a variety of purposes in MTFs, including space heating and sterilization. Depending on the age and purpose, steam system O&M will vary. Preventive maintenance for steam systems should be addressed in the Building Operating Plan. Steam traps are a common problem area and offer significant savings potential. A steam trap maintenance program can result in energy savings up to 10%.[36] Steam traps are valves that release condensate from a steam system while preventing the loss of live steam. Once steam has transferred heat through a process and becomes hot water, the trap removes it. Once removed, the hot water is either returned to the boiler via condensate return lines or discharged.

Steam Traps Case Study*

Three VA Hospitals located in Providence, RI; Brockton, MA; and West Roxbury, MA were assessed under FEMP's SAVEnergy Program. The facilities were served by 15, 40, and 80 psi steam lines. The Providence system included approximately 1,100 steam traps. Cost of the steam trap audit was $25,000 for all three facilities. Estimated savings totals $104,000 with a cost to repair and replace the traps at $10,000. The payback period was about four months.

** U.S. Dept. of Energy. Federal Energy Management Program. Operations & Maintenance Best Practices. July 2004.*

STEAM SYSTEM BEST PRACTICES

The following actions will help reduce energy consumption associated with steam hydronic systems:

- **Repair leaks**: Infrared cameras may be useful in identifying steam and condensate leaks and faulty traps that are hard to see or reach.
- **Keep steam traps clean**: Dirt is constantly accumulating in steam systems from pipe-scale and chemicals. As the dirt builds up, it can prevent valves from closing.
- **Optimize heat transfer**: Efficient burner operation keeps surfaces cleaner. Monitor stack gas chemistry and temperature to determine burner and heat exchange efficiency to reduce deposit buildup on heat exchange surfaces.
- **Optimize steam supply**: Use the minimum required steam pressure and temperature. Identify areas of the facility for study and possible retrofit that require considerably higher pressures. Properly insulate steam and condensate lines. Keep condensate return temperatures high to minimize thermal shock in the boiler.
- **Minimize make-up water**: Improve overall system efficiency and reduce oxygen introduction and subsequent chemical treatment and de-aeration requirements. Properly condition make-up water with chemicals, de-aerators, and filters. Water treatment requirements are determined by local conditions.

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[36] U.S. DOE, EnergySmart Hospitals. *Energy Management Training*

- **Perform routine maintenance**: Maintain and test steam traps with scheduled inspection and maintenance as recommended in Appendix E.

STEAM SYSTEM RESOURCES

FEMP Operations & Maintenance Best Practices
http://www1.eere.energy.gov/femp/pdfs/omguide_complete.pdf

Better Bricks
http://www.betterbricks.com/

3.8 SETPOINTS

SETPOINT OVERVIEW

The temperature at which a building is maintained impacts how much energy it uses. For cooling, the goal is to keep the temperature setpoint as high as possible while providing a reasonable comfort level for occupants. For heating, the goal is to keep the setpoint as low as possible. MHS recommends that building operators establish the most optimal set points in the Building Operating Plan to maximize efficiency while maintaining indoor environments that meet all applicable building code and health and safety requirements for the space type. When a building is unoccupied, the HVAC equipment should be turned off or set back unless there is an operational reason (i.e., health and safety risk) that prevents the setback.

SETPOINT BEST PRACTICES

When a building is unoccupied, the HVAC equipment should be turned off or set back by a time clock or Energy Management Control System (EMCS). FEMP's Operations and Maintenance Guide recommends unoccupied setbacks for heating should be 5°F to 10°F cooler than the occupied setpoint, and the unoccupied setback for cooling should be 5°F to 10°F warmer than the occupied setpoint. In a typical building, a 10% reduction in energy consumption can be achieved if the thermostat setting is lowered 10°F an average of 8 hours a day.[37]

In many MTFs, heat producing equipment (e.g., diagnostic or imaging) is installed in a room without adequate cooling capacity. One possible solution is to focus exhaust or return air to remove the heat instead of cooling with greatly increased supply air when the outside temperature is less than the desired room temperature. It may also be possible to add cooling coil capacity or radiant cooling panels, which can remove more heat without requiring more airflow.

Temperature setpoints can be set by space-use type in complex buildings with numerous thermal zones. The following is a sample of guidelines provided by ASHRAE Standard 170-2008, Ventilation of Health Care Facilities.

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[37] *FEMP. Tips to Conserve Natural Gas. October, 2005. http://www.nrel.gov/docs/fy06osti/39012.pdf)*

Refer to the Standard for a full list of specifications for all space types. Facility Managers are responsible for confirming any updates to these parameters published by ASHRAE. Note that Facility Managers can also reference UFC 4-510-01, Appendix A for space-by-space temperature setpoints as well as relative humidity standards.

Table 3: Temperature Setpoints by Space-Use Type

Facility / Space Type	Cooling		Heating	
	Temperature[a] (ºF DB)	Humidity[b] (% RH)	Temperature[a] (ºF DB)	Humidity[b] (% RH)
Patient Rooms	75	< 60	70	< 60
Corridor	75	-	70	-
Delivery Rooms	75	20 – 60	68	20 – 60
Class B and C Operating Rooms[c]	75	20 – 60	68	20 – 60
Class A Operating Rooms[c]	75	20 – 60	70	20 – 60
Recovery Room	75	30 – 60	70	30 – 60
Critical and Intensive Care	75	20 – 60	70	20 – 60
Triage	75	< 60	70	< 60
ER Waiting Rooms	75	< 65	70	< 65
X-Ray (diagnostic and treatment)	78	-	72	-
Pharmacy	75	30–60	70	30–60
Food Preparation Center	78	-	72	-
Bathrooms	78	-	72	-
Laboratory (general)	75	-	70	-

Notes:
a: Systems shall be capable of maintaining the rooms within the range during normal operation. Lower or higher temperatures shall be permitted when patients' comfort and/or medical conditions require those conditions.
b: The relative humidity ranges provided are the minimum and maximum limits where control is specifically needed.
c: Surgeons or surgical procedures may require room temperatures and humidity ranges that exceed the indicated range.

SETPOINT RESOURCES

ASHRAE Standard 90.1-2007, *Energy Standards for Buildings Except Low-rise Residential Buildings*

ASHRAE Standard 55-2004, *Thermal Environmental Conditions for Human Occupancy*

ASHRAE Standard 170-2008, *Ventilation of Health Care Facilities*

3.9 INDOOR AIR QUALITY OPTIMIZATION

Ventilation air is one of many factors that influence indoor air quality. In general, the more outside ventilation air used, the higher the energy use, especially in extreme climate zones. However, during the right time of year, outside air may be used to offset energy use with economizers. Facility Managers need to determine the optimal balance between ventilation and energy consumption that best aligns with the facility's uses. All MTFs should provide uncompromised indoor air quality that meets the requirements of all applicable codes and standards.

Sample indoor air quality specifications from ASHRAE Standard 170-2008, Ventilation of Health Care Facilities, are presented in Table 4. Refer to the Standard for a full list of specifications for all space types. Facility Managers are responsible for confirming any updates to these parameters published by ASHRAE. These requirements are for comfort, asepsis, and odor control in areas of acute care hospitals that directly affect patient care. Outpatient diagnostic and treatment facilities have different ventilation standards than surgical suites and hospitals. In general, outpatient facilities (excluding surgery) follow the local building code requirements, which typically reference a version of ASHRAE/ASHE Standard 62.1. Surgery facilities and hospitals will most often reference ASHRAE Standard 170 or FGI's Guidelines for Design and Construction of Health Care Facilities. Note that Facility Managers can also reference UFC 4-510-01, Appendix A.

VENTILATION BEST PRACTICES

The following strategies will help minimize the energy needed to condition the ventilation air: [38]

- **Scheduling**: Test unoccupied sequences to prevent unnecessary ventilation during off hours. In areas that do not require directional control, ventilation systems may be shut down when the space is unoccupied and ventilation is not otherwise needed. In areas that do require directional control, reduce the number of air changes by 25% when spaces are unoccupied. It is important to maintain pressure relationships with the surrounding rooms. Provisions must be in place to ensure the correct number of air changes is reestablished when the space is occupied.
- **Optimize ventilation rates**: Do not base ventilation rates on the occupant density used for egress design. Instead, reduce ventilation based on design occupant densities or observed occupant densities and patterns.
- **Maintain proper pressurization relationships**: As much as possible, provide air movement from clean to less clean areas. This strategy can reduce the amount of outside air needed, thereby reducing cooling and heating loads.
- **Economizer**: Utilize a dedicated outdoor air system or an enthalpy economizer cycle
- **Energy recovery**: Take advantage of exhaust air energy recovery, which can reduce sensible outdoor air cooling during summer and reduce outdoor air heating load in mixed and cold climates
- **Upgrade controls**: Utilize demand-controlled ventilation, which adjusts the amount of outside air based on the number of occupants in the space with CO_2 sensors. It is most effective in areas where occupancy varies throughout the day, such as conference rooms.

[38] ASHRAE. *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*. 2007

Table 4: Ventilation Requirements for Areas Affecting Patient Care

Function Space	Pressure Relationship to Adjacent Areas	Minimum Air Changes of Outside Air per Hour	Minimum Total Air Changes per Hour	All Air Exhausted Directly to Outside	Air Recirculated Within Room Units[a]
Patient Rooms	-	2	6	-	-
Corridor	-	-	2	-	-
Delivery Rooms	Positive	4	20	-	No
Class B and C Operating Rooms[b]	Positive	4	20	-	No
Class A Operating Rooms[b]	Positive	3	15	-	No
Recovery Room	-	2	6	-	No
Critical and Intensive Care[a]	-	2	6	-	No
Triage	Negative	2	12	Yes	-
ER Waiting Rooms[c]	Negative	2	12	Yes	-
X-Ray (diagnostic and treatment)	-	2	6	-	-
Pharmacy	Positive	2	4	-	-
Food Preparation Center[d]	-	2	10	-	No
Bathrooms	Negative	-	10	Yes	No
Laboratory (general)[e]	Negative	2	6	-	No

Notes:

a: Recirculating room HVAC units are acceptable to achieve the required air change rates. Because of the cleaning difficulty and the potential for buildup of contamination, recirculating units shall not be used in areas marked "No." Isolation and intensive care rooms may be ventilated by reheat induction units in which only the primary air supplied from a central system passes through the reheat unit.

b: Surgeons or surgical procedures may require different ventilation rates, air changes, and air distribution.

c: For waiting rooms programmed to hold patients awaiting chest x-rays for diagnosis of respiratory diseases, a recirculating ventilation system with HEPA filters shall be permitted instead of exhausting the air from these spaces to the outdoors, provided the return air passes through the HEPA filters before it is introduced into any other space.

d: Minimum total air changes per hour shall be required to provide proper makeup air to kitchen exhaust systems as specified in ASHRAE Standard 154.

e: When required, appropriate hoods and exhaust devices for the removal of noxious gases or chemical vapors shall be provided in accordance with NFPA 99.

INDOOR AIR QUALITY OPTIMIZATION RESOURCES

ASHRAE Advanced Energy Design Guide for Small Healthcare
http://www.ashrae.org/publications/page/1604

U.S. Environmental Protection Agency's IAQ Building Education and Assessment Model
http://www.epa.gov/iaq/largebldgs/i-beam/index.html

ASHRAE Standard 170-2008, Ventilation of Health Care Facilities

ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality

4. BUILDING OPTIMIZATION

SECTION SUMMARY

Facility Managers have the ability to reduce energy consumption beyond manipulating the individual elements of an HVAC system. Control systems, data communications (datacom) spaces, pharmacies, facility lighting, and plug loads can be evaluated and operated with energy savings in mind. This chapter shares several suggestions and best practices to improve energy efficiency. Many of the energy reduction methods discussed are simple and inexpensive to implement.

TAKEAWAY

After reading this chapter, Facility Managers will be able to execute energy savings best practices that can be realistically achieved in the near term with minimal investment.

QUICK WINS

- Implement maintenance of EMCS
- Implement recommended power management settings for computer systems
- Modify environmental setpoints for datacom spaces
- Identify over-lit areas and delamp to achieve desired lighting levels

MEASURES OF SUCCESS

- Reduced energy consumption realized in quantifiable monthly energy bill savings
- Reduction in building cooling loads generated from IT and lighting equipment
- Reduced building occupant complaints and improved building occupant survey results from a better maintained EMCS

4.1 ENERGY MANAGEMENT AND CONTROL SYSTEMS

EMCS are also known as Building Automation Systems (BAS). Their purpose is to provide an optimal level of control over building systems (e.g., HVAC, lighting) while maintaining occupant comfort and energy efficiency. Types of controls vary widely, from simple on/off switches to complex algorithms that integrate system components to control temperature, pressure, humidity, and flow rates.

Modern DDC systems are the most efficient and effective available and should be installed whenever possible. They provide the quickest and most accurate responses. However, many buildings still operate on legacy pneumatic control systems.

The installation of an EMCS does not by itself save energy. However, if properly implemented and commissioned, an EMCS gives Facility Managers many opportunities to optimize building systems operations. In healthcare facilities, the introduction of outside air is a critical aspect of managing indoor health and safety. Because the EMCS controls ventilation rates and outside air volumes, regular checks of system operation and setpoints are required.

Basic EMCS energy-saving strategies include:[39]

- **Scheduling**: Schedule the HVAC system for night setback, holiday/weekend schedules, optimal start/stop, and morning warm-up/cool-down functions.
- **Resets:** Controlling and resetting temperatures of supply air, mixed air, hot water, and chilled water optimizes the overall systems for efficiency.
- **Economizers:** Controlling economizer functions with an EMCS assures proper integration with other system components.
- **Advanced Strategies**: More sophisticated systems include capabilities to stage chillers and boilers, variable-speed drive control, zoned and occupancy-based lighting, and electrical demand limiting.
- **Perform Maintenance:** Properly maintain EMCS by following the recommendations in Appendix E.

The data provided to the system determine the EMCS's ability to manage and optimize energy use. A proactive maintenance program that ensures proper sensor calibration is therefore critical.

The goal is to schedule HVAC start/stop as closely as possible to actual occupant schedules while still providing a comfortable and safe indoor environment. The Facility Manager should monitor changes to occupant schedules throughout the year and update the HVAC schedule in the ECMS as appropriate. When available, utilize a DDC optimal start/stop program, which activates the HVAC system using an algorithm that assesses indoor and outdoor temperatures. In buildings with electromechanical and pneumatic controls, apply a start/stop schedule based on the amount of time it takes to condition the building.

Although specific temperature setpoints are based on the space-use type and ambient relative humidity (see Table 3), in general FEMP recommends[40] 68-72°F in the heating season and 72-78°F in the cooling season. A larger throttling range or dead band gap between the two setpoints is more efficient – the larger the gap, the less energy the building will use to condition the space. In humid climates the activator should be the relative humidity ratios. The unoccupied temperatures should be allowed to float as long as the humidity ratios are maintained.

FEMP reports that air side static pressure is often higher than necessary in VAV systems. Facilities can reduce energy waste by monitoring the pressure and adjusting EMCS setpoints appropriately. High static pressure readings are sometimes caused by staff attempting a quick fix when one of the fans is not operating properly. Common causes include failed sensors, failed inlet vane controls, and slipping belts. The Facility Manager should determine the design air-side static pressure for the AHU and ensure current operation is as close as possible to

[39] ASHRAE. *Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities*. 2007

[40] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

that value. Also, the Facility Manager should check the location of static pressure gauges, which should be about two-thirds of the way down the longest section of duct work.[41]

With DDC systems, Facility Managers have the option of implementing unoccupied pressure setpoints in conjunction with unoccupied temperature setpoints. In VAV systems, this increases energy savings by allowing a greater dead-band temperature range and circulating less air through the building. This strategy may not be appropriate for health care spaces but could be applied in offices and other ancillary/administrative areas.

Other common maintenance issues that the EMCS can help diagnose and address include valve failure and malfunction. Because valves cannot be visually inspected, their failure often goes unnoticed. Valves are one of the HVAC system components most likely to fail or malfunction; common problems include valves that are manually overridden in the open position, stuck in a fixed position, leaking, or wired incorrectly (backwards). One simple diagnostic approach is comparing the zone request for service with the heating/cooling coil temperature. For example, if the coil is hot but the space is not calling for heat, a malfunctioning valve could be the cause. The DDC can also be used to check dampers (including economizers); one operator should use the EMCS to manually open and close dampers while another visually inspects the dampers to ensure proper response and function.

The accuracy of most sensors will degrade over time. Accordingly, preventive maintenance programs should include a periodic assessment and re-calibration of sensors, consistent with manufacturers' recommendations.

The Facility Manager should regularly review overrides programmed into the EMCS and remove those that are no longer necessary. Overrides are sometimes needed to address unique circumstances such as extreme weather, abnormal occupancy, or special events. When programmed, the operator should include notes about why the override is needed and when it can be removed. Often, overrides remain in place long after they are necessary, resulting in inefficient system operation.

Simultaneous heating and cooling is a common problem. Although often required in health care environments to provide needed humidity levels and temperatures, it should be avoided as much as possible. In general, heating systems should be disabled when cooling is activated and vice versa. In electromagnetic and pneumatic systems, this may need to be accomplished through manual override.

When dehumidification is not required, DDC can be set to eliminate simultaneous heating and cooling by locking out hot water pumps during hot weather (e.g., outside temperature greater than 70°F) and chilled water pumps during cool weather (e.g., outside temperature less than 60°F). When it is unavoidable, simultaneous heating and cooling should be monitored to minimize energy waste. A proper dead band (i.e., heating and cooling setpoints sufficiently apart) will ensure that the HVAC is not continuously "hunting" or providing heating and cooling to maintain a temperature and humidity level.[42]

Historically, time clocks were often installed in older buildings to control the operating time of the HVAC equipment. They allowed the system to operate during occupied hours and turned building systems off after operating hours. The performance and accuracy of these systems may have deteriorated over time. When no

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[41] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

[42] U.S. DOE, FEMP. *Operations & Maintenance Best Practices*. July 2004.

other means are available to control the operating times of the HVAC equipment, existing time clocks should be repaired, recalibrated, or replaced.

- When a time clock is used to control an AHU, night setback/setup thermostats are required to keep the space temperature within controlled limits. The space temperature should be allowed to drift down to 55°F DB (dry bulb) before heating activates, or up to 85°F DB before cooling activates. When the space temperature moves outside these limits, the air handler and the heating or cooling equipment should come on until the space temperature is brought back within the limits and then shut off.
- Time clocks should be capable of having one time set for each day of the week and a means to continue running for up to 10 hours if a power failure occurs.

ENERGY MANAGEMENT AND CONTROL SYSTEM RESOURCES

Portland Energy Conservation, Inc.'s (PECI) Energy Management Systems: A Practical Guide
http://www.peci.org/documents/PECI_PracticalGuide1_0302.pdf

FEMP's Greening Federal Facilities
http://www1.eere.energy.gov/femp/pdfs/29267.pdf

Energy Management and Control System: Desired Capabilities and Functionality
http://www1.eere.energy.gov/femp/pdfs/29267.pdf

4.2 DATA COMMUNICATIONS SPACES

Datacom spaces include network and telephone rooms/closets and data centers. Environmental conditions can have a substantial impact on energy efficiency in a datacom space. In 2008, ASHRAE reviewed available data from a number of IT manufacturers and expanded the recommended environmental envelope from the existing 2004 standards. The environmental envelope shown in Table 5 is the currently agreed-upon envelope that is acceptable to all IT manufacturers. Operation within this envelope will not compromise overall reliability of IT equipment. Facility Managers are responsible for confirming any updates to these parameters published by ASHRAE.

Table 5: Comparison of 2004 and 2008 Recommended Environmental Envelope Data[43]

	2004	2008
Low-End Temperature	20°C (68°F)	18°ºC (64.4°F)
High-End Temperature	25°C (77°F)	27°C (80.6°F)
Low-End Moisture	40% RH	5.5°ºC DP (41.9°ºF)
High-End Moisture	55% RH	60% RH and 15°C (59°F DP)

The ranges included in Table 5 apply to inlets of all equipment in the data center (except where IT manufacturers specify other ranges). The recommended maximum temperature is decreased by 1°C/300 meters (1.8°F/984 feet) above 1800 meters (5906 feet). It is important that appropriate inlet conditions are achieved for the top portion of the IT equipment because temperatures tend to be warmer at the top of racks.

When possible, maximize return air temperature by supplying air directly to the loads. Cooling air can be supplied directly to the IT equipment air intake location; unlike with office spaces, the average room condition is not the critical parameter.

If possible, adopt a hot aisle and cold aisle containment strategy in server rooms. This strategy isolates chilled air and waste heat as much as possible. Arrange the IT equipment so that all heat is exhausted into the hot aisle, and all air intakes draw directly from the cool aisle, with return air being drawn directly from the hot aisle. This arrangement will reduce the total amount of cooling required.[44] To improve isolation of hot and cold aisles, use blanking panels to block open spaces in server racks and utilize air curtains above the racks.

Excess heat from IT equipment can be utilized in a heat recovery system by directing exhaust from a datacom space to a space that will typically require more heat than the datacom space. In this configuration, it is important a VFD is used to control exhaust air from the datacom space and dampers are controlled by heating demands of the space that the heat is being supplied to. In the summer, exhaust excess heat outside.

DATACOM BEST PRACTICES

The following best practices will help to maintain energy efficient operation:[45]

- Adopt ASHRAE temperature and humidity ranges to achieve greater equipment efficiency and increase economizer hours
- Use dew-point control in data centers to efficiently control both humidification and dehumidification

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[43] ASHRAE. "2008 ASHRAE Environmental Guidelines for Datacom Equipment – Expanding the Recommended Environmental Envelop"

[44] http://hightech.lbl.gov/DCtraining/strategies/mam.html

[45] ASHRAE. *Best Practices for Datacom Facility Energy Efficiency.* 2008.

- Size filters for low initial pressure drop, and ensure consistent maintenance to keep filtration energy losses low
- When possible, use economizer cycles to minimize energy use. Use integrated economizer controls to allow partial use of economizer cycle.
- Select as high a supply air temperature that will provide sufficient cooling
- Develop an efficient part-load operation sequence that uses effective variable-speed control and variable-capacity control
- Replace older IT equipment with more efficient ENERGY STAR equipment
- Consolidate and virtualize storage to reduce the number of required servers
- Properly select storage technologies that match the speed and frequency requirements for access may allow less energy intensive IT equipment to be utilized
- Reconsider redundancy in power supplies and uninterruptable power supplies (UPS); increased redundancy over what is needed can drastically increase energy consumption

IT RESOURCES

U.S. Department of Energy Office of Energy Efficiency and Renewable Energy
    http://www1.eere.energy.gov/industry/datacenters/

LBNL Data Center Energy Management Training
    http://hightech.lbl.gov/DCtraining/about.html

ASHRAE Datacom Series:
    Best Practices for Datacom Facility Energy Efficiency
    High Density Data Centers: Case Studies and Best Practices
    Thermal Guidelines for Data Processing Environments

4.3 LABORATORIES

Laboratories are highly energy intensive, largely due to ventilation requirements and plug loads. The U.S. EPA estimates that most existing laboratories can reduce their energy use by 30 to 50% by utilizing existing technologies.[46]

Addressing ventilation rates in labs should be a priority. Many systems are over-designed and provide more than necessary ventilation. While many believe "more is better," excessive ventilation can actually diminish safety

[46] *U.S. EPA, Laboratories for the 21st Century: Best Practice Guide, September 2008*

conditions.[47] A small change in ceiling height can make a big difference in exhaust air; rather than specify air change requirements, consider exhaust rates specified as cubic feet per minute per square foot (CFM/SF).

LABORATORY BEST PRACTICES

The following best practices will help maintain energy efficient operation in laboratories:

- Scrutinize air changes and consider specifying ventilation requirements in CFM/SF rather than in minimum air changes required
- If ventilation rates have been successfully reduced, consider implementing a panic switch to raise ventilation in case of an emergency (if applicable)
- Consider implementing controls to setback ventilation rates when the lab is unoccupied, or consider using demand-controlled ventilation
- Cascade air from clean to dirtier spaces to minimize make-up air requirements
- Scrutinize the number and size of fume hoods
- Consider using variable-air volume and/or restricting the sash opening on fume hoods to avoid exhausting excessive air
- Educate occupants on the importance of closing the sash or install automatic sash closers on fume hoods
- Consider implementing a setback ventilation rate on fume hoods when the lab is unoccupied
- Reduce plug loads by raising awareness of energy consumption and working with lab personnel to reduce unnecessary redundancy
- Utilize power strips so lab staff can quickly cut power to many pieces of equipment at the end of the day and reduce "vampire" energy

LABORATORY RESOURCES:

Laboratories for the 21st Century
http://www.labs21century.gov/index.htm

Energy Efficient Laboratory Equipment Wiki
http://labs21.lbl.gov/wiki/equipment/index.php/Energy_Efficient_Laboratory_Equipment_Wiki

[47] *U.S. EPA, Laboratories for the 21st Century: Best Practice Guide, September 2008*

4.4 PHARMACEUTICAL STORAGE

Pharmacies can use excessive energy when they are not maintained at appropriate space temperatures. Pharmacies are often kept excessively cool to accommodate storage. MHS recommends that pharmacy spaces should not be maintained outside of normal operating conditions to accommodate storage. Products with storage specifications should be stored in designated containers (e.g., refrigerators, cabinets).

Pharmaceutical storage requirements are typically stated on monographs or packaging and can vary greatly. These specifications can include specific temperature ranges, appropriate places for storage, and may limit other environmental conditions including exposure to light and humidity. These specifications should be followed to ensure proper storage and shelf life. Storage conditions are defined by the U.S. Pharmacopeia.[48]

Pharmaceutical Storage Requirements	
	Recommended Conditions
Freezer	A place in which the temperature is thermostatically maintained between -13°F and 14°F
Cold	Any temperature not exceeding 46°F
Refrigerator	A cold place in which the temperature is thermostatically maintained between 36°F and 46°F
Cool	Any temperature between 46°F and 59°F (an article for which storage in a cool place is directed may, alternatively, be stored and distributed in a refrigerator, unless otherwise specified)
Room Temperature	The temperature prevailing in a working area
Controlled Room Temperature	A temperature thermostatically maintained that encompasses the usual and customary working environment of 68°F to 77°F, and allows for excursions between 59°F and 86°F that may be experienced in pharmacies, hospitals, and warehouses (an article which storage at controlled room temperature, may alternatively be stored and distributed in a cool place, unless otherwise specified)
Warm	Any temperature between 86°F and 104°F
Excessive Heat	Any temperature above 104°F
Protection From Freezing	Where, in addition to the risk of breakage of the container, freezing subjects an article to loss of strength or potency, or to destructive alteration of its characteristics, the container label bears an appropriate instruction to protect the article from freezing

[48] *United States Pharmacopia. USP 34: General Notices 1, May 1, 2011 http://www.usp.org/pdf/EN/USPNF/USP34-NF29General%20Notices.pdf*

Pharmaceutical Storage Requirements	
	Recommended Conditions
Dry Place	Denotes a place that does not exceed 40% average relative humidity at controlled room temperature or the equivalent vapor pressure at other temperatures. Values of up to 45% relative humidity may be tolerated, as long as the average values if 40%. Storage in a container validated to protect the article from moisture vapor, including storage in bulk, in considered a dry place.
Storage under Nonspecific Conditions	Where no specific directions or limitations are provided, the conditions of storage shall include storage at controlled room temperature, protection from moisture, and where necessary, protection from light. Articles shall be protected from moisture, freezing, and excessive heat, and, where necessary, from light during shipping and distribution. Active pharmaceutical ingredients are exempt from this requirement.

Conditions outside those defined above may be required, and appropriate equipment should be supplied to ensure necessary environmental conditions are met. When selecting equipment, properly sizing the unit is vital to ensure efficient operation.

Facilities staff is encouraged to engage pharmaceutical personnel to increase cooperation and understanding of requirements. Facilities staff should work to ensure all environmental conditions and monitoring requirements are met, and pharmaceutical staff can assist in achieving energy efficiency goals.

PHARMACUETICAL STORAGE BEST PRACTICES

Actions that will help reduce energy consumption in pharmacies include:

- Consolidating redundant equipment
- When possible, avoiding using storage with small amounts of stored articles; a freezer/refrigerator that is full will use less energy than one that is mostly empty
- Utilizing the most energy efficient storage possible first, and power down units that are not needed
- Maintaining refrigerators and freezers per the manufacturer's recommendations and inspect the coils and door seals often to ensure they are clean and operating properly
- Placing pharmaceutical refrigerators/freezers away from heat sources and direct sunlight
- Improving organization within a refrigerator/freezer can reduce the time needed to locate the desired article
- Considering replacement of older, upright units (greater than 10 years old) with newer, more efficient chest-style storage

PHARMACUETICAL STORAGE RESOURCES

The United Stated Pharmacopeia
http://www.usp.org/

4.5 LIGHTING

LIGHTING OVERVIEW

In MTFs, proper O&M of lighting systems will provide appropriate lighting for each space type and improve the indoor environment while maximizing energy efficiency. Lighting efficiency is typically considered low-hanging fruit because many strategies are simple and inexpensive to implement. A well-designed and properly functioning lighting system will:

- Provide patient, guest, and staff comfort
- Promote staff productivity by assisting in the completion of tasks in an efficient and effective manner
- Provide indoor safety for patients, guests and staff with adequate lighting for quick egress from the facility in case of an emergency. The lighting helps guide occupants toward the exits.
- Provide outdoor safety for patients, guests, and staff with adequate lighting around the building and in parking areas

Lighting is a significant portion of a building's energy use; it accounts for 25–30% of energy use in a typical commercial building and more than 10% of overall hospital energy consumption, according to DOE. Also, a portion of each watt of electricity used for lighting is converted into heat; therefore, reducing lighting energy will reduce a building's cooling load.

Hospital lighting requirements vary greatly depending on activity and area. Some areas are similar to commercial spaces (e.g., offices, cafeteria, conference facilities), while others are unique to medical centers and hospitals. In general, the Facility Manager should follow published lighting standards specific to specialized hospital activities, such as ANSI's *Lighting for Hospitals and Health Care Facilities* publication. This will support energy conservation with a standardized, proven approach.

LIGHTING METRICS

Common metrics used when addressing the quality of light in a space are color rendering index (CRI) and Color Temperature (in Kelvin). CRI indicates the effect of a light source on the color appearance of an object. Natural light has a CRI of 100. A CRI greater than 75 is generally considered excellent. 65 to 75 is considered good, and below 65 is fair to poor. For example, high pressure sodium lights have a poor CRI and, as noted below, produce a very yellow light.

Color temperature is a measure of the warmth or coolness of the light. A color temperature less than 3,200K is considered warm and is on the red side of the color spectrum. A color temperature greater than 4,000K is on the blue side of the spectrum and considered a cool light source. For example, a standard incandescent has a color temperature of about 2,700k and a cool white florescent is about 4,200K.

Lighting levels are measured in foot candles (lumens per ft^2) or lux (lumens per m^2). Consensus standards for light levels are set by the Illuminating Engineering Society of North America (IESNA).

Finally, light source efficacy measures the efficiency of the light output per energy input, measured in lumens per Watt (lm/W). A 40 Watt incandescent has an efficacy of about 13 lm/W; a T-8 with electronic ballast is about 80-100 lm/W. High intensity discharge lighting has the highest efficacy. For example, high pressure sodium lamps are about 150 lm/W.[49]

COMMON LAMP TYPES

A lighting system consists of light sources or lamps, the ballasts or other devices that regulate power, luminaires, and the lighting controls. The lamp is the source of electric light, the device that converts electric power into visible light. The three lamp types most commonly found in MTFs are incandescent, fluorescent, and high intensity discharge (HID). A luminaire is the entire lighting assembly that includes a light source, a ballast to control the power, and a housing with components necessary for light distribution and shielding.

Incandescent lamps operate by heating a small element (filament) to a very high temperature, which produces light and heat. Benefits and drawbacks of incandescent lighting include:

- They are inefficient lamps. Only about 15% of the wattage produces light while the remaining 85% produces heat.
- They do not require a ballast
- They reach their full light output almost instantaneously
- Halogen lamps are a newer, more efficient variety of incandescent lamp
- Incandescent lamps work well in very cold climates, such as walk-in freezers
- CRI of incandescent lamps is 100, and their color temperature is 2,700 K

Fluorescent lamps operate by exciting gases from their normal atomic state to a higher energy state, which then returns to their normal state. In the process, the gas releases energy as light. Benefits and drawbacks of fluorescent lighting include:

- They are typically more efficient than incandescent lamps, but less efficient than HID lamps
- They require a ballast to convert electricity to higher voltage and frequency required for the lamp to operate

[49] Association of Energy Engineers. *Certified Energy Manager Training Program*

- Compact fluorescent lamps are a compact version of the standard fluorescent lamp. They are made in a variety of styles so they can be used to replace a variety of incandescent lamps.
- Light output decreases as the surrounding temperature decreases. Special, "cold weather" fluorescent lamps and/or jacketed lamps can help ensure reliable performance.
- CRI of fluorescent lamps range from 52 to 95 depending on the lamp, and their color temperature ranges from about 2,700K to 5,000K and higher

HID lamps operate by establishing and maintaining a high voltage arc within a glass tube containing a metallic vapor. This tube is inside a glass enclosure to protect it from ambient temperature and draft effects. There are two main types in current use – metal halide (MH) and high-pressure sodium (HPS).

- They are more efficient than either incandescent or fluorescent lamps. A smaller HID lamp can be used to achieve the same lighting levels found with other lamps.
- They require the use of a ballast
- They often require an extended warm-up time to reach their full light output. This is especially true after a momentary power interruption.
- HID lighting is typically used in outdoor lighting or high ceiling applications
- MH provides a white light with a CRI of 65 to 95, while HPS emits a yellow-tinted light with a CRI of 22 to 85. The color temperature of HID lights can vary between 2,000K and 14,000K.

LIGHTING BEST PRACTICES

In planning O&M for MTF lighting systems, it is important to consider visual comfort, ability to perform tasks, lighting for the human biological clock (circadian rhythms), and lighting for special needs of patients. The following strategies are intended to help facility staff better manage lighting systems while providing improved lighting to occupants. Although maintenance personnel may handle routine maintenance such as changing lamps or cleaning luminaires, all troubleshooting and repair must be handled by a licensed electrician.

- **Identify consistency issues** or manufacturing problems that result in O&M staff replacing certain lighting components more often than expected. Track maintenance on different types of lamps and ballasts. For example, if a certain type of lamps or ballast needs replacement frequently, facility staff can save time and money by identifying a more reliable alternative.
- **Eliminate unnecessary lamp types** (different lamps with same purpose). Some hospitals store inventories of more than 200 types of lamps. Consolidate lamp inventories to minimize the cost and storage space requirements of on-site lamp inventories. In renovations, limit new lamp types as much as possible.
- **Adopt “downtime” lighting**, which reduces overall lighting levels to allow patients to rest and lowers energy usage. Some hospitals turn a portion of lights down or off for 1 to 2 hours in the afternoon to save energy and provide a more restful environment.
- **Provide “cheat sheets”** to help O&M staff. Include pictures and installation instructions for different ballast and lamp types.

- **Establish scheduled cleaning routes** for lamps and luminaires. Without cleaning, dirt and dust can reduce light output by as much as 15% per year. IESNA provides resources to help determine the best cleaning schedule. In a clean environment, some enclosed and ventilated luminaires can be cleaned every 24 to 30 months. An open luminaire without ventilation typically requires cleaning every 12 months.
- **Replace discolored plastic diffusers** in fluorescent fixtures. Diffusers tend to darken with age and should be replaced when they start to reduce light output.
- **Use light colored** paints, carpets, tile, and upholstery. The reflective characteristics of the interior finishes can have a large impact on the efficiency of the lighting system and the quality and comfort of the light provided. Light levels can be better maintained by regular cleaning of the work surfaces. Light output, comfort, and lighting quality can be improved by repainting the walls a lighter color.
- **Implement group relamping**. In areas with similar hours, replace all lamps simultaneously to reduce labor costs. Replace lamps on a single switch at 70% - 80% of the average lamp life. Beyond 80%, lamps will burn out in a relatively short time, which can cause a maintenance problem, use more energy, and provide insufficient light. Benefits of group relamping include:
    - Lower labor cost
    - More light
    - Fewer burned out lights awaiting replacement
    - Less lamp stocking
    - Fewer work interruptions
- **Measure light levels** in all areas and compare to IESNA standards (or other appropriate standard). Consider delamping, technology upgrades, or other options to address areas that are over- or under-lit. **Delamping** refers to the practice of removing one or multiple lamps from a light fixture (e.g., removing the middle lamp in a three-lamp fluorescent fixture). It is a simple strategy for reducing light levels in over-lit areas and is frequently used in common areas such as hallways and waiting areas. Important considerations for this strategy include:
    - Ensure that the lighting level after delamping is adequate.
    - Consider how delamping will impact the aesthetics of the area. It is usually best in fixtures with covers (e.g., plastic diffusers) as opposed to open light fixtures where occupants can clearly see the lamps.
    - The change will be less noticeable if it is implemented over a weekend or holiday (i.e., a three-day weekend).
    - Check the warranty. If something were to happen to the fixture during delamping it could potentially void the warranty.
    - To delamp T-12 fixtures, which usually contain four lamps, remove the lamps in pairs. In a T-8 fixture any of the lamps can be removed.
- At least once a year, **inspect and repair** lighting equipment and recalibrate lighting controls.

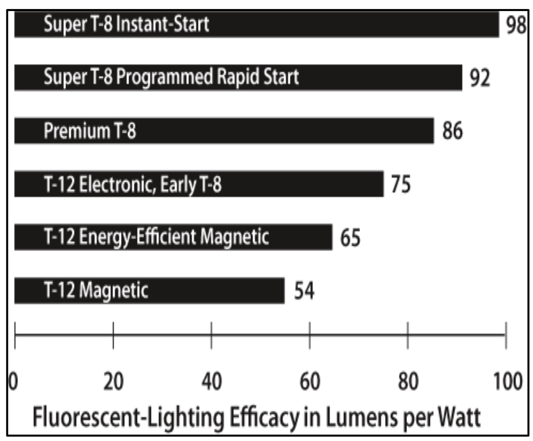
LIGHTING TECHNOLOGY UPGRADES

Lighting technology upgrades are often accomplished with O&M funding by O&M staff or contractors. These projects tend to be relatively low cost and have short payback periods. Improvements in lighting efficiencies are so rapid that it can be cost effective to implement upgrades, retrofits, or redesigns to lighting systems that are only 5 to 10 years old.[50]

Begin by upgrading lighting technology in areas with the best opportunity and fastest return on investment (ROI). Examples of these projects include: [51]

Potential LED Applications
Parking Lots
Food Preparation Areas
Under Cabinet Lighting
Adjustable Task Lighting
Elevator Lighting
Step and Path Lighting
Exit Sign Lighting

- **Upgrade all exit signs** with light-emitting diodes (LEDs), which can last up to 25 years. LED exit signs use significantly less energy than both incandescent and compact fluorescent exit signs. The combination of energy and maintenance savings typically results in short payback periods (e.g., two years or less).
- **Consider additional LED applications**. As with exit signs, the payback analysis should include both the energy savings and the maintenance and labor savings. For example, LEDs may be cost effective in parking lots because of the avoided costs associated with changing these lights.
- Replace older T-8/T-12[52] fluorescent lamps with "super" or **premium T-8 lamps** and high-efficiency electronic ballasts, reducing energy usage by 20-30%. As shown in the figure below, Super T-8s have the highest lumens per Watt output. Premium T-8s have a higher initial cost, but the increased energy efficiency and life make them the recommended light source for most fluorescent installations.
- **Eliminate incandescent lamps** where feasible and replace with compact fluorescents (CFLs), which use a quarter of the electricity and last up to 10 times longer. Note that in areas such as conference rooms, where dimming is needed, a CFL with a dimmable ballast is required.
- **Consider scotopically enhanced lighting** as part of any lighting upgrades. These lamps have a better CRI and color temperature, which is translated by the human eye as light that is brighter and of higher quality. Energy savings are possible because enhanced lighting allows equivalent visual perception with lower lighting levels. DOE estimates savings of approximately 20% and a payback between 3 and 4 years when replacing a T-8 system.[53] For example, if the



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[50] U.S. DOE, FEMP.

[51] U.S. DOE, EnergySmart Hospitals.

[52] A "T" is 1/8 of an inch and refers to the diameter of the fluorescent tube. A T-12 tube, is 12/8 or 1.5 inches. A T-8 is 8/8 or one inch around.

[45] U.S. DOE, Office of Energy Efficiency and Renewable Energy. http://www1.eere.energy.gov/femp/technologies/newtechnologies_demo5.html

visual benefit from the enhanced lighting is 20%, the lighting levels could be reduced by 20%, which would translate into a 20% savings in energy.[54]

DOE suggests the following technical guidelines for hospitals:[55]

- Replace current lamps with 25 or 28 W T-8s
- Install instant start electronic ballasts with a ballast factor ≤ 0.85
- Specify high performance T-8 lamps with:
    - A CRI of 85 or higher
    - A 92% lumen maintenance efficiency over rated lamp's lifetime
    - Lamps turned on/off more than five times per day or controlled by occupancy sensors should have program/rapid start ballasts to extend lamp life

The average lamp costs between $4 to $10 per lamp, and the average ballast costs between $20 to $48 each. Labor rates are site specific, but the average labor time should be 1 to 4 hours per fixture.[56]

The following considerations are important when retofitting with low wattage T-8s:

- New ballast must be rated to power a 28 Watt T-8 or a 25 Watt T-8 (new lamp and ballast must be electrically matched)
- Low wattage T-8 lamps are sensitive to cold temperatures (≤ 60 F°)
- Low wattage T-8 lamps have limited dimming capabilities

LIGHTING CONTROL STRATEGIES

Common types of lighting controls include timers, occupancy sensors, pre-set controls and daylighting. As a general rule, lamps that are turned on/off more than five times per day or that are controlled by occupancy sensors should have program/rapid start ballasts installed to extend lamp life.[57] If the control is accessible to occupants, provide training and post a contact number near the control in case occupants need assistance. Perhaps the greatest cause of lighting energy waste is controls that do not reduce energy consumption because they have failed or are improperly calibrated, or lighting controls that have been overridden or disabled. Users may damage or manually disable settings, so O&M staff should regularly check settings to ensure energy savings are realized.

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[54] U.S. DOE, Building Technologies Program. *Energy Conservation Using Scotopically Enhanced Fluorescent Lighting In An Office Environment.* March 2004.

[55] U.S. DOE, Hospital Energy Alliance. http://www1.eere.energy.gov/buildings/alliances/hospital_energy_alliance.html

[56] U.S. DOE, Hospital Energy Alliance. http://www1.eere.energy.gov/buildings/alliances/hospital_energy_alliance.html

[57] Saturn Resource Management. "High Performance T8 Lighting," 2008.

- **Install occupancy sensors** in rooms frequently unoccupied such as restrooms, service areas, and stairwells. Typically, occupancy sensors cost $30–$90 per fixture and labor time for installation ranges from 1 to 8 hours. [58]
- **Modify illumination levels** to meet task/comfort requirements
- **Timers** are a good control option in indoor areas with predictable occupancy and exterior lighting. Settings will need to be adjusted if the scheduled use of the space changes and to accommodate changing sunset and sunrise times.
- **Evaluate lighting controls annually** to determine if they are in need of recalibration. Document all settings and dates of recalibration.

OCCUPANCY SENSORS

Occupancy sensors automatically turn off lights in unoccupied spaces when no motion is detected. Installing lighting sensors where feasible will save energy by helping to ensure that unnecessary lighting is turned off (e.g., in rooms frequently unoccupied such as restrooms, service areas, and stairwells). For office areas and conference rooms, consider controls that require the occupant to switch the light on but turn off automatically after a period of inactivity.

During installation, carefully check sensors to ensure they are not set off by irrelevant movement, such as motion outside a window or door. Preventive maintenance plans should include annually commissioning sensors to ensure they are operating correctly.

Current sensors use infrared and ultrasonic technology, which eliminates problems common with older technologies, such as lights shutting off when a room is occupied. Most occupancy sensors now use both ultrasonic (US) and passive infrared (PIR) technology to detect occupancy. The sensor usually requires that both US and PIR sense occupancy before turning on. The lights will remain on as long as either technology detects someone in the space.

Occupancy sensors are typically mounted on the ceiling, high-wall, corner, or wall box, depending on the room size and layout. Ceiling-mounted sensors are the most versatile because their view is less obstructed. Wall box sensors take the place of the room's wall switch, and they are economical and easy to retrofit. Wall box sensors are appropriate for small, unobstructed spaces.

Most sensors can be adjusted for the desired degree of activity that will trigger a sensor response. The time-delay (i.e., the time elapsed between the moment a sensor stops sensing an occupant and the time it turns off) can also be selected. The setting can range from 30 seconds to 30 minutes, and the choice becomes a balance between energy conservation, user tolerance, and lamp life. DOE suggests no less than 15 minutes if controlling instant start ballasts.

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[58] U.S. DOE, Hospital Energy Alliance. http://www1.eere.energy.gov/buildings/alliances/hospital_energy_alliance.html

PRE-SET CONTROLS

Timers are a simple type of pre-set control that can be used in indoor areas with predicatable occupancy and in exterior lighting. Settings will need to be adjusted if the scheduled use of the space changes and to accommodate changing sunset and sunrise times.

More sophisticated pre-set controls include switching, dimming, or a combination of the two functions that can be automatically preprogrammed so the user can select an appropriate lighting environment ("scene") at the touch of a button. Each scene uses a different combination of luminaires in the room (sometimes dimmed) to provide the most appropriate light for one of several planned activities in that room.

A "pre-set controller" and wiring plan organizes the options. For example, the occupant of a conference room could select one pre-set scene from a five-button "scene selector" wall-mounted in the room, labeled "Conference", "Presentation", "Slide Viewing", "Cleaning", and "Off." This allows multiple lighting systems to be installed to meet the varying needs of separate activities, but prevents them from all being used at full intensity for every activity. A pre-set scene should be included for the cleaning crew, which should use the most energy-efficient lights.

DAYLIGHTING

Daylighting is the practice of using natural light, rather than electric light, to illuminate a space. By keeping lights off, users increase the life of the lamps and reduce maintenance costs. Depending on the availability of daylight, the hours of operation, and the space function, photoelectrically controlled lighting can save 10-60% of a building's lighting energy. This can translate into even more savings because daylight availability coincides with the hours of the day when peak demand charges apply.

Benefits of daylighting include:

- Reduces lighting power density (Watts/square foot) without reducing measured light levels
- Increases reliability during power failures; less lighting needed
- Increases productivity and job satisfaction, studies have shown, and reduces absenteeism by improving the indoor environment

Natural lighting has significant potential when combined with dimmable control technologies, but retrofit opportunities can be limited. The simplest approach is to install sensors or encourage staff to turn off lights when adequate natural lighting is available from windows and sky lights. Photosensors dim or switch off lights when daylight reaches a given level of brightness. These sensors must be properly calibrated and should work with the dimming ballast to provide smooth dimming in indoor areas. Smooth and continuous dimming is the preferred strategy for automated daylighting controls in offices or other work areas because it is not distracting to workers.

Dimming ballasts are most commonly installed in new construction but may be appropriate in some retrofit situations. Dimming can also be achieved manually by occupants if dimming swithces are installed. If using flourescent dimable lights, make sure dimmable ballasts are used. Otherwise, both the lamps and the ballasts will fail quickly.

Direct sunlight should generally be shielded in order to reduce glare and thermal gains. In particular, direct sun penetration should be kept out of work environments. Interior window blinds are almost always needed to control sky glare and sun penetration, even when overhangs or light shelves exist.

Strategically opening or tilting window blinds will help reduce heat loss in the winter and solar heat gain in the summer. Tilted window blinds can also help occupants manage glare while taking advantage of natural lighting. If solar heat gain is a significant issue during the summer, installing window films can help reduce this heat gain as well as cut down on glare. However, the film will also reduce the amount of available daylight.

LIGHTING RESOURCES:

IESNA's *Recommended Practice for Planned Indoor Lighting Maintenance*
www.IESNA.org

U.S. DOE, Office of Energy Efficiency and Renewable Energy, Solid State Lighting Program
http://www1.eere.energy.gov/buildings/ssl/index.html

4.6 PLUG LOADS

The term plug loads refers to all devices that are plugged into a building's electrical system through a wall outlet, including office equipment, appliances, soda machines, drinking fountains, TVs, etc. Reducing plug loads reduces energy use directly and can potentially reduce cooling requirements by eliminating the waste heat generated by this equipment.

Numerous mandates and pieces of legislation require procurement of energy efficient products. EO 13423 Section 2(h) requires that 95% of the electronic products purchased meet EPEAT standards where applicable. EISA Section 524 directs agencies to purchase commercially available, off-the-shelf products that use one or less Watts of standby power, or if not available, the lowest wattage available. EPAct Section 104 requires agencies to procure only ENERGY STAR- or FEMP-designated products when available and cost effective over the life of the product. Facility Managers should comply and also consider energy use and efficiency when buying equipment not covered by FEMP or ENERGY STAR.

LOCAL HEATING AND COOLING PLUG LOADS

Facility personnel constantly respond to complaints of spaces being too hot or too cold, especially in office areas. Many employees will add space heaters or desk fans; however, the best policy is to not allow these items without prior approval from the Facility Manager and safety officer, particularly because space heaters present a fire hazard. A space heater in one area of a zone can cause temperature sensors to sense the zone is warm and reduce or shut off the heating in that zone. This exacerbates the problem because occupants close to the space heater may be warm, but those in the rest of the zone may not receive adequate heat. Energy awareness campaigns can also help occupants understand this problem and the unintended impacts of personal space heaters.

The existence of space heaters and desk fans typically indicates an uncomfortable working environment caused by improper or faulty operation, which usually means energy is being wasted. It is important for the facility staff to provide a comfortable working environment, but energy awareness campaigns should also ask occupants to dress appropriately to maintain their individual comfort.

Actions that will help reduce the use of space heaters and desk fans include:

- Adjust the individual zone temperature setpoint according to the occupants' comfort
- Balance zone airflow if space heaters are used in a portion of the zone
- Adjust AHU supply-air temperature and static pressure if the entire building is either too cold or too hot
- Repair existing mechanical and control problems, such as replacing diffusers of the wrong type and relocating return air grilles, to maintain a comfortable zone temperature

COMPUTER-RELATED PLUG LOADS

The increasing use of computers and peripheral equipment has led to significant amounts of energy use, and the waste heat generated from it burdens the cooling system. HVAC systems in older facilities were not designed for the added heat load provided by computers, and modifications to accommodate computing equipment can be expensive and complicated.

Strategies to minimize the energy use of computers and the associated heat gain in the space include:

Recommended Power Management Settings
Turn off monitor in 15 minutes
System Standby in 30 minutes
Hibernation in 45 minutes

- Take advantage of existing power management settings on personal computers. Many times, users do not know that these power settings exist or need to be adjusted to take advantage of the personal computer's power management capabilities, even on ENERGY STAR-labeled computers. To activate power management settings on computers through the existing Windows tools averages about 15 minutes, with a potential annual savings of $10-$100 per desktop computer.
- Computer sleep settings can be implemented on an individual PC or across an entire enterprise. EPA's Power Management Website (www.energystar.gov/powermanagement) provides recommendations on how to properly implement sleep settings to save up to $50 per computer annually.
- MTFs should consider software for networked computers that activate power management settings across the network. This is beneficial for organizations with a large number of standard computers. However, before implementing this type of software, be certain that it will not interfere with operations, such as research computers left on to run over a long period of time (e.g., running a simulation overnight and/or on the weekend). Costs include license fees, maintenance fees, and installation fees, although free, open-source software is also available. Note that laptop and desktop computers must be grouped separately.
- Replace old computer monitors with liquid crystal display (LCD) monitors. They are better for the user's eye, produce less waste heat, and consume less than 20% of the energy of a comparable cathode ray tube (CRT) monitor.

- Look for opportunities to consolidate redundant equipment, for example, install network printers to reduce the number of personal printers.

NON-COMPUTER RELATED PLUG LOADS

Strategies for plug loads other than computers include:

- Consolidate redundant equipment (e.g., underused refrigerators and freezers)
- Utilize ENERGY STAR products for office, kitchen, and laundry equipment
- Reduce vending machine energy use. To address this opportunity an MTF may have to coordinate with the host installation and/or the vending provider. One option is to remove light lamps from the front of the machines, which impacts only the appearance of the machines. Another option is to install Vending Misers. These devices reduce energy consumed in refrigerated vending machines by up to 46%, saving about 1300 kWh annually. They cost about $180 each and the average installation time is 2 hours.[59]
- Manage and minimize "phantom" energy loads. Phantom energy load refers to the energy used by equipment even when it is off or in standby mode; it is also called standby power or "vampire" power. Encourage employees to unplug cell phone chargers, coffee pots, and similar equipment when it is not in use. Unplug other appliances if they will not be used for extended periods of time. Use power strips to provide a central point for turning equipment on and off (e.g., TV and DVD player, computer and peripherals).

MEDICAL PLUG LOADS

Medical equipment accounts for a significant portion of MTF energy use. Currently, it is difficult to accurately assess how much of an MTF's total energy use is due to medical equipment. Limited information is available, and few hospitals have the monitoring equipment necessary to track medical equipment plug loads. Examples of medical equipment plug loads include MRI, CAT Scans, PET scans, X-Rays and associated photo equipment, respirators, heart monitors, and centrifuges.[60] MTF Facility Managers can help address medical equipment plug loads by working with staff to identify opportunities to power down equipment and by encouraging the use of life-cycle cost analysis in purchasing decisions.

PLUG LOAD RESOURCES

ENERGY STAR
http://www.energystar.gov/

Better Bricks
http://www.betterbricks.com/

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[59] USA Technologies www.usatech.com; South Bay Energy Savings Center (Southern California Edison) www.sbesc.org

[60] Labs21. "Should EPA Expand the ENERGY STAR Rating to Medical Equipment?" http://www.labs21century.gov/training/conf/past/2006/abstracts/worksymp/reed.htm

APPENDIX A – RESOURCES

This document addresses many of the day-to-day challenges a medical Facility Manager may face while addressing energy efficiency. The following is a list of references that have been used to create this document or that may be useful to facility and energy managers in reducing energy consumption and operational costs:

- ASHE Healthcare Energy Guidebook

  Available at: http://www.ashe.org/e2c/resources.html

- ASHE O&M Benchmarks for Health Care Facilities Report

- ASHRAE's Advanced Energy Design Guide for Small Hospitals

  Available at: http://www.ashrae.org/publications/page/1604

- ASHRAE's Best Practices for Datacom Facility Energy Efficiency

- ASHRAE's Datacom Series, including:

  Best Practices for Datacom Facility Energy Efficiency
  High Density Data Centers: Case Studies and Best Practices
  Thermal Guidelines for Data Processing Environments

- ASHRAE's HVAC Design Manual for Hospitals & Clinics

- ASHRAE Standard 55-2004 – Thermal Environmental Conditions for Human Occupancy

- ASHRAE Standard 62.1-2..7 – Ventilation for Acceptable Indoor Air Quality

- ASHRAE Standard 90.1-2007 – Energy Standards for Buildings Except Low-rise Residential Buildings

- ASHRAE Standard 170-2008 – Ventilation of Healthcare Facilities

- ASHRAE's Thermal Guidelines for Data Processing Environments

- ASHRAE's 2007 ASHRAE Handbook: HVAC Applications

- Better Bricks O&M Best Practices

  Available at: http://www.betterbricks.com/DetailPage.aspx?ID=489

- DoD Energy Manager's Handbook

  Available at: http://www.wbdg.org/ccb/DOD/DOD4/dodemhb.pdf

- DoD Operation and Maintenance Guide to Energy Efficiency in Air Force Medical Facilities

- DOE's Greening Federal Facilities

  Available at: https://www1.eere.energy.gov/femp/pdfs/29267-0.pdf

- ENERGY STAR's Portfolio Manager

  http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

- EPA's IAQ Building Education and Assessment Model
  Available at: http://www.epa.gov/iaq/largebldgs/i-beam/index.html
- FEMP's Continuous Commissioning Guidebook

  Available at: http://www1.eere.energy.gov/femp/pdfs/ccg01_covers.pdf

- FEMP's Operations & Maintenance Best Practices

  Available at: http://www1.eere.energy.gov/femp/operations_maintenance/om_bpguide.html

- FEMP's Guidance for Electric Metering in Federal Buildings

  Available at: http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf

- Green Guide for Health Care Operations V2.2

  Available at: http://www.gghc.org/tools.2.2overview.php

- GSA's Commissioning Guide Book

  Available at: http://www.wbdg.org/ccb/GSAMAN/buildingcommissioningguide.pdf

- HVAC Equations and Rules of Thumb by Arthur A. Bell, Jr.

- JCI Accreditation Standards for Hospitals

- Lawrence Berkeley National Laboratory, "Chiller Controls-related Energy Savings Opportunities," January 2003

- PECI's Energy Management Systems: A Practical Guide

  Available at: http://www.peci.org/documents/PECI_PracticalGuide1_0302.pdf

- USGBC's LEED Reference Guide for Green Building Operations and Maintenance

- U.S. Pharmacopoeia (USP) 797 – Guidebook to Pharmaceutical Compounding – Sterile Preparations

- Whole Building Design Guide

  Available at: http://www.wbdg.org

APPENDIX B – ABBREVIATIONS AND ACRONYMS

AEE – Association of Energy Engineers

AHU – Air Handler Unit

AIA – American Institute of Architects

ANSI – American National Standards Institute

ASHRAE – American Society of Heating, Refrigeration and Air-Conditioning Engineers

ASHE – American Society for Healthcare Engineers

ASD(HA) – Assistant Secretary of Defense (Health Affairs)

BAS – Building Automation System

BCA – Building Commissioning Association

BOMA – Building Owners and Managers Association

BTU – British Thermal Unit; BBTU: Billion BTU; kBTU: Thousand BTU

CAT – also recognized as CT; Computed Tomography

CBECS – Commercial Building Energy Consumption Survey

CEQ – Council on Environmental Quality

CFL – Compact Fluorescent Light

CFM – Cubic Feet per Minute

CHP – Combined Heat and Power

CMMS – Computerized Maintenance Management System

CO – Contracting Officer

CRI –Color Rendering Index

CRT – Cathode Ray Tube

DB – Dry Bulb

DDC – Direct Digital Control

DHP – Defense Health Program

DoD – Department of Defense

DoDD – Department of Defense Directive

DOE – Department of Energy

DP – Dew Point

ECM – Energy Conservation Measure

EISA – Energy Independence and Security Act

EMCS – Energy Management Control System

EMS – Environmental Management System

EO – Executive order

EPA – Environmental Protection Agency

EPAct – Energy Policy Act of 2005

EPEAT – Electronic Product Environmental Assessment Tool

ESPC – Energy Savings Performance Contract

FEMP – Federal Energy Management Program

ft^2 – Square feet

FY – Fiscal Year

GHG – Greenhouse Gas

HEPA – High Efficiency Particulate Air

HID – High-intensity Discharge

HP – Horsepower

HPS – High-pressure Sodium

HSC – Health Science Center

HVAC – Heating, Ventilation and Air-conditioning

IAQ – Indoor Air Quality

IESNA – Illuminating Engineering Society of North America

IT – Information Technology

JCAHO – Joint Commission on Accreditation of Healthcare Organizations

LCD – Liquid Crystal Display

LED – Light Emitting Diode

LEED – Leadership in Energy and Environmental Design

MEDCOM – Army Medical Command

MH – Metal Halide

MHS – Military Health System

MOU – Memorandum of Understanding

MTF – Medical Treatment Facility

NDAA – National Defense Authorization Act

NEMA – National Electric Manufacturing Association

NFPA – Nation Fire Protection Association

OSHA – Occupational Safety and Health Administration

OMB – Office of Management and Budget

O&M – Operations and Maintenance

PECI – Portland Energy Conservation, Inc.

PET – Positron Emission Tomography

PIR – Passive Infrared

RH – Relative Humidity

ROI – Return on Investment

RPM – Revolutions per Minute

SF – Square Feet

TMA – TRICARE Management Activity

TV - Television

UESC – Utility Energy Service Contract

UFC – Unified Facilities Code

US – Ultrasonic

U.S. – United States

USGBC – United States Green Building Council

VAV – Variable Air Volume

VFD – Variable Frequency Drive

VSDVT – Variable Speed Drive Volume Tracking

WBDG – Whole Building Design Guide

APPENDIX C – GLOSSARY

Aerator – A device installed in a faucet or showerhead that adds air to the water flow, thereby maintaining an effective water spray while reducing overall water consumption.

Air changes – Replacement of the total volume of air in a room over a period of time (e.g., six air changes per hour).

Ambient temperature – The temperature of the air surrounding an object or building.

Ballast – A device used to supply the proper voltage and limit the current to operate one or more fluorescent or high-intensity discharge lamps.

Baseline – A selected period of time with consumption levels or dollar amounts, to which all future usage or costs are compared.

Blowdown – The discharge of water from a boiler or a cooling tower sump that contains a high proportion of total dissolved solids.

British thermal unit (BTU) – A unit of energy. Specifically, it is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2 degrees Fahrenheit.

Building commissioning – A systematic process of assuring that a building or facility performs in accordance with design intent and the owner's operational needs. Verifies and documents that all building facility systems perform interactively in an efficient manner and that operations and maintenance personnel are well trained.

Centrifugal compressor – A special class of radial-flow, work-absorbing turbo-machinery that includes pumps, fans, blowers and compressors.

Chiller – A refrigeration machine using mechanical energy input to drive a centrifugal compressor to generate chilled water.

Cold deck – A cold air chamber forming a part of an air conditioning system.

Color rendering index, CRI – The color appearance of an object under a light source as compared to a reference source.

Condensate – Water obtained by charging the state of water vapor (i.e., steam or moisture in air) from a gas to a liquid, usually by cooling.

Condenser – A heat exchanger that removes heat from vapor, changing it to its liquid state. In refrigeration systems, this is the component that rejects heat.

Cooling tower – A device that cools water directly by evaporation.

Cubic feet per minute, CFM – Volumetric flow rate, which usually refers to the volume of air being moved through an air duct.

Damper – A device used to limit the volume of air passing through an air outlet, inlet, or duct.

Dry bulb temperature – The measure of the sensible temperature of air.

Economizer cycle – A method of operating a ventilation system to reduce refrigeration load. Whenever the outside air conditions are more favorable (lower heat content) than return air conditions, outdoor air quantity is increased.

Efficacy – Ratio of usable light to energy input for a lighting fixture or system (lumens per watt).

Energy management control system, EMCS– A microprocessor-based system for controlling equipment and monitoring energy and other operating parameters in a building.

Evaporator – A heat exchanger in which a liquid evaporates while absorbing heat.

Evaporation – The act of water or other liquids dissipating or becoming vapor or steam.

Flow restrictors – Washer-like disks that fit inside faucet or shower heads to restrict water flow.

Foot candle – Illumination at a distance of one foot from a standard candle.

Grey water – Wastewater generated from domestic activities that can be recycled on-site for uses such as landscape irrigation.

Gross square feet – The total number of square feet contained in a building envelope using the floors as area to be measured.

Heat gain – As applied to HVAC calculations, it is that amount of heat gained by space from all sources including people, lights, machines, sunshine, etc. The total heat gain represents the amount of heat that must be removed from a space to maintain indoor comfort conditions. This is usually expressed in Btu's per hour.

Heat loss – The heat loss from a building when the outdoor temperature is lower than the desired indoor temperature it represents the amount of heat that must be provided to a space to maintain indoor comfort conditions. This is usually expressed in Btu/hour.

Horsepower (hp) – British unit of power, 1 hp = 746 Watts or 42,408 Btu per minute.

Hot deck – A hot air chamber forming part of a multi-zone or dual duct air handling unit.

Humidity, relative, RH – A measurement indicating the moisture content of the air.

Infiltration – The process by which outdoor air leaks into a building by natural forces through cracks around doors and windows.

Life-cycle cost – The cost of the equipment over its entire life including operating costs, maintenance costs, and initial cost.

Low flow toilet – A toilet that uses 3.5 gallons of water per flush.

Load profile – Time distribution of building heating, cooling, and electrical load.

Lumen – Unit of measurement of the rate of light flow.

Luminaire – Light fixture designed to produce a specific effect.

Modular – System arrangement whereby the demand for energy (heating, cooling) is met by a series of units sized to meet a portion of the load.

Potable water – Clean, drinkable water; also known as "white" water.

Ton (of refrigeration) – A means of expressing cooling capacity: 1 ton = 12,000 Btu/hour cooling (removal of heat).

Variable speed drive – See "Variable frequency drive"

Variable frequency drive – A means of changing the speed of a motor in a step-less manner. In the case of an AC motor, that is accomplished by varying the frequency.

Wet bulb temperature – The lowest temperature attainable by evaporating water in the air without the addition or subtraction of energy.

Title	Summary	Comments
Executive Order (EO) 13514: Federal Leadership in Environmental, Energy and Economic Performance		
EO 13514, Sec. 2(a) Reduction Target (Scope 1 and 2)	Within 90 days (Jan. 3, 2010), establish and report to the CEQ Chair and the OMB Director a percentage reduction target for agency-wide reductions of scope 1 and 2 greenhouse gas emissions in absolute terms by FY2020, relative to FY2008. In establishing the target, the agency head shall consider reductions associated with: (i) reducing energy intensity in agency buildings; (ii) increasing agency use of renewable energy and implementing renewable energy generation projects on agency property; and (iii) reducing the use of fossil fuels.	Scope 1: direct greenhouse gas emissions from sources that are owned or controlled by the Federal agency; Scope 2: direct greenhouse gas emissions resulting from the generation of electricity, heat, or steam purchased by a Federal agency DoD established targets in 2010 SSPP Objective 2: ▸ DoD is a U.S. Government Leader in Reducing Greenhouse Gas Emissions – Goal 3: Greenhouse Gas Emissions from Scope 1 and 2 Sources Reduced 34% by FY 2020, Relative to FY 2008

Title	Summary	Comments
EO 13514, Sec. 2(b) Reduction Target (Scope 3)	Within 240 days (Jun. 2, 2010), establish and report to the CEQ Chair and the OMB Director a percentage reduction target for reducing scope 3 greenhouse gas emissions in absolute terms by FY2020, relative to a FY2008 baseline.	Scope 3: greenhouse gas emissions from sources not owned or directly controlled by a Federal agency but related to agency activities GHG reduction targets were published in the DoD Strategic Sustainability Performance Plan (SSPP) in August 2010. SSPP Objective 2: ▸ DoD is a U.S. Government Leader in Reducing Greenhouse Gas Emissions – Goal 4: Greenhouse Gas Emissions from Scope 3 Sources Reduced 13.5% by FY 2020, Relative to FY 2008
EO 13514, Sec. 2(c) Inventory and Reporting	Establish and report to the CEQ Chair and OMB Director a comprehensive inventory of absolute greenhouse gas emissions, including scopes 1, 2, and 3 emissions within 15 months of the date of this order (Jan. 2011) for FY2010, and thereafter annually at the end of January, for the preceding fiscal year.	Absolute greenhouse gas emissions: total greenhouse gas emissions without normalization for activity levels, including any allowable consideration of sequestration DoD completed its first GHG inventory in January 2011.

Title	Summary	Comments
EO 13514, Sec. 2(d) Water Intensity Reduction Target	Improve water use efficiency and management by: Reducing potable water consumption intensity by 2% annually through FY2020, or 26% by the end of FY2020, relative to the FY2007 baseline	Expands the EO 13423 water intensity reduction target (see below) <u>Water consumption intensity:</u> Water consumption per ft^2 <u>SSPP Objective 1:</u> - The Continued Availability of Resources Critical to the DoD Mission is Ensured – Goal 2: Water Resources Management Improved
EO 13514, Sec. 2(d) Industrial, Landscaping and Agricultural Water	Reduce agency industrial, landscaping, and agricultural water consumption by 2% annually or 20% by the end of FY2020 relative to a baseline of the agency's industrial, landscaping, and agricultural water consumption in FY2010	<u>SSPP Objective 1:</u> - The Continued Availability of Resources Critical to the DoD Mission is Ensured – Goal 2: Water Resources Management Improved

Title	Summary	Comments
EO 13514, Sec. 2(f) Regional and Local Integrated Planning	(i) Participate in regional transportation planning and recognize existing community transportation infrastructure; (ii) Align Federal policies to increase the effectiveness of local planning for energy choices such as locally generated renewable energy; (iii) Ensure that planning for new Federal facilities or new leases includes consideration of sites that are pedestrian friendly, near existing employment centers, and accessible to public transit, and emphasizes existing central cities and, in rural communities, existing or planned town centers; (iv) Identify and analyze impacts from energy usage and alternative energy sources in all Environmental Impact Statements and Environmental Assessments for proposals for new or expanded Federal facilities (v) Coordinate with regional programs for Federal, State, tribal, and local ecosystem, watershed, and environmental management.	SSPP Objective 4: ▸ Continuous Improvement in the DoD Mission Achieved through Management and Practices Built on Sustainability and Community – Goal 8: Sustainability Built into DoD Management Systems

Title	Summary	Comments
EO 13514 Sec. 2(g) High Performance Buildings	(i) Beginning in 2020 and thereafter, ensure that all new Federal buildings that enter the planning process are designed to achieve zero-net-energy by 2030; (ii) Ensure that all new construction, major renovation, or repair and alteration of Federal buildings complies with the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* (Guiding Principles); (iii) Ensure that at least 15% of existing buildings (above 5,000 gross square feet) and building leases (above 5,000 gross square feet) meet the Guiding Principles by FY2015 and make annual progress toward 100% conformance with the Guiding Principles for its building inventory; (iv) Pursue cost-effective, innovative strategies, such as highly reflective and vegetated roofs, to minimize consumption of energy, water, and materials; (v) Manage existing building systems to reduce the consumption of energy, water, and materials, and identifying alternatives to renovation that reduce existing assets' deferred maintenance costs; (vi) When adding assets to the agency's real property inventory, identify opportunities to consolidate and dispose of existing assets, optimize the performance of the real-property portfolio, and reduce associated environmental impacts; (vii) Ensure that rehabilitation of federally owned historic buildings utilizes best practices and technologies in retrofitting to promote long-term viability of the buildings	Guiding Principle were originally defined in an interagency MOU in 2006: 1. Employ Integrated Design Principles 2. Optimize Energy Performance 3. Protect and Conserve Water 4. Enhance Indoor Environmental Quality 5. Reduce Environmental Impact of Materials SSPP Objective 4: ▸ Continuous Improvement in the DoD Mission Achieved through Management and Practices Built on Sustainability and Community – Goal 7: Sustainability Practice Becomes the Norm

Title	Summary	Comments
EO 13514, Sec. 2(g) Sustainable Acquisition	Ensure that 95% of new contract actions including task and delivery orders, for products and services, are energy-efficient (ENERGY STAR or FEMP designated), water-efficient, bio-based, environmentally preferable (e.g., EPEAT certified), non-ozone depleting, contain recycled content, or are non-toxic or less-toxic alternatives, where such products and services meet agency performance requirements	Consistent with requirements of earlier legislation and Executive orders SSPP Objective 4: ▸ Continuous Improvement in the DoD Mission Achieved through Management and Practices Built on Sustainability and Community – Goal 7: Sustainability Practice Becomes the Norm

Title	Summary	Comments
EO 13514, Sec. 2(i) Electronics Stewardship	(i) Ensure procurement preference for EPEAT-registered electronic products; (ii) Establish and implement policies to enable power management, duplex printing, and other energy-efficient or environmentally preferable features on eligible electronic products; (iii) Employ environmentally sound practices with respect to the disposition of excess or surplus electronic products; (iv) Ensure the procurement of ENERGY STAR and FEMP-designated electronic equipment; (v) Implement best management practices for energy-efficient management of servers and Federal data centers	Consistent with earlier requirements SSPP Objective 3: ‣ The Ongoing Performance of DoD Assets Ensured by Minimizing Waste and Pollution – Goal 6: The Use and Release of Chemicals of Environmental Concern Minimized SSPP Objective 4: ‣ Continuous Improvement in the DoD Mission Achieved through Management and Practices Built on Sustainability and Community Goal 7: Sustainability Practice Becomes the Norm

<table>
<tr><th>Title</th><th>Summary</th><th>Comments</th></tr>
<tr><td>EO 13514 Sec. 2(j)

Environmental Management Systems</td><td>Sustain environmental management, including by:

(i) Continuing implementation of formal environmental management systems (EMS) at all appropriate organizational levels; and

(ii) Ensuring these formal systems are appropriately implemented and maintained to achieve the performance necessary to meet the goals of this order.</td><td><u>SSPP Objective 3:</u>

▸ The Ongoing Performance of DoD Assets Ensured by Minimizing Waste and Pollution

– Goal 5: Solid Waste Minimized and Optimally Managed</td></tr>
<tr><td colspan="3">Executive Order 13423: Strengthening Federal Environmental, Energy and Transportation Management</td></tr>
<tr><td>EO 13423, Sec. 2(a)

Energy Efficiency and Greenhouse Gas Emissions</td><td>Improve energy efficiency and reduce greenhouse gas emissions by agency through the reduction of energy consumption intensity by:

(i) 3% annually through the end of FY2015; or

(ii) 30% by the end of FY2015, relative to the agency's FY2003 baseline energy use</td><td></td></tr>
<tr><td>EO 13423, Sec. 2(b)

New Renewable Sources</td><td>Modifies the EPAct 2005 renewable energy requirement. It requires that half of the renewable energy purchased in each fiscal year comes from "new renewable sources."

To the extent feasible, if an agency implements renewable energy generation projects, it shall do so on agency property for agency use.</td><td>Adds to EPAct 2005 Sec. 203 requirement

''New renewable sources'' means sources of renewable energy placed into service after January 1, 1999</td></tr>
</table>

Title	Summary	Comments
EO 13423, Sec. 2(c) Water Intensity Reduction Target	Beginning in FY2008, reduce water consumption intensity through life-cycle cost-effectiveness measures and sustainable facility design practices by 2% annually or 16% by the end of FY2015 using FY2007 as the baseline year	Expanded by EO 13514
EO 13423, Sec. 2(d) Environmentally Preferable Purchasing	Require, in agency procurement of goods and services, the use of sustainable environmental practices, including biobased, environmentally preferable, energy-efficient, water-efficient, and recycled-content products. The Instructions for Implementing EO 13423 direct agencies to give preference in its procurement and acquisition programs to the purchase of the following: • ENERGY STAR products identified by DOE and the EPA, as well as FEMP-designated energy-efficient products • Water-efficient products, including those meeting EPA's WaterSense standards • Energy from renewable sources • Environmentally preferable products and services, including EPEAT-registered electronic products	
EO 13423, Sec. 2(f) Guiding Principles	Incorporate the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings, Memorandum of Understanding (Guiding Principles) (2006) into new facility construction and renovation projects. Ensure that 15% of the existing federal capital asset building inventory incorporates the sustainable practices in the Guiding Principles by the end of FY2015	

Title	Summary	Comments
EO 13423, Sec. 2(h) Electronics	Requires that: • 95% of the electronic products purchased meet EPEAT standards where applicable. • The Energy Star feature on agency computers and monitors be enabled. • Agencies establish and implement policies to extend the useful life of electronic equipment. • The use of environmentally sound practices with respect to disposition of agency electronic equipment that has reached the end of its useful life.	
EO 13423, Sec 3(b) Environmental Management Systems	Implement, within the agency, environmental management systems (EMS) at all appropriate organizational levels to ensure use of EMS as the primary management approach for addressing environmental aspects of internal agency operations and activities, including environmental aspects of energy and transportation functions.	

Title	Summary	Comments
Energy Independence and Security Act of 2007 (EISA)		
EISA Sec. 431 **Energy Reduction Goals**	Section 431 amends Section 543(a)(1) of NECPA and adopts the energy intensity reduction goals of EO 13423 Sec. 2(a). Each agency shall apply energy conservation measures, and shall improve the design for the construction, so that the energy consumption intensity of the Federal buildings of the agency in FY2006 through FY2015 is reduced, as compared with the energy consumption intensity of the Federal buildings of the agency in FY2003.	
EISA Sec. 432 Covered facilities (75% of energy use)	Agencies were required to identify their lists of covered facilities not later than Jan. 1 2009 (DOE Evaluations Guidance, http://www1.eere.energy.gov/femp/regulations/guidance.html)	DoD covered facilities have been identified. For DoD, a covered facility is defined as an installation (as opposed to buildings on an installation).

Title	Summary	Comments
EISA Sec. 432 Evaluations	Energy managers must complete, for each calendar year, comprehensive energy and water evaluations for approximately 25% of covered facilities in a manner that ensures that an evaluation of each facility is completed at least once every four years The evaluations must assess opportunities for re/retro commissioning and contain a component addressing audits Auditing results will contain sufficient and actionable information on ECMs so that sound project decisions can be made (DOE Evaluation Guidance)	
EISA Sec. 432 Implementation of identified ECMs	Energy managers may implement energy conservation measures within two years after the completion of each evaluation	
EISA Sec. 432 Follow up on implemented ECMs	For each energy conservation measure implemented, energy managers shall ensure that: • Equipment is fully commissioned to be operating at design specifications, • An O&M and repair plan is in place and is followed, • Equipment and system performance is measured during its entire life • Energy and water savings are measured and verified DOE provides guidance on commissioning, measurement and verification.	

Title	Summary	Comments
EISA Sec. 432 Tracking System	For each covered facility, the energy manager shall use a web-based tracking system to certify compliance with • Energy and water evaluations • Implementation of identified energy and water measures • Follow-up on implemented measures	DOE is launching the web based tracking system *The Compliance Tracking System (CTS)* in 2011.
EISA Sec. 432 Benchmarking	Requires the designated agency energy managers to enter energy use data for each metered building that is (or is a part of) a covered facility into a building energy use benchmarking system, such as the ENERGY STAR Portfolio Manager tool. In addition, energy managers shall post and update the benchmarking data each year in the Web-Based tracking system developed by the Secretary of Energy to track compliance. DOE Benchmarking Guidance is available at: http://www1.eere.energy.gov/femp/regulations/guidance.html	DOE selected ENERGY STAR Portfolio Manager as the benchmarking system. DOE is launching the web based tracking system *The Compliance Tracking System (CTS)* in 2011.

<table>
<tr><th>Title</th><th>Summary</th><th>Comments</th></tr>
<tr><td>EISA Sec. 433

Building fossil fuel use reduction</td><td>New construction and major renovation projects are to be designed so that the fossil fuel-generated energy consumption of the buildings is reduced, as compared with such energy consumption by a similar building in fiscal year 2003 CBECS

<table><tr><th>Fiscal Year</th><th>% Reduction</th></tr><tr><td>2010</td><td>55</td></tr><tr><td>2015</td><td>65</td></tr><tr><td>2020</td><td>80</td></tr><tr><td>2025</td><td>90</td></tr><tr><td>2030</td><td>100</td></tr></table></td><td>DOE published a Notice of Proposed Rulemaking (NOPR) for implementation of EISA 433 in October 2010.</td></tr>
<tr><td>EISA Sec. 433

Sustainable Design principles</td><td>Sustainable design principles shall be assigned to the siting, design, and construction of new construction and major renovation projects.

Design & construction guidance is available through the Whole Building Design Guide website: http://www.wbdg.org/index.php. DOE guidance can be found at http://www.wbdg.org/pdfs/hpsb_guidance.pdf</td><td></td></tr>
<tr><td>EISA Sec. 434

Management of Federal Building Efficiency</td><td>Major replacements of installed equipment (such as heating and cooling systems), or renovation or expansion of existing space, must employ the most energy efficient designs, systems, equipment and controls that are life-cycle cost effective.</td><td></td></tr>
</table>

Title	Summary	Comments
EISA Sec. 434 Advanced Metering	EPAct 2005 established requirements for electrical metering of Federal buildings (see below). This section of EISA extends the mandate by requiring equivalent meters for natural gas and steam by October 1, 2016.	
EISA Sec. 435 Leasing	Effective December 10, 2010, Federal agencies must lease space that has received the EPA ENERGY STAR® designation in the most recent year. Agencies may make exceptions if: • No space is available that meets the functional requirements of the agency, including locational needs. • The agency proposes to remain in a building that it has occupied previously. • The agency proposes to lease a building of historical, architectural, or cultural significance (as defined in 40 USC §3306(a)(4)) or space in such a building. • The lease is for not more than 10,000 gross square feet of space.	

Title	Summary	Comments
EISA Sec. 438 Storm Water Run Off	A) EISA 438 requires that the sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 ft^2 shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume and duration of flow B) EO 13514 Sec. 14 requires EPA to develop guidance for implementing this requirement within 60 days (Dec. 4, 2009) EPA guidance is available at: http://www.epa.gov/oaintrnt/stormwater/requirements.htm#guidance	EO 13514 Sec. 2 requires agencies to implement and achieve the objectives identified in that EPA guidance
EISA Sec. 512 & 513 Funding and Implementation	Federal agencies are restricted from limiting the duration of ESPCs to less than 25 years or limiting the amount of obligations	
EISA Sec. 517 Contracting Officer training	Related primarily to Contracting Officers (COs) negotiating ESPCs	CO training available from DOE

Title	Summary	Comments
EISA Sec. 523 Solar Hot Water Heaters	Federal agencies are required to use solar hot water heaters for not less than 30% of demand where life-cycle cost effective	
EISA Sec. 524 Standby Power	Directs agencies to purchase products that use not more than one watt of standby power, or, if not available, the lowest wattage available. This applies only to commercially available, off-the-shelf products where life-cycle cost effective and practicable. Additionally, the Department of Energy publishes a list of cost effective eligible products that will be subject to this purchase requirement.	DOE information available from: http://www1.eere.energy.gov/femp/technologies/standby_power.aspx
Energy Policy Act of 2005 (EPAct 05)		
EPAct 05 Sec. 102 Retained Savings	An agency may retain any funds appropriated to that agency for energy, water or wastewater treatment expenditures that are not made because of energy or water savings. Such funds may be used only for energy efficiency, water conservation or unconventional and renewable energy resources projects.	
EPAct 05 Sec. 102 Advanced Metering	Not later than October 1, 2012, each agency shall install electric meters and advanced meters in Federal buildings to the maximum extent practicable. DOE advanced metering guidance is available at: http://www1.eere.energy.gov/femp/regulations/guidance.html	

<table>
<tr><th>Title</th><th>Summary</th><th>Comments</th></tr>
<tr><td>EPAct Sec. 104

Product Procurement</td><td>Agencies are required to procure only ENERGY STAR or FEMP designated products and shall incorporate these criteria into the specifications for all procurements involving energy consuming products and systems. Includes requirements for electric motors.

Exception may be granted by the agency head or designee when:

1. An ENERGY STAR or FEMP product is not cost-effective over the life of the product taking energy cost savings into account

2. No ENERGY STAR or FEMP product is reasonable available that meets the functional requirements</td><td></td></tr>
<tr><td>EPAct 05 Sec 109

Efficiency Standards</td><td>If life-cycle cost-effective, new and replacement buildings will be designed to achieve energy consumption levels that are at least 30% below the levels established in the latest ASHRAE Standard 90.1</td><td></td></tr>
<tr><td>EPAct 05 Section 203(a)

Renewable Electric Energy Consumption Goals</td><td>Requires federal renewable electricity consumption to not be less than the amounts listed in the Table

<table><tr><th>Fiscal Year</th><th>Percent</th></tr><tr><td>2007–2009</td><td>3%</td></tr><tr><td>2010–2012</td><td>5%</td></tr><tr><td>2013 and beyond</td><td>7.5%</td></tr></table>
The amount of renewable energy can be doubled for counting purposes if the renewable energy is—
Produced and used on-site at a federal facility
Produced on federal lands and used at a federal facility
Produced on Indian land as defined by federal law</td><td></td></tr>
</table>

Title	Summary	Comments
National Defense Authorization Act of 2007		
NDAA of 2007 Sec. 2911 Energy Performance Goals for DoD	It shall be the goal of the DoD to produce or procure not less than 25% of the total quantity of electric energy it consumes within its facilities and in its activities during FY2025 and each FY thereafter from renewable energy sources	
NDAA of 2007 Sec. 2912 Availability and Use of Energy Cost Savings	A) <u>Availability</u>: An amount of funds appropriated to DoD equal to the amount of energy cost savings (including from performance contracts) shall remain available for obligation until expended without additional authorization or appropriation B) <u>Use</u>: These funds shall be used as follows: One half shall be used for additional energy conservation measures by the DoD department or agency that realized the savings; one half shall be used by the Commanding Officer at the installation where the savings were realized for: a. Improvements to existing military family housing b. Any unspecified minor construction project that will that will enhance the quality of life of personnel c. Any morale, welfare, or recreation facility or service	Unique authority for DoD to reinvest energy savings

APPENDIX E – MAINTENANCE CHECKLISTS

The tables provided in this appendix suggest minimum preventative and predictive maintenance practices for the specified pieces of equipment. Properly maintaining equipment will allow it to operate longer and more efficiently. These charts originally appeared in FEMP's Operations & Maintenance Best Practices.

BOILERS

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Boiler use	Turn off/sequence unnecessary boilers	X			
Visual Inspection	Complete visual inspection to be sure all equipment is operating and safety systems are in place	X			
Follow manufacturer's recommended procedures in lubricating all components	Compare temperatures with tests performed after annual cleaning	X			
Check steam pressure	Is variation in steam pressure as expected under different loads? Wet steam may be produced if the pressure drops too fast	X			
Check unstable water levels	Unstable levels can be a sign of contaminates in feedwater, overloading of boiler, or equipment malfunction	X			
Check burner	Check for proper control and cleanliness	X			
Check motor condition temperatures	Check for proper function	X			
Check air temperatures in boiler room	Temperatures should not exceed or drop below design limits	X			
Boiler blowdown	Verify the bottom, surfaces, and water column blow downs are occurring and are effective	X			

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Boiler logs	Keep daily logs on: • Type and amount of fuel used • Flue gas temperature • Makeup water volume • Steam pressure, temperatures, and amount generated Look for variations as a method of fault detection.	X			
Check oil filter assemblies	Check and clean/replace oil filters and strainers	X			
Inspect oil heaters	Check to ensure that oil is at proper temperature prior to burning	X			
Check boiler water treatment	Confirm water treatment system is functioning properly	X			
Check flue gas temperature and composition	Measure flue gas composition and temperatures at selected firing positions. Recommended O_2% and CO_2% **Fuel** **O_2%** **CO_2%** Natural Gas 1.5 10 No. 2 fuel oil 2.0 11.5 No. 6 fuel oil 2.5 12.5 Note: Percentages may vary due to fuel composition variations		X		
Check all relief valves	Check for leaks		X		
Check water level control	Stop feedwater pump and allow control to stop fuel flow to burner. Do not allow water level to drop below recommended level.		X		
Check pilot and burner assemblies	Clean pilot and burner following manufacturer's guidelines. Examine for mineral or corrosion buildup.		X		
Check boiler operating characteristics	Stop fuel flow and observe flame failure. Start boiler and observe characteristics of flame.		X		
Inspect system for water/steam leaks and leakage opportunities	Look for leaks, defective valves and traps corroded piping, condition of insulation		X		
Inspect boiler for air leaks	Check damper seals		X		

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Check blowdown and water treatment procedures	Determine if blowdown is adequate to prevent solids buildup			X	
Inspect all linkages on combustion air dampers and fuel valves	Check for proper setting and tightness		X		
Flue gases	Measure and compare last month's readings flue gas composition over entire firing range			X	
Combustion air supply	Check combustion air inlet to boiler room and boiler to make sure openings are adequate and clean			X	
Check fuel system	Check pressure gauge, pumps, filters, and transfer lines. Clean filters as required.			X	
Check belts and packing glands	Check belts for proper tension. Check packing glands for compression leakage.			X	
Check for air leaks	Check for air leaks around access openings and flam scanner assembly			X	
Check all blower belts	Check for tightness and minimum slippage			X	
Check all gaskets	Check gaskets for tight sealing; replace if they do not provide a tight seal			X	
Inspect boiler insulation	Inspect all boiler insulation and casings for hot spots			X	
Steam control valves	Calibrate steam control valves as specified by manufacturer			X	
Pressure reducing/regulating valves	Check for proper operation			X	
Perform water quality test	Check water quality for proper chemical balance			X	
Clean waterside surfaces	Follow manufacturer's recommendation on cleaning and preparing waterside surfaces				X
Clean fireside	Follow manufacturer's recommendation on cleaning and preparing fireside surfaces				X
Inspect and repair refractories on fireside	Use recommended material and procedures				X

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Relief valve	Remove and recondition or replace				X
Feedwater system	Clean and recondition feedwater pumps. Check condensate receivers and deaeration system				X
Fuel system	Clean and recondition system pumps, filters, pilot, oil preheaters, oil storage tanks, etc.				X
Electrical systems	Clean all electrical terminals. Check electronic controls and replace any defective parts.				X
Hydraulic and pneumatic valves	Check operation and repair as necessary				X
Flue gases	Make adjustments to give optimal flue gas composition. Record composition, firing position and temperature.				X
Eddy current test	As required, conduct eddy current test to assess tube wall thickness				X

STEAM TRAPS

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Test steam traps	Daily/weekly test recommended for high pressure traps (250 psig or more)	X			
Test steam traps	Weekly/monthly test recommended for medium-pressure traps (30-250 psig)		X		
Test steam traps	Monthly/annually test recommended for low-pressure traps			X	
Repair/replace steam traps	Shows problems when testing. Typically, traps should be replaced every 3-4 years.			X	
Replace steam traps	When replacing, take time to make sure traps are sized properly				X

CHILLERS

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Chiller use	Turn off/sequence unnecessary chillers	X			
Overall visual inspection	Complete overall visual inspection to ensure all equipment is operating and safety systems are in place	X			
Check setpoints	Check all setpoints for proper settings and function	X			
Evaporator and condenser coil fouling	Assess evaporator and condenser coil fouling as required		X		
Compressor motor temperature	Check temperature per manufacturer's specifications		X		
Perform water quality test	Check water quality for proper chemical balance		X		
Leak testing	Conduct leak testing on all compressor fittings, oil pump joints and fittings, and relief valves		X		
Check all insulation	Check insulation for condition and appropriateness		X		
Control operation	Verify proper control function including: • Hot gas bypass • Liquid injection		X		
Check vane control settings	Check settings per manufacturer's specification			X	
Verify motor load limit control	Check settings per manufacturer's specification			X	
Verify load balance operation	Check settings per manufacturer's specification			X	
Check chilled water rest settings and function	Check settings per manufacturer's specification			X	

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Check chiller lockout setpoint	Check settings per manufacturer's specification				X
Clean condenser tubes	Clean tubes at least annually as part of shutdown procedure				X
Eddy current test condenser tubes	As required, conduct eddy current test to assess tube wall thickness				X
Clean evaporator tubes	Clean tubes at least annually as part of shutdown procedure				X
Eddy current test evaporator tubes	As required, conduct eddy current test to assess tube wall thickness				X
Compressor motor and assembly	Check all alignments to specification and check all seals and provide lubrication when necessary				X
Compressor oil system	Conducted analysis on oil and filter, change as required. Check oil pump, seals, oil heater, thermostat, strainers, valves, etc.				X
Electrical connections	Check all electrical connections/terminals for contact and tightness				X
Water flows	Assess proper water flow in evaporator and condenser				X
Check refrigerant level and condition	Add refrigerant as required. Record amounts and address leakage issues.				X

COOLING TOWERS

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Cooling tower use / sequencing	Turn off/sequence unnecessary cooling towers	X			
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place.	X			
Inspect for clogging	Make sure water is flowing in tower	X			
Fan motor condition	Check the condition of the fan motor through temperature or vibration analysis and compare to baseline values		X		
Clean suction screen	Physically clean screen of all debris		X		
Test water samples	Test for proper concentrations of dissolved solids, and chemistry. Adjust blowdown and chemicals as necessary.		X		
Operate make-up water float switch	Operate switch manually to ensure proper operation		X		
Vibration	Check for excessive vibration in motors, fans, and pumps		X		
Check tower structure, belts, and pulleys	Check for loose fill, connections, leaks, etc. Adjust all belts and pulleys.		X		
Check lubrication, motor supports, fan blades, drift eliminators, louvers and fill	Assure that all bearings are lubricated per manufacturer's recommendation. Check for excessive wear and secure fastening. Look for proper positioning and scale build up.			X	
Motor alignment	Aligning the motor coupling allows for efficient torque transfer			X	
Clean tower	Remove all dust, scale, and algae from tower basin, fill, and spray nozzles				X
Check bearings	Inspect bearings and drive belts for wear. Adjust, repair, or replace as necessary.				X

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Motor condition	Check the condition of the motor through temperature or vibration analysis assures long life				X

AIR COMPRESSORS

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Compressor use	Turn off/sequence unnecessary compressors	X			
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place	X			
Leakage assessment	Look for and report any system leakages	X			
Compressor operation	Monitor operation for run time and temperature variance from trended norms	X			
Dryers	Dryers should be observed for proper function	X			
Compressor ventilation	Make sure proper ventilation is available for compressor and inlet	X			
Compressor lubricant	Note level, color and pressure. Compare with trended values.	X			
Condensate drain	Drain condensate from tank, legs, and/or traps	X			
Operating temperature	Verify operating temperature is per manufacturer specification	X			
Pressure relief valves	Verify all pressure relief valves are functioning properly		X		
Check belt tension	Check belt tension and alignment for proper settings		X		
Intake filter pads	Clean or replace intake filter pads as necessary		X		
Air-consuming devices check	All air-consuming devices need to be inspected on a regular basis for leakage. Leakage typically occurs in: • Worn/cracked/frayed hoses • Sticking air valves • Cylinder packing		X		
Drain traps	Clean out debris and check operation		X		

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Motor bearings	Lubricate motor bearings to manufacturer's specification			X	
System oil	Depending on use and compressor size, develop periodic oil sampling to monitor moisture, particulate levels, and other contamination. Replace oil as required.			X	
Couplings	Inspect all couplings for proper function and alignment				X
Shaft seals	Check all seals for leakage or wear				X
Air line filters	Replace particulate and lubricant removal elements when pressure drop exceeds 2-3 psid				X
Check mountings	Check and secure all compressor mounting				X

MOTORS AND PUMPS

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Monthly	Annually
Sequencing	Turn off/sequence unnecessary pumps/motors	X			
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place	X			
Motor condition	Check the condition of the motor through temperature or vibration analysis and compare to baseline values		X		
Check lubrication	Ensure all bearings are lubricated per the manufacture's recommendations			X	
Check packing	Check packing for wear and repack as necessary. Consider replacing packing with mechanical seals.			X	
Check alignment	Aligning the pump/motor coupling allows for efficient torque transfer			X	
Check mounting	Check and secure all motor mountings			X	
Clean motors	Remove dust and dirt from the motor to facilitate cooling			X	
Check bearings	Inspect bearings and drive belts for wear. Adjust, repair, or replace as necessary.				X
Check for balanced three-phase power	Unbalanced power can shorten the motor life through excessive heat buildup.				X
Check for correct voltage	Over- or under-voltage situation can shorten the motor life through excessive heat buildup.				X

BUILDING CONTROLS

Description	Comments	Maintenance Frequency			
		Daily	Weekly	Semi-Annual	Annually
Overall visual inspection	Complete overall visual inspection to be sure all equipment is operating and safety systems are in place	X			
Verify control schedules	Verify in control software that schedules are accurate for season, occupancy, etc.	X			
Verify setpoints	Verify in control software that setpoints are accurate for season, occupancy, etc.	X			
Time clocks	Reset after every power outage	X			
Check all gauges	Check all gauges to make sure readings are as expected		X		
Control tubing (pneumatic system)	Check all control tubing for leaks		X		
Check outside air volumes	Calculated the amount of outside air introduced and compare to requirements		X		
Check setpoints	Check setpoints and review rational for setting		X		
Check schedules	Check schedules and review rational for setting		X		
Check deadbands	Ensure that all deadbands are accurate and the only simultaneous heating and cooling is by design		X		
Check sensors	Conduct thorough check of all sensors - temperature, pressure, humidity, flow, etc. - for expected values			X	
Time clocks	Check for accuracy and clean			X	
Calibrate sensors	Calibrate all sensors: temperature, pressure, humidity, flow, etc.				X

APPENDIX F – CODES AND STANDARDS

- The American Institute of Architecture's 2006 Guidelines for Design and Construction of Health Care Facilities
- ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy
- ASHRAE Standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality
- ASHRAE Standard 90.1-2007, Energy Standards for Building Except Low-rise Residential Buildings
- ASHRAE Standard 170-2008, Ventilation for Health Care Facilities
- Joint Commission International Accreditation Standards for Hospitals
- Unified Facilities Code 4-510-01, Medical Military Facilities
- Unified Facilities Code 4-010-01, DoD Minimum Antiterrorism Standards

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