# Fort Bragg Energy Management Program DRAFT

## 1 Introduction

1.1 The intent of this program is to increase Energy Security on Fort Bragg while being committed to purchasing and consuming energy in the most efficient, cost effective, and environmentally responsible manner possible. It is the intent of this program to require immediate and sustained action, otherwise Fort Bragg will continue on an irrevocable path of ever increasing demands on limited energy resources and diversion of funds that could be used for other critical mission requirements. Improving energy efficiency should translate into millions of dollars of avoided costs for Fort Bragg and help move our nation towards energy independence.

1.2 This program will address all building criteria that can affect the use or misuse of energy. Each appendix is intended to be used as a specification or guide to help you understand the Laws, processes and technologies that have been tested, implemented and approved here at Fort Bragg.

## 2 References

- Energy Policy Act of 2005, Public Law 109-58, 8 Aug 05
- Energy Independence and Security Act of 2007, 19 Dec 07
- Executive Order 13123, 8 Jun 99 (Revoked by E.O. 13423 - OSD continuing some reporting requirements)
- Executive Order 13423, Strengthening Federal Environmental, Energy and Transportation Management (Jan 2007)
- Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance, (OCT 09)
- OSD Memo – Installation Energy Policy Goals, 18 Nov 05
- DODI 4170.11 – Installation Energy Management, 22 Nov 05
- AR 420-1 – Army Facilities Management, 2 Nov 07
- Army Energy Strategy for Installations, 8 July 2005
- Army Energy & Water Campaign Plan for Installations, 1 Dec 07
- Unified Facilities Criteria (UFC) 3-400-1, Including Change 4, August 2008
- US Department of Energy (DOE) and US Environmental Protection Agency (EPA) Energy Star® Program
- Unified Facilities Criteria (UFC) 3-410-01FA, Including Change 3, August 2008
- American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 62.1 -2004
- United States Green Building Council (USGBC) Leadership in Energy and Environmental Design Rating System (LEED)
- Unified Facilities Guide Specifications (UFGS) 23 09 23

## 3. Energy Conservation Overview

3.1 All new Army facilities and all major renovations of existing Army facilities shall comply with the requirement of EPACT 2005 to reduce energy consumption by 30% compared to a facility designed in accordance with ASHRAE 90.1-2004. Building modifications should be classified as a major renovation if the cost of renovation project exceeds 25% of the building value with the project including all or some of the following elements: alteration of overall features of the building's envelope, substantial replacement of the building's lighting, plumbing, electrical, and heating, ventilating, and air conditioning (HVAC) systems in combination with other significant alterations of the building's spaces. Other modifications to a building may be categorized as a major renovation depending on the overall magnitude and scope of the work to be accomplished. Buildings classified as major renovation projects will comply with all energy and water conservation requirements (EO 13423), and all methods and standards applicable to new construction. All building components and systems being renovated or replaced must comply with their respective energy and water conservation criteria. Major upgrades to "new building" energy and water conservation levels should be planned for funding as early as possible on DD Form 1391. Funding requirements to implement energy and water conservation measures will be an integral part of the concept design.

3.2. The target energy consumption budget (excluding plug and process loads) developed in compliance with the requirements of EPACT 2005 for selected tier 1 Army facilities and different DOE Climate Zones in kBtu per $ft^2$ per year not to be exceeded are listed in the *Chapter 3 Energy Conservation Appendix 1.2*. The use of the Prescriptive Technology Solution Set, listed in the Energy Appendix, will result in an annual energy consumption less than or equal to the target energy budget figure, meets life cycle cost effectiveness requirements and does not require calculations according to the ASHRAE Standard 90.1 Appendix G. When Prescriptive Technology Solution Sets are used, mandatory requirements of the ASHRAE Standard 90.1-2007 shall also be met. For the building types addressed in the *Chapter 3 Energy Conservation Appendices 14-17*, requirements of the EPACT 2005 can be also met using designer developed specific .technology sets. In this case to prove that target energy consumption budgets are met, calculations prescribed in the ASHRAE Standard 90.1 Appendix G shall be performed and life cycle cost effectiveness analysis be provided.

3.3. Energy efficient and sustainable building design shall be a collaborative and coordinated effort of architects, electrical, mechanical and structural engineers. It can not be achieved through analysis and optimization of the individual components and subsystems. A holistic "whole building" design approach shall collaboratively integrate different building elements and systems to optimize the overall project sustainability, water and energy efficiency. Creative design of the building floor plan and configuration, envelope, orientation and fenestration can minimize energy needed to ventilate, condition and light the facility. Integration of the mechanical systems design must be coordinated with the designs of other involved building systems and features including the building envelope, lighting system, and occupant activities. Understanding how one system (or individual components within a given system) affects another is essential to making the most of the available opportunities for energy savings.

3.4. A building's cooling and heating needs are affected by the performance of interrelated building systems and characteristics, including building envelope characteristics; passive solar design elements, such as daylighting, lighting systems, plug-in and other internal loads. The appropriate HVAC design solution shall be determined only after the requirements and contributing thermal loads of these interrelated systems have been thoroughly reviewed and all possible efficiency gains through sustainable design strategies have been carefully considered.

3.5 In all new Army facilities and all major renovations only Energy Star or FEMP designated products shall be used. The term "Energy Star product" means a product that is rated for energy efficiency under an Energy Star program. The term "FEMP designated product" means a product that is designated under the Federal Energy Management Program of the Department of Energy as being among the highest 25 percent of equivalent products for energy efficiency. When selecting integral sized electric motors, choose NEMA PREMIUM type motors that conform to NEMA MG 1, minimum Class F insulation system. Motors with efficiencies lower than the NEMA PREMIUM standard may only be used in unique applications that require a high constant torque speed ratio (e.g., inverter duty or vector duty type motors that conform to NEMA MG 1, Part 30 or Part 31).

3.6. Building envelope insulation is critical in reducing heating and cooling loads throughout the year round performance. Levels of the building envelop insulation for new construction and major renovation shall meet requirements listed in The *Chapter 3 Energy Conservation Appendix 3.1*

3.7. Windows are a critical design component of an energy efficient and sustainable building envelope. They affect the building's thermal performance as well as provide natural daylight to enter the structure. Windows for new Army facilities and major renovations shall meet requirements specified in the *Chapter 3 Energy Conservation Appendix 3.2*

3.8. Building envelopes for new office buildings, office portions of mixed office and open space (e.g., company operations facilities), dining, barracks and instructional/training facilities and undergoing major renovations shall be designed and constructed with a continuous air barrier to control air leakage into, or out of, the conditioned space. Mandatory requirements for the continuous air barrier design and construction are provided in *Chapter 3 Energy Conservation Appendix 3.5*

Performance of the continuous air barrier for the opaque building envelope shall be demonstrated by the following tests:

(a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25cfm/ft2 at a pressure differential of 0.3" w.g. (75 Pa) in accordance with ASTM's E 779 (2003) or E-1827-96 (2002). Accomplish tests using either pressurization or depressurization or both. Divide the volume of air leakage in CFM @ 0.3" w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to

produce the air leakage rate in cfm/ft2 @ 0.3” w.g. (L/s.m2 @ 75 Pa). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner.

(b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997). Determine air leakage pathways using ASTM E 1186-03 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems, and perform corrective work as necessary to achieve the whole building air leakage rate specified in (a) above. (c) Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.

3.9. Lighting systems in new, retrofitted or acquired buildings shall have the correct light level for the tasks being performed (*Chapter 3 Energy Conservation Appendix 2.3*) and be equipped with Energy Star or FEMP designated lighting technologies.

3.10 Energy conservation and sustainability criteria for new and renovated Army facilities are shown in the *Chapter 3 Energy Conservation Appendix 1.3*.

3.11 New buildings and buildings undergoing major renovations shall 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 (as measured by Commercial Buildings Energy Consumption Survey or Residential Energy Consumption Survey data from the Energy Information Agency), by the percentage specified in the following table [EISA2007]:

| Fiscal Year | Percentage Reduction |
|---|---|
| 2010 | 55 |
| 2015 | 65 |
| 2020 | 80 |
| 2025 | 90 |
| 2030 | 100 |

Unless it is demonstrated not to be LCC effective, reduce energy consumption beyond the requirement of EPACT 2005 (Section 1.18.1) and use renewable energy to the extent specified in the above table.

3.12. Not less than 30 percent of the hot water demand for each new Federal building or Federal building undergoing a major renovation will be met through the installation and use of solar hot water heaters [IESA 2007] unless demonstrated to not be lifecycle cost-effective. The amount that is cost effective will be installed.

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**Appendix 1: Fort Bragg Energy Policy Letter 53**

a. Purpose: To establish Energy Security policies and procedures for Fort Bragg.

b. Mission: To increase Energy Security on Fort Bragg while being committed to purchasing and consuming energy in the most efficient, cost effective, and environmentally responsible manner possible. It is the intent of this policy to require immediate and sustained action, otherwise Fort Bragg will continue on an irrevocable path of ever increasing demands on limited energy resources and diversion of funds that could be used for other critical mission requirements. Improving energy efficiency even by only a small amount would translate into millions of dollars of avoided costs for Fort Bragg and help move our Nation towards energy independence.

c. Applicability**:** This policy applies to all units, and activities assigned, attached or tenant on Fort Bragg. Organizations shall improve energy efficiency continuously by establishing and implementing effective energy management programs which support all operations while providing a safe and comfortable work environment. Fort Bragg will also follow all applicable regulations and requirements for energy consumption in facilities.

d. General**:** It is an objective of Fort Bragg to use energy efficiently and provide energy security throughout the organization for both immediate and long range plans by following the Army's Energy Strategy and Army Energy Security Implementation Strategy (AESIS). All energy consuming entities on Fort Bragg will pursue with, success in mind, the five pillars of this plan to provide sustainable energy support to the Army Energy Goals. Army Energy Goals are to:

(1) ESG 1 Reduce Energy Consumption
(2) ESG 2 Increase Energy Efficiency Across all Platforms and Facilities
(3) ESG 3 Increase the use of Renewable and Alternative Energy
(4) ESG 4 Assure Access to Sufficient Energy Supply
(5) ESG 5 Reduce adverse Impacts on the Environment

e. Responsibility**:**

1. The Fort Bragg Management Program will be administered through the Directorate of Public Works (DPW).

2. The Energy Manager will:

    a. Report directly to the Director of the DPW.

    b. Have overall responsibility for carrying out the Energy Management Program.

    c. Appoint an Energy Committee to be comprised of representatives from various departments and activities.

    d. Provide energy training at all levels of the company.

e. Conduct an annual review of this policy and make recommendations for updating.

f. Energy Committee Members will:

    i. Serve for one year and may be reappointed at the discretion of the Energy Manager.

    ii. Meet quarterly to advise the Energy Manager on the operation of the Energy Management Program, and to provide assistance on specific tasks when needed.

    iii. Conduct an annual review of this policy and make recommendations for updating.

g. Energy Coordinators. Also known as Building Energy Monitors (BEM) will be appointed to facilities across Fort Bragg. The Energy Manager will establish minimum qualification standards for BEMs, and will have joint approval authority for each BEM appointed.

h. BEMs will:

    i. Be responsible for maintaining an ongoing awareness of energy consumption and expenditures in their assigned areas.

    ii. Recommend and implement energy conservation projects and energy management practices.

    iii. Provide necessary information for reporting from their specific areas into the Energy Star Portfolio Manager.

    iv. Be assigned on a full-time or part-time basis; as required to implement programs in their areas.

    v. Keep the Energy Office advised of all efforts to increase energy efficiency in their areas. A summary of energy cost savings shall be submitted each quarter to the Energy Office.

i. Reporting will be in accordance with ESIA 2007 Sec 432:

    i. Metering for all facilities.

    ii. Benchmarking in EnergyStar Portfolio Manager.

    iii. Demonstrate the success of energy reduction measures.

**Appendix 2: Fort Bragg Memorandum of Information**

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Army Energy Conservation

1. PURPOSE. To set forth the installation policy and understanding concerning the commitment to consuming energy in the most efficient, cost effective, and environmentally responsible manner possible and to provide guidance for accountability of the Army civilian and military personnel to eliminate energy waste, reduce dependence on fossil fuels and improve energy security. It is an objective of Fort Bragg to use energy efficiently and provide energy security throughout the organization for both immediate and long range plans by following the Army's Energy Strategy and Army Energy Security Implementation Strategy (AESIS). All energy consuming entities on Fort Bragg will pursue with, success in mind, the five pillars of this plan to provide sustainable energy support to the Army Energy Goals.

ESG 1 Reduce Energy Consumption
ESG 2 Increase Energy Efficiency Across all Platforms and Facilities
ESG 3 Increase the use of Renewable and Alternative Energy
ESG 4 Assure Access to Sufficient Energy Supply
ESG 5 Reduce adverse Impacts on the Environment

2. APPLICABILITY:

a. This policy applies to all Fort Bragg units/activities, including tenants who shall improve energy efficiency continuously by establishing and implementing effective energy management programs which support all operations while providing a safe and comfortable work environment. Fort Bragg will also follow all applicable regulations and requirements for energy consumption in facilities.

3. REFERENCES:

a. E.O. 13423 and 13

b. AR 420 Facilities

c. All other applicable DoD Issuances

d. Army Strategy for Installations

e. Energy Policy Act of 2005

f. Energy Independence and Security Act 2007

g. Fort Bragg Energy Policy 53

4. GENERAL:

a. Energy in all facilities will be measured and proven reductions per square foot of space compared to the 2003 baseline will comply with the following schedule:

| Fiscal Year | Percent Reductions |
|---|---|
| 2006 | 2 |
| 2007 | 4 |
| 2008 | 9 |
| 2009 | 12 |
| 2010 | 15 |
| 2011 | 18 |
| 2012 | 21 |
| 2013 | 24 |
| 2014 | 27 |
| 2015 | 30 |

b. The Energy Policy Act of 2005 (EPACT2005)requires the DoD to report annually on the energy consumption of Federal buildings to the DOE.

c. When appropriate, all Headquarters Department of the Army Principal Officials, Commanders or Directors of Army Commands, Army Service Component Commands, and Direct reporting Units will ensure that energy considerations are included in the functional responsibilities of their agencies, staffs, and commands, and in turn, in the functional responsibilities of their subordinate elements Army-wide.

d. Army tenant commanders and civilian supervisors will comply with and support the host installation's energy program and ensure at a minimum, individual actions included in the interim policy guidance are implemented.

5. Tasks:

a. Prevent infiltration which is heat lost or gained due to outside air entering a building through cracks around windows, doors, and through the outside shell of the structure. Not only does it cause discomfort to building occupants, it is also a major contributor to unnecessary heating and cooling costs and energy losses.

i. Ensure that all outside doors remain closed, especially during the heating and cooling seasons.

ii. Ensure that all windows remain closed!

iii. Keep the doors closed to prevent infiltration to conditioned spaces in buildings with unconditioned rooms or areas

iv. Initiate a work order for the installation of dock curtains for loading docks if they are not present

v. You should periodically check the weather stripping and caulking. If it is old and dried or peeing, be sure to submit a work order for repairs.

vi. Inspect for air leakage in and around electrical outlets. Rubber inserts are generally available through self-help to seal any leaky outlets.

vii. If you find a crack and notice that there was never any weather stripping or caulking, suggest that it be installed. Some caulking and weather stripping are self-help. Check with DPW

viii. If the building is drafty, check to see if there is insulation in the attic (if there is one), or in the walls to the exterior. If there is none, report your findings to DPW.

ix. If you see cracked or missing windows, be sure to submit a work order for their immediate repair.

x. You may notice cracks or openings in the outside of the building, such as the joint where the foundation meets the siding or wherever exterior walls are penetrated by pipes, ducts, and conduits. Such openings are great candidates for caulking or spray foam.

xi. If your building has many entrances suggest closing some off—if the fire laws would permit.

xii. If people open their windows it may be an indication of a broken control system. Check to see if repairs are needed.

b. Ventilation has a significant impact on a building's total energy consumption. Each unit of air brought into your facility must be heated or cooled and, in some cases, humidified or dehumidified. If excess air, beyond that required for the comfort and safety of your buildings occupants is brought in a considerable waste of energy is inevitable.

i. Ventilation units should only be operate as needed. Consider shutting them off to any area that will remain unoccupied

ii. Replace or Repair the faulty air dampers

iii. Timers should be installed on the system where special ventilation needs are required.

iv. If economically feasible motion sensors or timers should place in areas such as toilets so that the fans and lights there are not energized all the time.

v. Check crawl space ventilators to assure they're open in the summer and closed in the winter.

c. Hot water generation and its consumption often account for up to ten percent of a building's energy use, more if your building has a dining facility, cafeteria, or laundry. There are many opportunities for saving energy here, but most will require the installation of new equipment. This work should be done together

with the Energy Manger. All appliances purchased for federal facilities must be Energy Star Rated

i. Self-closing faucets should be installed on hot water taps.

ii. Spray-type faucets with flow restrictions

iii. Insulation should be in good condition on hot water piping and tanks

iv. Repair all leaks, including those at the faucet

v. Shut off hot water pumps when the building is unoccupied

vi. Solar Thermal Energy should be considered where applicable in all renovations and new construction

d. The heating and cooling systems make up the largest energy consuming group in buildings, therefore the greatest energy savings can arise from cutting waste. Much of these savings are developed at the central plant on your installation. However, not all buildings receive their heating and cooling from the central plant and there are many operational items that you should keep in mind: your building is a unique combination of systems—heating, cooling, and ventilation.

i. Radiators or heating resisters should be shut off completely in vestibules, corridors, stairwells and lobbies.

ii. All buildings should have thermostats that are capable of night and weekend setback.

iii. If your building is used afterhours, recommend that the areas occupied be very limited to assure that you do not heat the entire building unnecessarily.

iv. Make sure that the thermostats in your building are tamperproof. Recommend installing cover locks if necessary.

v. During particularly cold weather, encourage your building's occupants to wear warm clothing.

vi. Change Air filters Monthly

vii. Keep foliage and plants out of air intakes and air exhausts.

e. Temperature Settings are as follows:

i. During the heating season, temperatures in occupied facilities will be maintained in the range of 70°-74° degrees Fahrenheit during working hours and heating setback temperatures during unoccupied times shall be set at 50°-60° degrees Fahrenheit. Temperatures in warehouses and similar active working spaces, like maintenance bays, will be at

55°-65° degrees Fahrenheit during occupancy and 40°-50° Fahrenheit during unoccupied periods. Warehouses will not be heated if they are usually devoid of human activity and if freezing and condensation are not issues. Wherever mechanical cooling is authorized, cooling season temperatures for occupied working and living spaces shall be maintained in the range 72°-76° degrees Fahrenheit. Cooling set-up temperatures during unoccupied times shall be set at 80°-90° degrees Fahrenheit. Space temperature for medical and medical research operations will comply with these standards unless exempted by UFC 4-510-01. Museum activities recognized by the Center of Military History will maintain heating and cooling in accordance with AR 870-20.

f. Electrical lighting is a major energy consumer on Army installations. This is partially due to the fact that many of our existing buildings were designed without knowledge about final space use and without the benefit of recent developments in high efficiency lighting systems.

    i. Mark all switches so that occupants will remember to turn off the lights

    ii. lights should be out if not needed in storage rooms, vending machines, meeting rooms, bulletin boards, unassigned areas

    iii. Make sure that building lights are turned off when the facility is unoccupied except those needed for security

    iv. Lighting fixtures, especially around fluorescent lamps, should be kept clean

    v. Interior building walls should be kept clean and painted using light colored paint

    vi. If lighting in offices or corridors seems excessive, ask for a lighting survey to tell if the lighting is appropriate or could be reduced

    vii. Areas which have sufficient natural light during sunny days could benefit from light sensors to turn off unneeded lights

    viii. There are many high efficiency lamps available for use. Suggest that these replace the old ones that burn out

    ix. Suggest to building occupants that they use “task” lighting if additional illumination is needed for their work

g. All facilities shall be reporting energy consumption in Energy Star Portfolio Manager - Contact Energy Manager for details and instruction. All facilities will

appoint Energy Coordinators also know as Building Energy Monitors (BEM). Each facility on Fort Bragg will have a BEM assigned to monitor energy usage. The Energy Manager shall establish minimum qualification standards for BEM, and shall have joint approval authority for each BEM appointed.

h. BEMs shall be responsible for maintaining an ongoing awareness of energy consumption and expenditures in their assigned areas. They shall recommend and implement energy conservation projects and energy management practices.

i. BEMs shall provide necessary information for reporting from their specific areas into the Energy Star Portfolio Manager. They may be assigned on a full-time or part-time basis; as required to implement programs in their areas.

6. RESPONSIBILITIES:

a. The Agency will make the terms of this Memorandum known by publication.

b. Exceptions to this policy may exist for medical facilities.

## Appendix 3: Energy Polices and Army Requirements to Energy Use

### Appendix 3.1: Current Polices and Directives on Energy Conservation

New and existing Federal buildings will be more energy efficient. There are many policies, regulations, executive orders, and legislative mandates driving both energy conservation and green buildings to make it feasible to ignore energy conservation.

The three most significant drivers of energy efficiency in the DOD and other Federal buildings are (listed chronologically):

- The Energy Policy Act of 2005
- *Army Energy Strategy for Installations* of 2005
- Executive Order 13423
- The Energy Independence and Security Act of 2007

3.1.1. The Energy Policy Act of 2005 has 11 sections in Title 1 – Energy Efficiency, Subtitle A – Federal Programs that impact Federal agencies. See http://thomas.loc.gov/cgi-bin/bdquery/z?d109:h.r.00006: for complete text. From a building manager standpoint, the important requirements are:

- Percentage reduction in buildings energy use (Section 102)
- Energy use measurement (Section 103)
- Procurement of energy efficient products (Section 104)
- Use of energy saving performance contracts (Section 105)
- Voluntary reductions in industrial energy intensity (Section 106)
- Increased use of recovered mineral component in projects involving cement or concrete (Section 108)
- New Federal building energy efficiency and sustainability standards (Section 109)

3.1.2. Executive Order 13423 – Strengthening Federal Environmental, Energy, and Transportation Management – provides a number of goals for agencies in Section 2. See http://www.whitehouse.gov/news/releases/2007/01/20070124-2.html for complete text. Many of these goals are relevant to building managers, including:

- Improve energy efficiency and reduce greenhouse gas emissions
- Increase renewable energy use
- Reduce water consumption intensity
- Use of sustainable environmental practices
- Reduction of hazardous and toxic chemical disposal
- Use of the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings set forth in the Federal Leadership in High Performance and Sustainable Building Memorandum of Understanding

3.1.3. The Energy Independence and Security Act of 2007 has 9 sections that impact Federal agencies in Title 1 - Energy Savings in Buildings and Industry, Subtitle C – High Performance Federal Buildings. See http://thomas.loc.gov/cgi-

bin/bdquery/z?d110:h.r.00006: for complete text. From a building manager standpoint, the important requirements are:

- Increased percentage reduction in buildings energy use (Section 431)
- Energy and water evaluations every four years (Section 432)
- Identification of commissioning and retro-commissioning opportunities (Section 432)
- Use of an energy benchmarking system (Section 432)
- Fossil fuel reduction targets for selected buildings (Section 433)
- Requirement that capital energy investments that are not major renovations be life cycle cost-effective (Section 434)
- Requirement for Energy Star label on leased buildings (Section 435)
- Audits of Federal green building performance (Section 437)
- Specific requirement for storm water runoff on facilities more than 5000 square feet in footprint (Section 438)
- Increase in public building lifetime from 25 to 40 years (Section 441)

3.1.4. Army Energy Strategy for Installations. The Strategy sets the general direction for the Army in five major initiatives (http://army-energy.hqda.pentagon.mil/programs/plan.asp) :

- Eliminate energy waste in existing facilities
  Eliminate and reduce energy inefficiencies that waste natural and financial resources, and do so in a manner that does not adversely impact comfort and quality of the facilities in which Soldiers, families, civilians and contractors work and live.
- Increase energy efficiency in new construction and renovations
  Increase the use of energy technologies that provide the greatest cost-effectiveness, energy efficiency and support environmental considerations.
- Reduce dependence on fossil fuels
  Increase the use of clean, renewable energy to reduce dependency on fossil fuels and to optimize environmental benefits and sustainability.
- Conserve water resources
  Reduce water use to conserve water resources for drinking and domestic purposes.
- Improve energy security
  Provide for the security and reliability of energy and water systems in order to provide dependable utility services.

The Strategy sets forth the Army's energy goals for 25 years and the Campaign Plan defines the intermediate actions, approaches, initiatives, and funding over the 25 years to ensure the Army successfully achieves long-range energy and water management goals. The Army Energy and Water Campaign Plan for Installations was implemented in late 2005 and used in the FY 2008-2013 POM development process. This version is the current update to support the FY 2010-2015 POM development. The Army Energy and

Water Campaign Plan will be reviewed for updates every two calendar years during odd years.

The bottom line from all these documents is that the Army and other Federal buildings will be built to be more efficient and more sustainable, that these buildings' energy usage will decrease, and that design engineers, contractors and building managers are expected to play an active role in reducing energy and water usage.

## Appendix 3.2: Legislative Requirements for Energy (Construction) 2009

| | |
|---|---|
| ☐ | **Federal Building Performance Standards:** Minimum 30% more energy efficient than current ASHRAE or IECC standards; and Sustainable design principles are applied to the siting, design, and construction of all new and replacement buildings<br>EPAct05, sec 109 [Public Law 109-58]; 10 CFR 433; 10 CFR 435;<br>**OR** 20% below the FY2003 baseline for major renovations<br>EO 13423 sec 2(f)/ OAA 09, sec 748, [sec HPSB] |
| ☐ | **High Performance and Sustainable Building Guidance (HPSB):**<br>i) Beginning in 2020, ensure that all new buildings are designed to achieve net-zero-energy by 2030 (EO 13514, sec. 2(g))<br>ii) new construction, major renovations, and repairs/alterations must comply with Guiding Principles (Optimize Energy Performance: energy efficiency, on-site renewable energy, measurement and verification and benchmarking) and<br>iii) 15% of existing building inventory by end of FY2015 incorporates outlined sustainable practices<br>EO 13423, sec 2(f)/OAA 09, sec 748 |
| ☐ | **Day-lighting:** Achieve a minimum daylight factor of 2% in 75% of all spaces occupied for critical visual tasks.<br>EO 13423, sec 2(f) |
| ☐ | **Ventilation and Thermal Comfort:** meet or exceed the requirements of ASHRAE 55-2004<br>EO 13423, sec 2(f) /OAA 09, sec 748 |
| ☐ | **Moisture Control:** establish and implement a moisture control strategy<br>EO 13423, sec 2(f) /OAA 09, sec 748 |
| ☐ | **Protect Indoor Air Quality:** Follow the recommended approach of the Sheet Metal and Air Conditioning Contractor's National Association Indoor Air Quality Guidelines for Occupied Buildings under Construction, 2007<br>EO 13423, sec 2(f) /OAA 09, sec 748 |
| ☐ | **Commissioning:** Employ total building commissioning practices tailored to the size and complexity of the building<br>EO 13423, sec 2(f)(i), HPSB MOU (2006) |
| ☐ | **Meters:** Electric, natural gas and steam meters installed<br>EPAct05, sec 103[Public Law 109-58] & EISA07, sec 434 [Public Law 110-140] |
| ☐ | **Solar Hot Water**: 30% of hot water demand must be from solar hot water heaters<br>EISA07, sec 523 [Public Law 110-140] |
| ☐ | **Fossil Fuels:** New buildings must reduce fossil fuel-generated energy consumption, with 2003 as baseline, by 55% in 2010 and 100% by 2030<br>EISA07, sec 433 [Public Law 110-140] |
| ☐ | **Tax Incentives** are transferred to the Designer for Federal Buildings; $0.30-$1.80 per square foot, depending on technology and amount of energy reduction.<br>H.R. 1424: Div. B, Sec 303 (The Energy Improvement and Extension Act of 2008); 26 USC § 179D. Energy efficient commercial buildings deduction. |
| ☐ | **Energy Efficient Light bulbs**: establishes energy efficiency standards for general service incandescent lamps. Bans most incandescent bulbs by 2012. Natural lighting will be considered whenever possible; cost-effective lighting<br>EISA 2007, sec Public Law 110-140 Title IV 121 Stat. 1597 |
| ☐ | **Energy Efficient Products:** Federal procurement of only Energy Star or FEMP designated products<br>EPAct05, sec 104; EISA07, sec 525 [Public Law 110-140]; if not, then when replacing equipment, renovating, etc., use the most energy efficient designs that are life-cycle cost effective<br>EISA07 sec 434 |
| ☐ | **HVAC:** Direct Digital Control (DDC) <u>required</u> when upgrading, retrofitting or replacement of HVAC systems (FAR part 23). |
| ☐ | **Lighting:** Natural lighting will be considered whenever possible; cost-effective lighting (ESIA 2007 Public Law 110-140 Title IV 121 Stat. 1597). General service incandescent lamps: compact fluorescent lamps and LED (ESIA 2007 Public Law 110-140 Title 3 Subtitle B 121 Stat. 1576) |
| ☐ | **Life Cycle Cost Analysis:** This Section amends 42 USC 8254(a)(1) to change 25 years to 40 years;<br>EISA 07 Sec 441 [Public Law 110-140]; 10 CFR 436 |

## Legislative Requirements for Energy (Construction) 2009

**Federal Building Performance Standards:** Section 109 of EPAct 2005 required new federal buildings to be designed 30% below ASHRAE standards or IECC, to the extent that technologies employed are life-cycle cost-effective, and Sustainable Design Principles, EPAct05, sec 109 establishes''(i) if life-cycle cost-effective for new Federal buildings— ''(II) sustainable design principles are applied to the siting, design, and construction of all new and replacement buildings;" Sustainable Design Principles (SDD) are those outlined by the DoA, USACE, DoE, EPA, and on the WBDG W3 site (http://www.wbdg.org/index.php) .
**High Performance and Sustainable Building:** EO 13423, sec 2(f) [OAA 09, sec, states that design principles must be applied to new and replacement buildings. All agencies must identify new building projects in their budget requests and identify those that meet or exceed the standard. To help achieve these energy reductions, new construction and major renovation of agency buildings must comply with the "Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings" set forth in the *Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006)*, (High Performance and Sustainable Buildings Guidance, Final, 12/01/08 http://www.wbdg.org/pdfs/hpsb_guidance.pdf -) in addition to the energy goals and standards established by the federal Energy Policy Act of 2005. These building standards include a target energy use of 30% below the average building performance for new buildings (includes plug load, p. 6, HPSB), and a target that is 20% below the average for renovations. (Includes day-lighting, ventilation and thermal comfort, moisture control, protect indoor air quality and commissioning**.** EO 13423, sec 2(f) (i), HPSB MOU (2006).
**Meters:** EPAct05, sec 103, ''(e) METERING OF ENERGY USE.—''(1) DEADLINE.—By October 1, 2012, in accordance with guidelines established by the Secretary under paragraph (2), all Federal buildings shall, for the purposes of efficient use of energy and reduction in the cost of electricity used in such buildings, be metered. Each agency shall use, to the maximum extent practicable, advanced meters or advanced metering devices that provide data at least daily and that measure at least hourly consumption of electricity in the Federal buildings of the agency.
**Solar Hot Water:** Section 523 of the EISA 2007 requires that at least 30% of the hot water demand for each new federal building or existing federal buildings undergoing a major renovation be met through the use of solar hot water heating, if it is determined to be life-cycle cost-effective.
**Fossil Fuels:** EISA07, sec 433. For new buildings or building undergoing major renovations requiring a GSA prospectus to Congress or at least $2.5 million, fossil fuels use to be reduced as compared to a similar building's use in FY 2003; percentages may be adjusted downward and sustainable design principles shall be applied. 55% by 2010; 65% by 2015; 80% by 2020; 90% by 2025; and 100% by 2030.
**Energy Efficient Products:** Section 104 of EPAct 2005 directed federal agencies to purchase Energy Star and FEMP-designated products when procuring energy-consuming items covered by the Energy Star program, except when purchasing such items is not cost-effective or does not meet functional requirements of the agency. Agencies must also incorporate energy-efficient specifications in procurement bids and evaluations, and must only purchase premium efficient electric motors, air conditioning and refrigeration equipment. EISA 07 Section 525 requires Federal procurement to focus on ENERGY STAR and FEMP-designated products.
**Energy Efficient Lighting:** EISA2007, sec 321, **Subtitle B—Lighting Energy Efficiency, Sec. 321. Efficient Light Bulbs.** The Act establishes energy efficiency standards for general service incandescent lamps by modifying applicable sections of the Energy Policy and Conservation Act. Starting January 1, 2012, all general-service lamps must prove a minimum CRI, general service incandescent lamps must prove a minimum efficiency, and some incandescent lamps cannot exceed a maximum wattage.

**Tax Incentives:** H.R. 1424: Div. B, Sec 303 (The Energy Improvement and Extension Act of 2008); 26 USC § 179D. Energy efficient commercial buildings deduction. A tax deduction of $1.80 per square foot is available to owners of new or existing buildings who install (1) interior lighting; (2) building envelope, or (3) heating, cooling, ventilation, or hot water systems that reduce the building's total energy and power cost by 50% or more in comparison to a building meeting minimum requirements set by ASHRAE Standard 90.1-2001. Energy savings must be calculated using qualified computer software approved by the IRS. *In the case of energy efficient systems installed on or in government property, tax deductions will be given to the person primarily responsible for the systems' design.* Deductions are taken in the year when construction is completed.
http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=US40F&State=federal&currentpageid=1&ee=1&re=1
**Life Cycle Cost Analysis:** EISA 07 sec 441**.** PUBLIC BUILDING LIFE-CYCLE COSTS**.** Section 544(a)(1) of the National Energy Conservation Policy Act (42 U.S.C. 8254(a)(1)) is amended by striking ''25'' and inserting ''40''.)**:** Establishment of life cycle cost methods and procedures – The Secretary, in consultation with the Director of the Office of Management and Budget, the Secretary of Defense, the Director of the National Institute of Standards and Technology, and the Administrator of the General Services Administration, shall– (1) establish practical and effective present value methods for estimating and comparing life cycle costs for Federal buildings, using the sum of all capital and operating expenses associated with the energy system of the building involved over the expected life of such system or during a period of 40 years, whichever is shorter, and using average fuel costs and a discount rate determined by the Secretary; and (2) develop and prescribe the procedures to be followed in applying and implementing the methods so established.

## Appendix 3.3: Legislative Requirements for Energy (Non-construction) 2009

| | |
|---|---|
| ☐ | **Energy Reduction Goals:** Buildings must reduce by 3% annually the energy consumed, ending with a 30% reduction by 2015 using 2003 as a baseline.<br>OAA 09, sec 748 (EO13423, sec. 2(a)) & ESIA07, sec431 |
| ☐ | **Facility Energy Manager Requirements**: Agencies must identify all "covered facilities" that constitute at least 75% of the agency's facility energy use. An energy manager must be designated for each of these covered facilities. Each facility energy manager will be responsible for:<br><br>☐ Completing comprehensive energy and water evaluations of 25% of covered facilities each year, so that an evaluation of each facility is completed at least once every four years.<br>☐ Following up on implemented measures, including fully commissioning equipment, putting operation and maintenance (O&M) plans in place, and measuring and verifying energy and water savings.<br>☐ Using a DOE Web application to certify and track compliance for energy and water evaluations, project implementation and follow up measures, and estimated cost and savings. The Web application will be available to Congress, other Federal agencies, and the public, with some specific data exempted from disclosure for national security purposes.<br>☐ Entering energy use data for each metered building into a benchmarking system, such as the ENERGY STAR® Portfolio Manager<br><br>EISA 2007, sec 432 |
| ☐ | **Renewable energy**: consumption must be a minimum of 3% in FY07-09; 5% in FY 10-12; 7.5% in Fy2013+<br>EPAct05, sec 203 [Public Law 109-58] |
| ☐ | **Renewable energy consumed**: 50% of should come from new renewable sources and implement RE generation projects on the installation<br><br>OAA 09-EO13423, sec 2(b); HPSB, p. 11 |
| ☐ | **ESPC/UESC:** Energy Savings in Government and Public Institutions, ESPC – prohibits agency policy limiting contract length to <25 years (EISA 07, Title V, subtitle B) |
| ☐ | **Sustainable Practices:** 15% of the existing Federal capital asset building inventory of the agency as of the end of fiscal year 2015 incorporates the sustainable practices in the **Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings**<br><br>OAA 09 -E.O. 13423, sec 2(f) |
| ☐ | **Retention of Savings:** Section 546(c) of the National Energy Conservation Policy Act (42 U.S.C. 8256(c)) is amended by striking paragraph (5). 50% of the energy and water costs savings can be used at the installation level<br>EISA07, SEC. 516 |
| ☐ | **Electronics:** The Electronic Product Environmental Assessment Tool (EPEAT) requires that federal agencies to ensure that 95% or more of all computers purchased are qualified under the EPEAT green computer purchasing standard; Ensure that the agency enables the Energy Star feature on agency computers and monitors<br>EO 13423, sec 2 (h) ; 72 Federal Regulation 73215 December 26, 2007, |

## Legislative Requirements for Energy (Non-construction) 2009

**Energy Intensity Reduction**: EO 13423, sec 2 (a) improve energy efficiency and reduce greenhouse gas emissions of the agency, through reduction of energy intensity by (i) 3 percent annually through the end of fiscal year 2015, or (ii) 30 percent by the end of fiscal year 2015, relative to the baseline of the agency's energy use in fiscal year 2003

**Renewable Energy:** EPAct 05, sec 203 (a) REQUIREMENT.—The President, acting through the Secretary, shall seek to ensure that, to the extent economically feasible and technically practicable, of the total amount of electric energy the Federal Government consumes during any fiscal year, the following amounts shall be renewable energy: (1) Not less than 3 percent in fiscal years 2007 through 2009. (2) Not less than 5 percent in fiscal years 2010 through 2012. (3) Not less than 7.5 percent in fiscal year 2013 and each fiscal year thereafter.

**Renewable Energy Consumed:** EO 13423, sec 2(b) ensure that (i) at least half of the statutorily required renewable energy consumed by the agency in a fiscal year comes from new renewable sources, and (ii) to the extent feasible, the agency implements renewable energy generation projects on agency property for agency use;

**Energy Savings Performance Contracts:** EISA 07, Title V, subtitle B, **SEC. 513. PROMOTING LONG-TERM ENERGY SAVINGS PERFORMANCE CONTRACTS AND VERIFYING SAVINGS.** Section 801(a)(2) of the National Energy Conservation Policy Act (42 U.S.C. 8287(a)(2)) (as amended by section 512) is amended— (1) in subparagraph (D), by inserting ‘‘beginning on the date of the delivery order’’ after ‘‘25 years’’; and (2) by adding at the end the following: ‘‘(F) PROMOTION OF CONTRACTS.—In carrying out this section, a Federal agency shall not— ‘‘(i) establish a Federal agency policy that limits the maximum contract term under subparagraph (D) to a period shorter than 25 years; or ‘‘(ii) limit the total amount of obligations under energy savings performance contracts or other private financing of energy savings measures.

**High Performance and Sustainable Buildings:** EO 13423, sec 2, (f) ensure that (i) new construction and major renovation of agency buildings comply with the *Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings set forth in the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding (2006)*, and (ii) 15 percent of the existing Federal capital asset building inventory of the agency as of the end of fiscal year 2015 incorporates the sustainable practices in the Guiding Principles;

**Retention of Savings:** EISA 07 SEC. 516**.** Section 546(c) of the National Energy Conservation Policy Act (42 U.S.C. 8256(c)) is amended by striking paragraph (5). 2007 - Subsec. (c)(5). Pub. L. 110-140 struck out par. (5) which read as follows: "(5)(A) An amount equal to fifty percent of the energy and water cost savings realized by an agency (other than the Department of Defense) with respect to funds appropriated for any fiscal year beginning after fiscal year 1992 (including financial benefits resulting from energy savings performance contracts under subchapter VII of this chapter and utility energy efficiency rebates) shall, subject to appropriation, remain available for expenditure by such agency for additional energy efficiency measures which may include related employee incentive programs, particularly at those facilities at which energy savings were achieved. "(B) Agencies shall establish a fund and maintain strict financial accounting and controls for savings realized and expenditures made under this subsection. Records maintained pursuant to this subparagraph shall be made available for public inspection upon request."

**Electronic Purchasing:** EO13423, sec 2 (h) ensure that the agency (i) when acquiring an electronic product to meet its requirements, meets at least 95 percent of those requirements with an Electronic Product Environmental Assessment Tool (EPEAT)-registered electronic product, unless there is no EPEAT standard for such product, (ii) enables the Energy Star feature on agency computers and monitors, (iii) establishes and implements policies to extend the useful life of agency electronic equipment, and (iv) uses environmentally sound practices with respect to disposition of agency electronic equipment that has reached the end of its useful life.

## Appendix 3.4: Baseline and Target Energy Budgets to Meet EPACT 2005 Requirements for New Construction

The 2005 Energy Policy Act requires that Federal facilities be built to achieve at least a 30 percent energy savings over the 2004 International Energy Code or ASHRAE Standard 90.1-2004 as appropriate, and that energy efficient designs must be life cycle cost effective. A team comprised of researchers and engineers of Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Department of Energy National Renewable Energy Laboratory, USACE Centers of Standardization and the Military Technology Group of the American Society of Heating Refrigeration and Air-Conditioning Engineers has developed design guides to achieve 30 percent energy savings over a baseline built to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 for new buildings to be constructed under Military Transformation Program.

Phase 1 of this project addresses four building types: basic training barracks, unaccompanied enlisted personal housing (UEPH) barracks, battalion headquarters (BHQ), and tactical equipment maintenance facilities (TEMF). Phase 2 of this project is studying dining facilities (DFAC), child development centers (CDC), company operations facilities (COF) and reserve centers. To develop a baseline for target energy budgets which reflect the requirements of the EPACT 2005, typical buildings representing each category of the tier 1 facilities were selected and requirements of the ASHRAE Standard 90.1 2004 to the building envelope and energy consuming systems were defined. Based on this information a computer analysis was performed using EnergyPlus version 2 (DOE 2007) which resulted in baseline and target energy budgets for all DOE 15 climate zones (Figure 1-1) for each facility type. These results are summarized in Table 1-1.

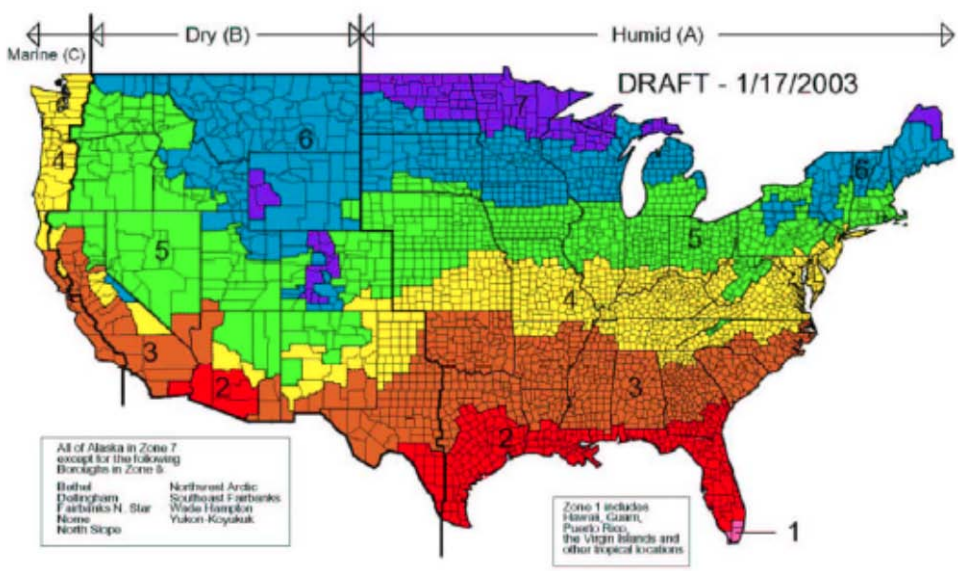



**Figure 0-1. DOE Climate zones**

Table 0-1. Baseline and target energy budgets (not including plug/process loads)

| UEPH Climate zone | 90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr) | 30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr) | Annual Process Loads (KBTU/sq ft-yr) |
|---|---|---|---|
| Miami, 1A | 82 | 58 | 20 |
| Houston, 2A | 82 | 57 | 20 |
| Phoenix, 2B | 45 | 32 | 20 |
| Memphis, 3A | 71 | 50 | 20 |
| El Paso, 3B | 42 | 30 | 20 |
| San Francisco, 3C | 47 | 33 | 20 |
| Baltimore, 4A | 75 | 52 | 20 |
| Albuquerque, 4B | 48 | 34 | 20 |
| Seattle, 4C | 60 | 42 | 20 |
| Chicago, 5A | 77 | 54 | 20 |
| Colo. Springs, 5B | 54 | 38 | 20 |
| Burlington, 6A | 83 | 58 | 20 |
| Helena, 6B | 68 | 47 | 20 |
| Duluth, 7A | 91 | 64 | 20 |
| Fairbanks, 8A | 123 | 86 | 20 |

| Training Barracks Climate zone | 90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr) | 30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr) | Annual Process Loads (KBTU/sq ft-yr) |
|---|---|---|---|
| Miami, 1A | 120 | 84 | 3 |
| Houston, 2A | 119 | 83 | 3 |
| Phoenix, 2B | 69 | 48 | 3 |
| Memphis, 3A | 122 | 85 | 3 |
| El Paso, 3B | 76 | 53 | 3 |
| San Francisco, 3C | 96 | 67 | 3 |
| Baltimore, 4A | 135 | 95 | 3 |
| Albuquerque, 4B | 93 | 65 | 3 |
| Seattle, 4C | 117 | 82 | 3 |
| Chicago, 5A | 146 | 102 | 3 |
| Colo. Springs, 5B | 111 | 78 | 3 |
| Burlington, 6A | 159 | 111 | 3 |
| Helena, 6B | 133 | 93 | 3 |
| Duluth, 7A | 176 | 123 | 3 |
| Fairbanks, 8A | 225 | 158 | 3 |

| BHQ Climate zone | 90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr) | 30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr) | Annual Process Loads (KBTU/sq ft-yr) |
|---|---|---|---|
| Miami, 1A | 31 | 22 | 10 |
| Houston, 2A | 30 | 21 | 10 |
| Phoenix, 2B | 31 | 22 | 10 |
| Memphis, 3A | 33 | 23 | 10 |
| El Paso, 3B | 28 | 20 | 10 |
| San Francisco, 3C | 25 | 18 | 10 |
| Baltimore, 4A | 37 | 26 | 10 |
| Albuquerque, 4B | 31 | 22 | 10 |
| Seattle, 4C | 32 | 22 | 10 |
| Chicago, 5A | 44 | 31 | 10 |
| Colo. Springs, 5B | 37 | 26 | 10 |
| Burlington, 6A | 51 | 36 | 10 |
| Helena, 6B | 47 | 33 | 10 |
| Duluth, 7A | 60 | 42 | 10 |
| Fairbanks, 8A | 92 | 65 | 10 |

| TEMF Climate zone | 90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr) | 30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr) | Annual Process Loads (KBTU/sq ft-yr) |
|---|---|---|---|
| Miami, 1A | 36 | 25 | 7 |
| Houston, 2A | 45 | 32 | 7 |
| Phoenix, 2B | 42 | 29 | 7 |
| Memphis, 3A | 56 | 39 | 7 |
| El Paso, 3B | 47 | 33 | 7 |
| San Francisco, 3C | 43 | 30 | 7 |
| Baltimore, 4A | 75 | 52 | 7 |
| Albuquerque, 4B | 61 | 43 | 7 |
| Seattle, 4C | 64 | 45 | 7 |
| Chicago, 5A | 93 | 65 | 7 |
| Colo. Springs, 5B | 80 | 56 | 7 |
| Burlington, 6A | 108 | 75 | 7 |
| Helena, 6B | 99 | 69 | 7 |
| Duluth, 7A | 134 | 94 | 7 |
| Fairbanks, 8A | 207 | 145 | 7 |

| DFAC - draft Climate zone | 90.1 Baseline Annual Energy Budget (w/o process loads) (KBTU/sq ft-yr) | 30% Better Target Energy Budget (w/o process loads) (KBTU/sq ft-yr) | Annual Process Loads (KBTU/sq ft-yr) |
|---|---|---|---|
| Miami, 1A | 242 | 170 | 113 |
| Houston, 2A | 250 | 175 | 112 |
| Phoenix, 2B | 236 | 165 | 112 |
| Memphis, 3A | 263 | 184 | 112 |
| El Paso, 3B | 243 | 170 | 112 |
| San Francisco, 3C | 220 | 154 | 111 |
| Baltimore, 4A | 291 | 204 | 111 |
| Albuquerque, 4B | 257 | 180 | 111 |
| Seattle, 4C | 261 | 182 | 111 |
| Chicago, 5A | 322 | 225 | 111 |
| Colo. Springs, 5B | 282 | 198 | 111 |
| Burlington, 6A | 353 | 247 | 111 |
| Helena, 6B | 324 | 227 | 111 |
| Duluth, 7A | 397 | 278 | 111 |
| Fairbanks, 8A | 519 | 364 | 111 |

Results for CDC, COF, and Reserve Centers will be included in Table 1-1 when complete.

The study also recommended a set of energy efficient solutions for each type of facilities and climate zone (see Appendices 14-17) that enable the 30 percent energy savings, and create more productive environments that provide better thermal conditions and indoor air quality to soldiers and workers.

## Appendix 3.5: LEED Energy Credits

**1. U.S. Green Building Council Leadership in Energy and Environmental Design – New Construction (LEED®-NC).** All vertical construction projects with climate control, beginning with the FY08 military construction program (except family housing), are required to be certifiable at a minimum of the Silver level of the LEED®-NC.

**2. LEED Certification and EPACT Compliance.** For new Army facilities that will be self-certified in LEED, all applicable results from the EPACT 2005 30% better study discussed above may be used to determine applicable LEED credits without the need for further energy analyses.

Achieving the EPACT 2005 mandated 30% improvement in energy consumption compared to a minimum ASHRAE 90.1-2004 facility will directly facilitate achievement of maximum credit for LEED credits EA1 “Optimize Energy Performance” which has 10 possible points. EPACT 2005 requires a 30% reduction in energy consumption <u>not including</u> plug or process loads. LEED EA1 requires percentage reductions in energy cost savings <u>including</u> plug and process loads. For self-certified Army projects, the LEED evaluation team may substitute site energy consumption, as determined in the EPACT 2005 30% Better energy analyses, for energy cost savings but must consider the plug and process loads in the calculations. Army buildings generally have small process loads. For all those buildings, a 30% savings in accordance with EPACT 2005 rules will equate to better than a 28% savings according to LEED NC rules which equates to a minimum of 6 LEED points for EA1.

The prescriptive solutions discussed in Appendices 14-17 generally result in savings significantly greater than 30%. Many of these cases result in the maximum of 10 LEED EA1 points. These prescriptive solutions also contribute to LEED points for credits EQ6.2 and EQ7.1.

## Appendix 3.6: LEED Checklist

**Federal High Performance Sustainable Building Checklist**

This checklist is used to track federal building compliance with the Guiding Principles for Sustainable Buildings and Major Renovations, which implement Executive Order 13423 and EISA 2007 for all new facilities and major renovations. The Government's goal is to incorporate (answer YES to) all numbered items. Refer to your contract for mandatory project requirements. **Complete and submit this checklist for each new climate-controlled building and major renovation of a climate-controlled building in the project at each of the project phases indicated below.**

| | **General Building and Project Information** | Input answers in this column. Prepare an updated checklist at each project phase. Obtain excel version of this document from Government's Project Manager. | Initial 1391 Programming Charette | Code 3/parametric estimate | Final RFP | RFP Technical Proposal | RFP Post-Award Final Design | Design Charette | Design Bid Build Final Design | Construction Closeout |
|---|---|---|---|---|---|---|---|---|---|---|
| | Project Phase (check box): | | | | | | | | | |
| | Date: | | | | | | | | | |
| | Project Name: | | | | | | | | | |
| | Installation: | | | | | | | | | |
| | PN: | | | | | | | | | |
| | FY: | | | | | | | | | |
| | Building this Checklist is for: | | | | | | | | | |
| | Building gross area: | | | | | | | | | |
| | Building footprint area: | | | | | | | | | |
| | **Integrated Design** | | | | | | | | | |
| 1 | Has a collaborative, integrated design process been used for all stages of project delivery? | | | | | | | | | |
| 2 | Have comprehensive performance goals for siting, energy, water , materials and indoor environmental quality been set? | | | | | | | | | |
| | Indicate building performance goals for siting: | | | | | | | | | |
| | Indicate building performance goals for energy: | | | | | | | | | |
| | Indicate building performance goals for water: | | | | | | | | | |
| | Indicate building performance goals for materials: | | | | | | | | | |
| | Indicate building performance goals for indoor environmental quality: | | | | | | | | | |
| 3 | Have performance goals been tracked and incorporated? | | | | | | | | | |
| 4 | Have all stages of building lifecycle been considered including deconstruction? | | | | | | | | | |
| | **Commissioning** | | | | | | | | | |
| 5A | Will/does project include whole building commissioning, tailored to complexity and systems? | | | | | | | | | |
| 5B | Will/does project include an experienced commissioning provider? | | | | | | | | | |

| | | |
|---|---|---|
| 5C | Will/does project include incorporation of commissioning requirements in contract documents? | |
| 5D | Will/does project include a commissioning plan and a commissioning report? | |
| | List special systems that require commissioning (in addition to HVAC & controls, lighting controls and domestic hot water): | |
| | Has commissioning of special systems been included in project 1391/cost estimate/budget? | |
| | **Optimize Energy Performance** | |
| 6 | Has a whole building energy performance target been established (Energy Star for applicable building types)? | |
| | If yes, indicate whole building energy performance target: | |
| 7A | For new building, will/does building achieve minimum 30% energy use reduction compared to ASHRAE 90.1 2007 baseline? | |
| | If yes, has this been included in project 1391/cost estimate/budget? | |
| | If no, indicate what energy use reduction building will/does achieve and indicate why 30% reduction is not feasible: | |
| 7B | For major renovation, will/does building achieve minimum 20% energy use reduction compared to pre-renovation 2003 baseline? | |
| | If yes, has this been included in project 1391/cost estimate/budget? | |
| | What is pre-renovation 2003 energy use baseline? | |
| | If no, indicate what energy use reduction building will/does achieve and indicate why 20% reduction is not feasible: | |
| 8 | Will/does building use Energy Star or FEMP designated energy efficient products where available? | |
| | **On-Site Renewable Energy** | |
| | Has LCCA been accomplished for solar heating of domestic hot water? | |
| | If yes, has 30% solar water heating been determined LCC effective? If not, indicate what percentage is LCC effective. | |
| | If no, indicate why: | |
| 9 | Will/does the building include the solar water heating that is LCC effective? | |
| | If no, indicate why: | |
| | Has LCCA been accomplished for on-site renewable energy features? | |
| | If no, indicate why: | |
| | If yes, indicate what renewable energy features were analyzed and which were determined to be LCC effective: | |
| | Have LCC effective renewable energy features been included in project 1391/cost estimate/budget? | |

| | | |
|---|---|---|
| 10 | Will/does the building include the LCC effective renewable energy features? | |
| | Indicate what percentage of building energy use is renewable energy: | |
| | **Measurement and Verification** | |
| 11 | Will/does project include building level metering for electricity, water, natural gas and steam if used? | |
| | **Benchmarking** | |
| 12 | Will building performance data be compared to whole building energy target after one year of operation? | Yes by Installation. |
| | If yes, does building meet or exceed design target or is it within 10% of design energy budget? | TBD |
| | **Protect and Conserve Water** | |
| 13 | Will/does building achieve minimum 20% potable water use reduction compared to IPC 2006 fixture performance requirements baseline? | |
| | If no, indicate what potable water use reduction building will/does achieve and indicate why 20% reduction is not feasible: | |
| 14 | If building has a permanent irrigation system, will/does building achieve minimum 50% outdoor potable water use reduction for irrigation compared to conventional plant species and density water use baseline? Answer YES if building has no permanent irrigation system. | |
| | If no, indicate what potable water use reduction building will/does achieve and indicate why 50% reduction is not feasible: | |
| | If building will use nonpotable water for irrigation, has this been included in project 1391/cost estimate/budget? | |
| 15 | If building has a permanent irrigation system, will/does building use EPA WaterSense labeled irrigation products or other water conserving irrigation products where available (answer YES if building has no permanent irrigation system)? | |
| | If no, indicate why: | |
| 16 | If building has a permanent irrigation system, will/does building use irrigation contractors that are certified through a EPA WaterSense labeled program (answer YES if building has no permanent irrigation system)? | |
| | If no, indicate why: | |
| 17 | Will/does building incorporate design and construction strategies that reduce storm water runoff and discharges of polluted water offsite? | |
| | If yes, indicate design and construction strategies: | |
| | If yes, has this been included in project 1391/cost estimate/budget? | |
| | If no, indicate why reduction is not feasible: | |
| 18 | Will/does building incorporate design and construction strategies that restore predevelopment hydrology of the site with regard to temperature, rate, volume and duration of flow to the maximum extent technically feasible? | |

| | | |
|---|---|---|
| | If yes, indicate design and construction strategies: | |
| | If yes, has this been included in project 1391/cost estimate/budget? | |
| | If no, indicate why: | |
| | Has LCCA been accomplished for features that reduce potable water use for process water? | |
| | If no, indicate why: | |
| | List features that LCCA has been accomplished for: | |
| | If yes, list features that have been determined LCC effective: | |
| | If yes, have LCC effective features been included in project 1391/cost estimate/budget? | |
| 19 | Will/does building include LCC effective potable process water conservation features? | |
| | **Enhance Indoor Environmental Quality** | |
| 20 | Will/does building comply with ASHRAE 55 2004? | |
| | If no, indicate why: | |
| 21 | Will/does building comply with ASHRAE 62.1 2007? | |
| | If no, indicate why: | |
| 22 | Will/does building include a moisture control strategy to minimize mold and condensation? | |
| | If yes, indicate control strategies: | |
| | If yes, have control strategies been included in project 1391/cost estimate/budget? | |
| | If no, indicate why: | |
| 23A | Will/does building achieve 2% daylight factor (excluding direct sunlight) in 75% of all space occupied for critical visual tasks OR earn LEED Daylighting credit? | |
| | If yes, indicate special building features required to achieve this: | |
| | If yes, have special building features required to achieve this been included in project 1391/cost estimate/budget? | |
| | If no, indicate why: | |
| 23B | Will/does building include automatic lighting dimming controls or occupant manual lighting controls and glare control? | |
| | If yes, indicate special building features required to achieve this: | |
| | If yes, have special building features required to achieve this been included in project 1391/cost estimate/budget? | |
| | If no, indicate why: | |
| 24 | Will/does the building include, to the maximum extent technically feasible, low emitting composite wood products, adhesives, sealants, interior paints and finishes, carpet and furniture? | |
| 25 | Will/does project comply with SMACNA Guidelines for Occupied Buildings Under Construction 2007 OR earn LEED IAQ Management During Construction credit? | |
| | If no, indicate why: | |

| | | |
|---|---|---|
| 26 | Will/does project include minimum 72 hour building flushout prior to occupancy with maximum 60% humidity OR earn LEED IAQ Management Before Occupancy credit? | |
| | If no, indicate why: | |
| 27 | Will/does building include signage prohibiting smoking inside the building and within 25 feet of all building entrances, operable windows and ventilation intakes? | |
| | If no, indicate why: | |
| | **Environmental Impact of Materials** | |
| 28 | Will/does building comply with EPA Comprehensive Procurement Guidelines for recycled content? | |
| | If no, indicate why: | |
| 29 | For all other products, will/does building include recycled content materials to earn LEED credit MR4.1, Recycled Content, 10 percent? | |
| | If no, indicate why: | |
| 30 | Will/does building comply with USDA Biobased Products Preferred Procurement Program requirements? | |
| | If no, indicate why: | |
| 31 | For all other products, will/does building include biobased content materials to the maximum extent technically feasible? | |
| | If no, indicate why: | |
| 32 | Will/does building include FSC certified wood to the maximum extent technically feasible? | |
| | If no, indicate why: | |
| 33 | Will/does building include environmentally preferable products (EPPs) to the maximum extent technically feasible? | |
| | If no, indicate why: | |
| 34 | Will/does building include adequate space, equipment and provisions for collection and transport of recyclables generated by occupants? | |
| | If no, indicate why: | |
| 35 | Will/does project include minimum 50% diversion of all non-hazardous construction, demolition and land clearing materials (excluding soil)? | |
| | If no, indicate why: | |
| 36 | Will/does project eliminate the use of ozone depleting compounds during and after construction where alternative environmentally preferable products are available, consistent with the Montral Protocol and Title VI of the Clean Air Act amendments of 1990 or equivalent air quality benefits that take into account lifecycle impacts? | |
| | If yes for major renovation, has this been included in project 1391/cost estimate/budget? | |
| | If no, indicate why: | |

## Appendix 4: Contract Language

## Appendix 4.1: Military Transformation RFP

## Appendix 4.1.1: Military Transformation RFP Chapter 3 (TBD)

**Appendix 4.1.2: Military Transformation RFP Chapter 4**

4.0 APPLICABLE CRITERIA (REV 2.17 – 31 JAN 2009)

4.1. INDUSTRY CRITERIA
Applicable design and construction criteria references are listed in Table 1 below. Unless a specific document version or date is indicated, criteria shall be taken from the most current references as of the date of issue of the contract or task order, unless otherwise stated in the task order. This list is not intended to include all criteria that may apply or to restrict design and construction to only those references listed. See also Paragraph 3 for additional facility-specific applicable criteria.

Table 1: Industry Criteria

Air Conditioning and Refrigeration Institute (ARI)
- ARI 310/380 Packaged Terminal Air-Conditioners and Heat Pumps
- ARI 440 Room Fan-Coil and Unit Ventilator
- ANSI/ARI 430-99 Central Station Air Handling Units
- ARI 445 Room Air-Induction Units
- ARI 880 Air Terminals

Air Movement and Control Association (AMCA)
- AMCA 210 Laboratory Methods of Testing Fans for Rating

American Architectural Manufacturers Association (AAMA)
- AAMA 605 Voluntary Specification Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels
- AAMA 607.1 Voluntary Guide Specifications and Inspection Methods for Clear Anodic Finishes for Architectural Aluminum
- AAMA 1503 Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors, and Glazed Wall Sections

American Association of State Highway and Transportation Officials (AASHTO)
- Roadside Design Guide [guardrails, roadside safety devices]
- Standard Specifications for Transportation Materials and Methods of Sampling and Testing [Road Construction Materials]
- Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals
- Guide for Design of Pavement Structures, Volumes 1 and 2 [pavement design guide]
- A Policy of Geometric Design of Highways and Streets

American Bearing Manufacturers Association (AFBMA)
- AFBMA Std. 9 Load Ratings and Fatigue Life for Ball Bearings
- AFBMA Std. 11 Load Ratings and Fatigue Life for Roller Bearings

American Boiler Manufacturers Association (ABMA)

- ABMA ISEI Industry Standards and Engineering Information

American Concrete Institute

- ACI 318 Building Code Requirements for Structural Concrete
- ACI 315 Details and Detailing of Concrete Reinforcement
- ACI 530 Building Code Requirements for Masonry Structures

ADA Standards for Accessible Design

- 28 CFR Part 36

American Institute of Steel Construction (AISC)

- Manual of Steel Construction – 13th Edition (or latest version)

American Iron and Steel Institute

- AISI/COS NASPEC 2001 North American Specification for the Design of Cold-Formed Steel
- Structural Members

American National Standards Institute 11 (ANSI)

- ANSI Z21.10.1 Gas Water Heaters Vol. 1, Storage water Heaters with Input Ratings of 75,000 Btu per Hour or less
- ANSI Z124.3 American National Standard for Plastic Lavatories
- ANSI Z124.6 Plastic Sinks
- ANSI Z21.45 Flexible Connectors of Other Than All-Metal Construction for Gas Appliances
- ANSI/IEEE C2-2007 National Electrical Safety Code
- ANSI/AF&PA NDS-2001 National Design Specification for Wood Construction

American Society of Civil Engineers (ASCE)

- ASCE 7 Minimum Design Loads for Buildings and Other Structures
- ASCE 37 Design and Construction of Sanitary and Storm Sewers, Manuals and Reports on Engineering Practice [sanitary sewer and storm drain design criteria]
- ASCE/SEI 31-03 Seismic Evaluation of Existing Buildings [Existing Building Alteration/Renovation]
- ASCE/SEI 41-06 Seismic Rehabilitation of Existing Buildings [Existing Building Alteration/Renovation]

American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)

- ASHRAE 90.1 - 2004 ANSI/ASHRAE/IESNA 90.1, Energy Standard for Buildings Except Low- Rise Residential Buildings
- ASHRAE Guideline 1.1 The HVAC Commissioning Process
- ASHRAE Hdbk-IP Handbook Fundamentals I-P Edition
- ASHRAE Standard 15 Safety Standard for Refrigeration Systems
- ASHRAE Standard 62.1 Ventilation for Acceptable Indoor Air Quality

American Society of Mechanical Engineers International (ASME)

- ASME BPVC SEC VII Boiler and Pressure Vessel Code: Section VII Recommended Guidelines for the Care of Power Boilers
- ASME A17.1 Safety Code for Elevators and Escalators
- ASME B 31 (Series) Piping Codes

American Water Works Association (AWWA)

- Standards [standards for water line materials and construction]

American Welding Society

- Welding Handbook
- Welding Codes and Specifications (as applicable to application, see International Building Code for example)

Architectural Woodwork Institute (AWI)

- Version 1.2 AWI Quality Standards 7th Edition

Associated Air Balance Council (AABC)

- AABC MN-1 National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems
- AABC Associated Air Balance Council Testing and Balance Procedures

ASTM International

- ASTM C1060-90(1997) Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings
- ASTM E 779 (2003) Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
- ASTM E1827-96(2002) Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door

Builders Hardware Manufacturers Association (BHMA)

- ANSI/BHMA American National Standards for Builders Hardware

Building Industry Consulting Service International

- Telecommunications Distribution Methods Manual (TDMM)
- Customer-Owned Outside Plant Design Manual (CO-OSP)

Code of Federal Regulations (CFR)

- 49 CFR 192 Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
- 10 CFR 430 Energy Conservation Program for Consumer Products

Consumer Electronics Association

- CEA 709.1B Control Network Protocol Specification

- CEA 709.3 Free-Topology Twisted-Pair Channel Specification
- CEA 852 Tunneling Component Network Protocols Over Internet Protocol Channels

Electronic Industries Association (EIA)

- ANSI/EIA/TIA 568-B Structured Cabling Series
- ANSI/EIA/TIA 569-B Commercial Building Standard for Telecommunications Pathways and Spaces
- J-STD EIA/TIA 607-A Commercial Building Grounding and Bonding Requirements for Telecommunications

Federal Highway Administration (FHWA)

- Manual on Uniform Traffic Control Devices for Streets and Highways [signage and pavement markings for streets and highways]
- FHWA-NHI-01-021 Hydraulic Engineering Circular No. 22, Second Edition, URBAN DRAINAGE DESIGN MANUAL

Illuminating Engineering Society of North America (IESNA)

- IESNA RP-1 Office Lighting
- IESNA RP-8 Roadway Lighting
- IESNA Lighting Handbook Reference and Application

Institute of Electrical and Electronics Engineers Inc. (IEEE)

- Standard for Use of the International System of Units (SI): the Modern Metric System
- Standard 1100 Recommended Practice for Powering and Grounding Sensitive Electronic Equipment

International Code Council (ICC)

- IBC International Building Code
- Note: All references in the International Building Code to the International Electrical Code shall be considered to be references to NFPA 70. All references in the International Building Code to the International Fuel Gas Code shall be considered to be references to NFPA 54 and NFPA 58. All references in the International Building Code to the International Fire Code shall be considered to be references to Unified Facilities Criteria (UFC) 3-600-01.
- IMC International Mechanical Code – Note: For all references to “HEATING AND COOLING
- LOAD CALCULATIONS”, follow ASHRAE 90.1 Note: For all references to “VENTILATION”, follow ASHRAE 62.1
- IRC International Residential Code
- IPC International Plumbing Code
- IEC Energy Conservation Code (IEC) – Deleted DEC 2007- Refer to Paragraph 5, ENERGY  CONSERVATION requirements.

- IGC International Gas Code - not applicable. Follow NFPA 54, National Fuel Gas Code and NFPA 58, Liquified Petroleum Gas Code.

International Organization for Standardization (ISO)
- ISO 6781:1983 Qualitative detection of thermal irregularities in building envelopes – infrared method

LonMark International (LonMark)
- LonMark Interoperability Guidelines (available at www.lonmark.org), including: Application Layer Guidelines, Layer 1-6 Guidelines, and External Interface File (XIF) Reference Guide
- LonMark Resource Files (available at www.lonmark.org), including Standard Network Variable Type (SNVT) definitions

Metal Building Manufacturers Association (MBMA)
- Metal Building Systems Manual

Midwest Insulation Contractors Association (MICA)
- National Commercial and Industrial Insulation Standards Manual

National Association of Corrosion Engineers International (NACE)
- NACE RP0169 Control of External Corrosion on Underground or Submerged Metallic Piping Systems
- NACE RP0185 Extruded, Polyolefin Resin Coating Systems with Adhesives for Underground or Submerged Pipe
- NACE RP0285 Corrosion Control of Underground Storage Tank Systems by Cathodic Protection
- NACE RP0286 Electrical Isolation of Cathodically Protected Pipelines

National Electrical Manufacturers Association (NEMA)

National Environmental Balancing Bureau (NEBB)
- Procedural Standards Procedural Standards for Testing Adjusting Balancing of Environmental Systems

National Fire Protection Association (NFPA)
- NFPA 10 Standard for Portable Fire Extinguishers
- NFPA 13 Installation of Sprinkler Systems
- NFPA 13R Residential Occupancies up to and Including Four Stories in Height Sprinkler Systems
- NFPA 14 Standard for the Installation of Standpipes and Hose Systems
- NFPA 20 Installation of Centrifugal Fire Pumps
- NFPA 24 Standard for the Installation of Private Fire Service Mains and Their Appurtenances [underground fire protection system design]
- NFPA 30 Flammable and Combustible Liquids Code

- NFPA 30A Motor Fuel Dispensing Facilities and Repair Garages
- NFPA 31 Installation of Oil Burning Equipment
- NFPA 54 National Fuel Gas Code
- NFPA 58 Liquefied Petroleum Gas Code
- NFPA 70 National Electrical Code
- NFPA 72 National Fire Alarm Code
- NFPA 80 Standard for Fire Doors and Fire Windows
- NFPA 90a Installation of Air Conditioning and Ventilating Systems
- NFPA 96 Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations
- NFPA 101 Life Safety Code
- NFPA 780 Standard for the Installation of Lightning Protection Systems

National Roofing Contractor's Association (NRCA)

- Roofing and Waterproofing Manual

National Sanitation Foundation, International

- NSF/ANSI Std. 2, 3, 4, 5, 6, 7, 8, 12, 13, 18, 20, 21, 25, 29, 35, 36, 37, 51, 52, 59, 169 Food Equipment Standards
- ANSI/UL Std. 73, 197, 471, 621, 763 Food Equipment Standards
- CSA Std. C22.2 No. 109, 120, 195 Food Equipment Standards

Occupational Safety and Health Administration (OSHA)

- Title 29, Part 1926 OSHA Construction Industry Standards, Title 29, Code of Federal Regulations, Part 1926, Safety and Health Regulations for Construction

Plumbing and Drainage Institute (PDI)

- PDI G 101 Testing and Rating Procedure for Grease Interceptors with Appendix of Sizing and Installation Data
- PDI WH201 Water Hammer Arrestors

Precast Concrete Institute

- PCI Design Handbook Precast and Prestressed Concrete

Sheet Metal and Air Conditioning Contractor's National Association (SMACNA)

- SMACNA HVAC Duct Construction Standards HVAC Duct Construction Standards - Metal and Flexible
- SMACNA Architectural Manual Architectural Sheet Metal Manual
- SMACNA HVAC TAB HVAC Systems - Testing, Adjusting and Balancing

State/Local Regulations

- State Department of Transportation Standard Specifications for Highway and Bridge Construction
- Sedimentation and Erosion Control Design Requirements
- Environmental Control Requirements

- Storm Water Management Requirements

Steel Door Institute (SDI)
- ANSI A250.8/SDI 100 Standard Steel Doors and Frames

Steel Deck Institute
- SDI Diaphragm Design Manual

Steel Joist Institute
- Catalog of Standard Specifications and Load Tables for Steel Joists and Joist Girders

Underwriters Laboratories (UL)
- UL 96A Installation Requirements for Lightning Protection Systems
- UL 300 Standard for Safety for Fire Testing of Fire Extinguishing Systems for Protection of Restaurant Cooking Areas

Uniform Federal Accessibility Guidelines (UFAS)

U.S. Architectural and Transportation Barriers Compliance Board

U.S. DEPARTMENT OF HEATH AND HUMAN SERVICES
- FDA National Food Code

U.S. GREEN BUILDING COUNCIL (USGBC)
- LEED-NC Green Building Rating System for New Construction & Major Renovations, Version 2.2
- Application Guide for Multiple Buildings and On-Campus Building Projects

4.2. MILITARY CRITERIA
The project shall conform to the following criteria. Certain design impacts and features due to these criteria are noted for the benefit of the offeror. However, all requirements of the referenced criteria will be applicable, whether noted or not, unless otherwise specified herein.

4.2.1. Energy Policy Act of 2005 (Public Law 109-58)

4.2.2. Executive Order 12770: Metric Usage In Federal Government
(a) Metric design and construction is required except when it increases construction cost. Offeror to determine most cost efficient system of measurement to be used for the project.

4.2.3. TB MED 530: Occupational and Environmental Health Food Sanitation

4.2.4. Unified Facilities Criteria (UFC) 3-410-01FA: Heating, Ventilating, and Air Conditioning – applicable only to the extent specified in paragraph 5, herein.

4.2.5. UFC 3-580-01 Telecommunications Bldg Cabling Systems Planning/Design

4.2.6. UFC 3-600-01 Design: Fire Protection Engineering for Facilities

4.2.7. UFC 4-010-01 DoD Minimum Antiterrorism Standards for Buildings

4.2.8. UFC 4-023-03 Design of Buildings to Resist Progressive Collapse (a) Options to use tie force method or alternate path design

4.2.9. UFC 4-021-01 Design and O&M: Mass Notification Systems

4.2.10. Technical Guide for Installation Information Infrastructure Architecture (I3A) (a) Email: DetrickISECI3Aguide@conus.army.mil

4.2.11. U.S. Army Information Systems Engineering Command (USAISEC) TG for the Integration of SECRET Internet Protocol (IP) Router Network (SIPRNET). See Paragraph 3 for applicability to specific facility type. May not apply to every facility.

4.3. PRECEDENCE
In the event of conflict between References and/or Applicable Military Criteria, the most stringent requirement will apply, unless otherwise specifically noted in the contract.

Additional criteria that is currently not in Chapter 4 of the MTRFP that should be.

- UFC 1-200-01, General Building Requirements, 20 June 2005.
- UFC 3-400-01, Energy Conservation, 05 July 2002.
- UFC 3-410-02A Design: Heating, Ventilating, and Air Conditioning (HVAC) Control Systems
- UFC 3-420-01 Plumbing Systems
- UFC 3-400-02 Design: Engineering Weather Data
- UFGS 23 09 23: Direct Digital Control for HVAC and other Local Building Systems, April 2006.
- Energy Independence and Security Act of 2007
- Executive Order 13423

**Appendix 4.1.3: Military Transformation RFP Chapter 5**

5.2.5. UTILITIES: See paragraph 6.4.6 for specific information on ownership of utilities and utility requirements. Meter all utilities (gas, water, and electric, as applicable) to each facility. For Government owned utilities, install meters that are wireless data transmission capable as well as have a continuous manual reading option. All meters will be capable of at least hourly data logging and transmission and provide consumption data for gas, water, and electricity. Gas and electric meters will also provide demand readings based on consumption over a maximum of any 15 minute period. Configure all meters to transmit at least daily even if no receiver for the data is currently available at the time of project acceptance. For privatized utilities, coordinate with the privatization utility(ies) for the proper meter base and meter installation.

5.5. THERMAL PERFORMANCE

5.5.1. STANDARDS AND CODES: Building construction and thermal insulation for mechanical systems shall conform to APPLICABLE CRITERIA.

5.5.2. BUILDING ENVELOPE SEALING PERFORMANCE REQUIREMENT. Design and construct the building envelope for office buildings, office portions of mixed office and open space (e.g., company operations facilities), dining, barracks and instructional/training facilities with a continuous air barrier to control air leakage into, or out of, the conditioned space. Clearly identify all air barrier components of each envelope assembly on construction documents and detail the joints, interconnections and penetrations of the air barrier components. Clearly identify the boundary limits of the building air barriers, and of the zone or zones to be tested for building air tightness on the drawings.

5.5.2.1. Trace a continuous plane of air-tightness throughout the building envelope and make flexible and seal all moving joints.

5.5.2.2. The air barrier material(s) must have an air permeance not to exceed 0.004 cfm / sf at 0.3” wg [0.02 L/s.m2 @ 75 Pa] when tested in accordance with ASTM E 2178

5.5.2.3. Join and seal the air barrier material of each assembly in a flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of these assemblies and components.

5.5.2.4. Support the air barrier so as to withstand the maximum positive and negative air pressure to be placed on the building without displacement, or damage, and transfer the load to the structure.

5.5.2.5. Seal all penetrations of the air barrier. If any unavoidable penetrations of the air barrier by electrical boxes, plumbing fixture boxes, and other assemblies are not airtight, make them airtight by sealing the assembly and the interface between the assembly and the air barrier or by extending the air barrier over the assembly.

5.5.2.6. The air barrier must be durable to last the anticipated service life of the assembly.

5.5.2.7. Do not install lighting fixtures with ventilation holes through the air barrier

5.5.2.8. Provide a motorized damper in the closed position and connected to the fire alarm system to open on call and fail in the open position for any fixed open louvers such as at elevator shafts.

5.5.2.9. Damper and control to close all ventilation or make-up air intakes and exhausts, atrium smoke exhausts and intakes, etc when leakage can occur during inactive periods.

5.5.2.10. Compartmentalize garages under buildings by providing air-tight vestibules at building access points.

5.5.2.11. Compartmentalize spaces under negative pressure such as boiler rooms and provide make-up air for combustion.

5.5.2.12. Performance Criteria and Substantiation: Submit the qualifications and experience of the testing entity for approval. Demonstrate performance of the continuous air barrier for the opaque building envelope by the following tests:

(a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25cfm/ft2 at a pressure differential of 0.3” w.g.(75 Pa) in accordance with ASTM’s E 779 (2003) or E- 1827-96 (2002). Accomplish tests using either pressurization or depressurization or both. Divide the volume of air leakage in cfm @ 0.3” w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to produce the air leakage rate in cfm/ft2 @ 0.3” w.g. (L/s.m2 @ 75 Pa). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner.
(b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997). Determine air leakage pathways using ASTM E 1186-03 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems, and perform corrective work as necessary to achieve the whole building air leakage rate specified in (a) above. (c) Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.

5.7.5. LIGHTING: Lighting shall comply with the recommendations of the Illumination Engineering Society of North America (IESNA).

5.7.5.1. Interior Lighting: Interior lighting shall utilize electronic ballast and energy efficient fluorescent lamps with a Correlated Color Temperature of 4100K. Compact fluorescent fixtures shall have a Color Rendering Index of (CRI) of 82 or higher. Linear fluorescent fixtures shall have a CRI of 85 or higher. Fluorescent lamps shall be the low mercury type qualifying as non-hazardous waste upon disposal. Surface mounted fixtures shall not be used on acoustical tile ceilings. An un-switched fixture with emergency ballast shall be provided at each entrance to the building.

5.8. HEATING, VENTILATING, AND AIR CONDITIONING

5.8.1. STANDARDS AND CODES: The HVAC system shall conform to APPLICABLE CRITERIA.

5.8.2. DESIGN CONDITIONS.

5.8.2.1 Outdoor and indoor design conditions shall be in accordance with UFC 3-410-01FA. Outdoor air and exhaust ventilation requirements for indoor air quality shall be in accordance with ASHRAE 62.1.

5.8.2.2 Design systems in geographical areas that meet the definition for high humidity in UFC 3-410-01FA in accordance with the special criteria for humid areas therein.

5.8.2.3 Cooling equipment may be oversized by up to 15 percent to account for recovery from night set forward. Heating equipment may be oversized by up to 30 percent to account for recovery from night setback. Design single zone systems and multi-zone systems to maintain an indoor design condition of 50% relative humidity for cooling only. For heating only where the indoor relative humidity is expected to fall below 20% for extended periods, add humidification to increase the indoor relative humidity to 30%. Where fan coil units are used, provide a non-permeable wall covering behind the unit. Provide ventilation air from a separate dedicated air handling unit. Do not condition outside air through fan coil units. Avoid the use of direct expansion cooling coils in air handling units with constant running fans that handle outside air.

5.8.3. BUILDING AUTOMATION SYSTEM. Provide a Building Automation System consisting of a building control network <NEW>, a Utility Monitoring and Control System (UMCS) </NEW><NEW_LNS_NONLNS>, and integrate the building control network into the UMCS </NEW_LNS_NONLNS><STANDALONE_LON> and a building management interface to provide a building-level graphical user interface </STANDALONE_LON>as specified. The building control network shall be a single complete non-proprietary Direct Digital Control (DDC) system for control of the heating, ventilating and air conditioning (HVAC) systems as specified herein. The building control network shall be an Open implementation of LONWORKS® technology using ANSI/EIA 709.1B as the only communications protocol and use only LonMark Standard Network Variable Types (SNVTs), as defined in the LonMark® Resource Files, for communication between DDC Hardware devices to allow multi-vendor interoperability. <NEW>The UMCS shall use the IP network to perform supervisory control and monitoring of a ANSI/CEA-709.1B

(LonWorks) network using LonWorks Network Services (LNS). The UMCS shall communicate with building control systems using ANSI/CEA-852 only.</NEW>

5.8.3.1. The building automation system shall be open in that it is designed and installed such that the Government or its agents are able to perform repair, replacement, upgrades, and expansions of the system without further dependence on the original Contractor. This includes, but is not limited to the following:

(a) Install hardware such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.
(b) Necessary documentation (including rights to documentation and data), configuration information, configuration tools, programs, drivers, and other software shall be licensed to and otherwise remain with the Government such that the Government or its agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor.

5.8.3.2. All DDC Hardware shall:
(a) Be connected to a TP/FT-10 ANSI/EIA 709.3 control network.
(b) Communicate over the control network via ANSI/EIA 709.1B exclusively.
(c) Communicate with other DDC hardware using only SNVTs
(d) Conform to the LonMark® Interoperability Guidelines.
(e) Be locally powered; link power (over the control network) is not acceptable.
(f) Be fully configurable via standard or user-defined configuration parameter types (SCPT or UCPT), standard network variable type (SNVT) network configuration inputs (*nci*), or hardware settings on the controller itself to support the application. All settings and parameters used by the application shall be configurable via standard or user-defined configuration parameter types (SCPT or UCPT), standard network variable type (SNVT) network configuration inputs (*nci*), or hardware settings on the controller itself
(g) Provide input and output SNVTs required to support monitoring and control (including but not limited to scheduling, alarming, trending and overrides) of the application. Required SNVTs include but are not limited to: SNVT outputs for all hardware I/O, SNVT outputs for all setpoints and SNVT inputs for override of setpoints.
(h) To the greatest extent practical, not rely on the control network to perform the application.

5.8.3.3. Controllers shall be Application Specific Controllers whenever an ASC suitable for the application exists. When an ASC suitable for the application does not exist use programmable controllers or multiple application specific controllers.

5.8.3.4. Application Specific Controllers shall be LonMark Certified whenever a LonMark Certified ASC suitable for the application exists. For example, VAV controllers must be LonMark certified.

5.8.3.5. Application Specific Controllers (ASCs) shall be configurable via an LNS plug-in whenever t an ASC with an LNS plug-in suitable for the application exists.

5.8.3.6. Each scheduled system shall accept a network variable of type SNVT_occupancy and shall use this network variable to determine the occupancy mode. If the system has not received a value to this network variable for more than 60 minutes it shall default to <CONFIG_OCC>a configured occupancy schedule</CONFIG_OCC><OCC_MODE>the occupied mode</OCC_MODE>.

5.8.3.7. Gateways may be used provided that each gateway communicates with and performs protocol translation for control hardware controlling one and only one package unit.

5.8.3.8. <NEW_NO>Not Used</NEW_NO><NEW>Provide a supervisory “Utility Monitoring and Control System” (UMCS) which meets the following requirements:

(a) The UMCS shall perform supervisory control and monitoring of a base-wide ANSI/CEA-709.1B (LonWorks) network using LonWorks Network Services (LNS).
(b) The UMCS shall be <DIACAP_CERT>DIACAP certified</DIACAP_CERT><DIACAP_PART>part of the DIACAP certification for the installation’s basewide LAN</DIACAP_PART> <DIACAP_PART_CERT>DIACAP certified or part of the DIACAP certification for the installation’s basewide LAN</DIACAP_PART_CERT> have a Certificate of Networthiness and shall use the installation’s basewide IP network to provide connectivity between building control systems. DIACAP, Networthiness and access to the IP network shall be coordinated with the installation’s IT organization (DOIM) and the DPW.
(c) The UMCS monitoring and control (M&C) software shall be a LonWorks Network Services (LNS)-
compatible client-server software package that performs supervisory monitoring and control functions including but not limited to Scheduling, Alarm Handling, Alarm Generation, Trending, Report Generation and Electrical Peak Demand Limiting. The software shall be expandable in both number of points and number of clients supported in order to support system expansion. The M&C Software may include drivers to other (non- ANSI/CEA-709.1B) protocols.
(d) The software shall be capable of scheduling SNVTs such that it can change the value of a SNVT according to an internal schedule.
(e) The software shall be capable of handling alarms by providing an alarm notification via a pop-up to a user display, printing to a printer, sending an email and sending a numeric page.
(f) The system shall include a <WEBBASED>web based</WEBBASED> Graphical User Interface which allows for hierarchical graphical navigation between systems, graphical representations of systems, access to real-time data for systems, ability to override points in a system, and access to all supervisory monitoring and control functions. Each system display shall clearly distinguish between the following point data types and information: Real-time data, User-entered data, Overridden or operator-disabled points, Devices in alarm (unacknowledged), and Out-of-range, bad, or missing data. The software shall allow the user to create, modify, and delete displays and graphic symbols. Data on graphics pages shall be no more than 10 seconds behind real time.

(g) Provide a network configuration tool. This software shall use LonWorks Network Services (LNS) for all network configuration and management of ANSI/CEA-709.1B devices, be capable of executing LNS plug-ins, and be capable of performing network database reconstruction of an ANSI/CEA-709.1B control network.</NEW>

5.8.3.9. <NEW_LNS_NONLNS_NO>Not Used</NEW_LNS_NONLNS_NO><NEW_LNS_NONLNS>Perform all necessary actions needed to fully integrate the building control system. These actions include but are not limited to:

- Configure M&C Software functionality including: graphical pages for System Graphic Displays including overrides, alarm handling, scheduling, trends for critical values needing long-term or permanent monitoring via trends, and demand limiting. </NEW_LNS_NONLNS><NEW_LNS>
- Install IP routers or ANSI/CEA-852 routers as needed to connect the building control network to the UMCS IP network. Routers shall be capable of configuration via DHCP and use of an ANSI/CEA-852 configuration server but shall not rely on these services for configuration. All communication between the UMCS and building networks shall be via the ANSI/CEA-709.1B protocol over the IP network in accordance with ANSI/CEA-852.</NEW_LNS>

5.8.3.10. Provide the following to the Government for review prior to acceptance of the system:

- The latest version of all software and user manuals required to program, configure and operate the system.
- Points Schedule drawing that shows every DDC Hardware device. The Points Schedule shall contain the following information as a minimum:
    - Device address and NodeID.
    - Input and Output SNVTs including SNVT Name, Type and Description.
    - Hardware I/O, including Type (AI, AO, BI, BO) and Description.
    - Alarm information including alarm limits and SNVT information.
    - Supervisory control information including SNVTs for trending and overrides.
    - Configuration parameters (for devices without LNS plug-ins)

Example Points Schedules are available at https://eko.usace.army.mil/fa/besc/

- Riser diagram of the network showing all network cabling and hardware. Label hardware with ANSI.CEA- 709.1 addresses<NEW_LNS_NONLNS>, IP addresses, and network names</NEW_LNS_NONLNS>.
- Control System Schematic diagram and Sequence of Operation for each HVAC system.
- Operation and Maintenance Instructions including procedures for system start-up, operation and shutdown, a routine maintenance checklist, and a qualified service organization list.
- LONWORKS® Network Services (LNS®) database for the completed system.
- Quality Control (QC) checklist (below) completed by the Contractor's Chief Quality Control (QC) Representative

5.8.3.11. Perform a Performance Verification Test (PVT) under Government supervision prior to system acceptance. During the PVT demonstrate that the system performs as specified, including but not limited to demonstrating that the system is Open and correctly performs the Sequences of Operation.

5.8.3.12. Provide a 1 year unconditional warranty on the installed system and on all service call work. The warranty shall include labor and material necessary to restore the equipment involved in the initial service call to a fully operable condition.

5.8.3.13. Provide training at the project site on the installed building system <NEW>and UMCS</NEW> Upon completion of this training each student, using appropriate documentation, should be able to start the system, operate the system, recover the system after a failure, perform routine maintenance and describe the specific hardware, architecture and operation of the system. <NEW>Operation of the UMCS includes but is not limited to:
• Configuring and managing alarms
• Configuring schedules
• Creation and modification of trends
• Creation of reports
• Performing operator overrides.</NEW> </LONWORKS>

5.8.4. TESTING, ADJUSTING AND BALANCING. Test and balance air and hydronic systems, using a firm certified for testing and balancing by the Associated Air Balance Council (AABC), National Environmental Balancing Bureau (NEBB), or the Testing Adjusting, and Balancing Bureau (TABB). The prime contractor shall hire the TAB firm directly, not through a subcontractor. Perform TAB in accordance with the requirements of the standard under which the TAB Firm's qualifications are approved, i.e., AABC MN-1, NEBB TABES, or SMACNA HVACTAB unless otherwise specified herein. All recommendations and suggested practices contained in the TAB Standard shall be considered mandatory. Use the provisions of the TAB Standard, including checklists, report forms, etc., as nearly as practicable to satisfy the Contract requirements. Use the TAB Standard for all aspects of TAB, including qualifications for the TAB Firm and Specialist and calibration of TAB instruments. Where the instrument manufacturer calibration recommendations are more stringent than those listed in the TAB Standard, adhere to the manufacturer's recommendations. All quality assurance provisions of the TAB Standard such as performance guarantees shall be part of this contract. For systems or system components not covered in the TAB Standard, the TAB Specialist shall develop TAB procedures. Where new procedures, requirements, etc. applicable to the Contract requirements have been published or adopted by the body responsible for the TAB Standard used (AABC, NEBB, or TABB), the requirements and recommendations contained in these procedures and requirements are mandatory.

5.8.5. COMMISSIONING: Commission all HVAC systems and equipment, including controls, and all systems requiring commissioning for LEED Fundamental commissioning, in accordance with ASHRAE Guideline 1.1 and LEED. The Contractor shall hire the Commissioning Authority, certified as a Commissioning Authority by AABC,

NEBB, or TABB, as described in Guideline 1.1. The Contracting Officer's Representative will act as the Owner's representative in performance of duties spelled out under OWNER in Annex A2 of ASHRAE Guideline 1.1

5.9. ENERGY CONSERVATION

5.9.1. The building including the building envelope, HVAC systems, service water heating, power, and lighting systems shall meet the Mandatory Provisions and the Prescriptive Path requirements of ASHRAE 90.1-2004. Substantiation requirements are defined in Section 01 33 16, Design After Award.

5.9.2. Design all building systems and elements to meet the minimum requirements of ANSI/ASHRAE/IESNA 90.1-2004. Design the buildings, including the building envelope, HVAC systems, service water heating, power, and lighting systems to achieve an energy consumption that is at least 30% below the consumption of a baseline building meeting the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004. Energy calculation methodologies and substantiation requirements are defined in Section 01 33 16, Design After Award.

5.9.3. Purchase Energy Star or FEMP designated products. The term "Energy Star product" means a product that is rated for energy efficiency under an Energy Star program. The term "FEMP designated product" means a product that is designated under the Federal Energy Management Program of the Department of Energy as being among the highest 25 percent of equivalent products for energy efficiency. When selecting integral sized electric motors, choose NEMA PREMIUM type motors that conform to NEMA MG 1, minimum Class F insulation system. Motors with efficiencies lower than the NEMA PREMIUM standard may only be used in unique applications that require a high constant torque speed ratio (e.g., inverter duty or vector duty type motors that conform to NEMA MG 1, Part 30 or Part 31).

5.9.4. Solar Hot Water Heating. Provide at least 30% of the domestic hot water requirements through solar heating methodologies, unless the results of a Life Cycle Cost Analysis (LCCA) developed utilizing the Building Life Cycle Cost Program (BLCC) or the Life Cycle Cost in Design (LCCID) Program which demonstrates that the solar hot water system is not life cycle cost effective in comparison with other hot water heating systems. The type of system will be established during the contract or task order competition and award phase, including submission of an LCCA for government evaluation to justify non-selection of solar hot water heating. The LCCA uses a study period of 25 years and the Appendix K utility cost information. The LCCA shall include life cycle cost comparisons to a baseline system to provide domestic hot water without solar components, analyzing at least three different methodologies for providing solar hot water to compare against the baseline system.

5.11. SUSTAINABLE DESIGN

5.11.1. STANDARDS AND CODES: Sustainable design shall conform to APPLICABLE CRITERIA.

5.11.2. LEED RATING AND VALIDATION: Except where indicated otherwise in Paragraph PROJECTSPECIFIC REQUIREMENTS, the following is required: The minimum requirement for the project is to achieve Silver level of Leadership in Energy and Environmental Design (LEED) rating. Each non-exempt facility (building plus sitework) must achieve this level. The project is required to be registered with the US Green Building Council (USGBC) and use the LEED Letter Templates for project documentation. The LEED-NC Application Guide for Multiple Buildings and On-Campus Building Projects applies to all projects with multiple facilities. Solutions which conserve energy, and improve livability are encouraged. See Paragraph PROJECT-SPECIFIC REQUIREMENTS for facilities that are exempt from the minimum Silver rating, for additional information on USGBC registration, for USGBC certification requirements and for other project-specific information.

5.11.3. Optimize Energy Performance: Project must earn, as a minimum, the points associated with compliance with paragraph ENERGY CONSERVATION.

5.11.4. COMMISSIONING. See paragraph 5.8.5 COMMISSIONING for commissioning requirements. USACE templates for the required Basis of Design document and Commissioning Plan documents are available at http://en.sas.usace.army.mil (click on Engineering Criteria) and may be used at Contractor’s option. <MRc2>

**Appendix 4.1.4: Military Transformation RFP Chapter 6**

6.4.6.5 Chilled and Hot Water. Honeywell manages Chilled and Hot Water: Chilled Water (CW), and High Temperature Water (HW) utility services on Fort Bragg. The point-of-contact (POC) for information is John Gallagher. See Appendix C, (Utility Connection) for additional information.

6.5.2.2. The design should address Fort Bragg's identified preferences. Implementation of these preferences shall consider the following:

(a) Achievable within the Contract Cost Limitation (CCL)
(b) Meets Milestones within Maximum Performance Duration.
(c) Achieves Full Scope identified in this Solicitation.
(d). Best Life-Cycle Cost Design
(e). Sustainability – LEED Silver
(f). Complies with Energy Conservation Requirements Specified in this RFP.

6.9.4 Exterior Lighting

6.9.4.1 Lighting within the Old Post Historic District must meet the requirements of the Old Post Historic District Design Guidelines

6.9.4.2 Design the site lighting for installation by SUS (under separate contract). Supply the site design to SUS for them to plan installation of supporting conduits, exterior lighting bases, and other equipment.

6.9.4.3 See Appendix C: UTILITY CONNECTIONS for additional information and requirements.

6.11 HEATING, VENTILATING, AND AIR CONDITIONING

6.11.1. Integrate the control system to the installation's existing UMCS. The existing UMCS is an LCS-8520 that utilizes the LonWorks® Technology to integrate LNS databases into a single front-end. The UMCS is based on UFGS 25 10 10.

6.11.1.1 Fort Bragg's System Integration (SI) Contractor will integrate the building's BAS in accordance with UFGS 25 10 10 and the Fort Bragg UMCS Integration SOW. Coordinate through Fort Bragg's UMCS System Manager.

6.11.1.2 General Requirements

(a) Do not modify the chiller microprocessor supplied with the equipment. Control and safety functions should be the chiller manufacture's responsibility.

(b) Do not modify the boiler microprocessor supplied with the equipment. Control and safety functions should be the chiller manufacture's responsibility. If heating water

systems are used, then design such systems to maintain the boiler manufacture's minimum temperature when in operation but vary the heating water supply temperature as required to meet the buildings requirements.

(c) Provide all DDC software, equipment and devices from a single common manufacturer whenever possible.

6.11.2 Mechanical Equipment Maintenance and Accessibility Requirements

6.11.2.1 Selected mechanical systems must be compatible with the existing systems and composed of standard commercially available items with readily available service and repair parts.

6.11.2.2 Any mechanical rooms above the first floor shall have an external access (door, removable louvers, etc of ample size such that the largest piece of installed equipment could be removed through the opening.

6.11.2.3 Install all piping, except individual fixture pipes, to permit access without requiring removal of permanent walls, floor, or ceilings.

6.11.2.4 Arrange all equipment, piping, etc in mechanical rooms so that each piece of equipment can be removed without having to remove any other piece of equipment. Consider things such as coil pull areas in the mechanical room layouts.

6.11.2.5 Chillers: Chillers shall include as a minimum the following features

(a) Scroll or screw type compressors with 5-year parts warranty
(b) Microprocessor controllers with self-diagnostic capabilities
(c) Low ambient controls to zero (0) degrees F.

6.11.2.6 Fuels

Natural gas is the preferred fuel source for heating.

6.11.2.7 Pumps

(a) Hot Water and Chilled Water pumps shall operate at 1,750 rpm or less
(b) Mechanical Rooms: Heat to 40 F for freeze protection where piping may be subject to freezing.

6.11.3 Site Mechanical Equipment. Design all exterior mechanical equipment to be compatible with existing mechanical equipment within the surrounding area. This includes color and screening.

6.15 SUSTAINABLE DESIGN

6.15.1 <ONLY_EXEMPT>LEED Minimum Rating. This project includes no facilities that are required to achieve LEED Silver level. Project shall achieve and document all points required by other portions of the RFP and all points that are feasible, but there is no minimum required LEED achievement level. </ONLY_EXEMPT> <NOT_ONLY_EXEMPT>LEED Minimum Rating Exempt Facilities: In addition to any facilities indicated as exempt in paragraph 3, the following facilities are exempt from the minimum Silver requirement: [EXEMPT]. </NOT_ONLY_EXEMPT> <SINGLECO>

6.15.2 Credit Validation: USGBC registration and use of the LEED Letter Templates is required. Registration and payment of registration fees will be by the [FEES]. Administration of the online project will be by the [ADMIN]. <USGBC> Validation of credits will be accomplished by the Government. USGBC certification of the project by the Contractor is required. The Contractor will obtain USGBC certification prior to project closeout. Application, payment of certification of fees and all coordination with USGBC during the certification process will be by the Contractor. USGBC interim review of design phase data is not required by the Government but is recommended. </USGBC> <USGBC_NO> Validation of credits will be accomplished by the Government. USGBC certification of the project by the Contractor is not required. The Government may choose to seek USGBC certification of the project, in which case the Government will pay certification fees and coordinate with the USGBC and the Contractor will furnish audit data as requested at no additional cost.</USGBC_NO> </SINGLECO><SITE_BLDGOTHER>

6.15.2 Credit Validation: The project is the site work <ADDITIONAL>and building(s) </ADDITIONAL> portion of a multiple contractor Combined Project. USGBC registration and use of the LEED Letter Templates is required Registration and payment of registration fees will be by the [FEES]. Administration of the online project will be <ADMINGOV>by the Government</ADMINGOV><ADMINSHARED>shared between the Contractor and the Government per Appendix LEED Requirements for Multiple Contractor Combined Projects</ADMINSHARED>. <ADMINCONTRACTOR> Administration of the online project will be by the Contractor per Appendix LEED Requirements for Multiple Contractor Combined Projects. </ADMINCONTRACTOR> Validation of credits will be accomplished by the Government. USGBC certification of the project by the Contractor is not required. The Government may choose to seek USGBC certification of the project, in which case the Government will pay certification fees and coordinate with USGBC and the Contractor will furnish audit data as requested at no additional cost.</SITE_BLDGOTHER><STDANDSITE>

6.15.2 Credit Validation: The project is a standard design building(s) portion of a multiple contractor Combined Project. USGBC registration and use of the LEED Letter Templates is required. Registration and payment of registration fees will be by the [FEES]. Administration of the online project will be by the [ADMIN]. See Appendix LEED Requirements for Multiple Contractor Combined Projects for information about registered standard designs. Validation of credits will be accomplished by the Government. USGBC certification of the project by the Contractor is not required. The Government may choose to seek USGBC certification of the project, in which case the Government will

pay certification fees and coordinate with USGBC and the Contractor will furnish audit data as requested at no additional cost.</STDANDSITE> <NSTDMULTI>

6.15.2 Credit Validation: The project is a non-standard design building(s) portion of a multiple contractor Combined Project. USGBC registration and use of the LEED Letter Templates is required. Registration and payment of registration fees will be by the [FEES]. Administration of the online project will be by the [ADMIN]. Validation of credits will be accomplished by the Government. USGBC certification of the project by the Contractor is not required. The Government may choose to seek USGBC certification of the project, in which case the Government will pay certification fees and coordinate with USGBC and the Contractor will furnish audit data as requested at no additional cost. </NSTDMULTI> <ONLY_EXEMPT>

6.15.2 Credit Validation: USGBC registration and use of the LEED Letter Templates is <CREDIT_NO>not required. Contractor has the option to register the project and use the LEED Letter Templates. In this case, payment of registration fees and administration of the online project will be by the Contractor. </CREDIT_NO> <CREDIT>required. Registration and payment of fees will be by the [FEES]. Administration of the online project will be by the [ADMIN]. </CREDIT></ONLY_EXEMPT>

Commissioning: See Appendix M for Owner's Project Requirements document(s).

6.15.3 LEED Credits Coordination. The following information is provided relative to Sustainable Sites and other credits. <MULTI_NOT>

**SS Credit 1 Site Selection:**

Project site **[FARMLAND]** considered prime farmland.

<FLOOD1>Project site is five feet or more above 100-year flood elevation. </FLOOD1> <FLOOD2>Delineation of 100-year flood elevation is shown on site drawings provided in this CONTRACT. </FLOOD2>

<HABITAT1>Project site contains no habitat for threatened or endangered species. </HABITAT1><HABITAT2>Delineation of threatened or endangered species habitat is shown on site drawings provided in this CONTRACT. </HABITAT2>

<WETLAND1>No portion of project site lies within 100 feet of any water, wetlands or areas of special concern.</WETLAND1><WETLAND2>Delineation of water, wetlands and areas of special concern is shown on site drawings provided in this CONTRACT.</WETLAND2>

Project site **[PARKLAND]** previously used as public parkland.

**SS Credit 2 Development Density & Community Connectivity**.

Project site **[DENSITY]** meet the criteria for this credit.

**SS Credit 3 Brownfield Redevelopment**.

Project site **[BROWN]** meet the criteria for this credit.

**SS Credit 4.1 Public Transportation Access**.

Project site **[TRANS]** meet the criteria for this credit.

**EA Credit 6 Green Power**.

35% of the project's electricity **[GREEN]** be provided through an Installation renewable energy contract.

**</MULTI_NOT>MR Credit 2 Construction Waste Management.**

The Installation <DOESNOT>does not have an on-post recycling facility available for Contractor's use. </DOESNOT><DOES>has an on-post recycling facility. </DOES> <CONTACT_KNOWN>Contact [CONWASTE_CONTACT] for information about materials accepted. </CONTACT_KNOWN> <MULTIPLE>

See LEED Strategy Table(s) for additional information. </MULTIPLE>

6.15.4 LEED Credit Preferences, Guidance and Resources. See Appendix L LEED Project Credit Guidance for supplemental information relating to individual credits.

6.15.5 <MULTI_NOT>Not Used</MULTI_NOT><MULTIPLE>Multiple Contractor Combined Project. When site work and building(s) are accomplished by separate contractors, it is a Multiple Contractor Combined Project for purposes of LEED scoring and documentation. This project is part of a Multiple Contractor Combined Project that includes site work and building(s) accomplished by separate contractors. See Appendix LEED Requirements for Multiple Contractor Combined Projects and Appendix LEED Strategy Table(s) for special requirements for this project. </MULTIPLE>

6.15.6 Additional Information

**Appendix 4.2: Design Build (TBD)**

**Appendix 4.3: SRM (TBD)**

**Appendix 4.4: Contract Checklist (TBD)**

## Appendix 5: Building Energy Monitor (BEM)

### 1. Overview

You serve a vital role; so to speak, on the firing line. You are in those facilities that need to be monitored and checked on a regular basis.

If you are in a building which have been modified to be more energy efficient, it is important to insure that people in the building are educated on how the building operates to provide comfort and improved efficiency.

If your building has not yet been modified, you need to look for those things which can help make the building operate as efficiently as possible.

### 2. Responsibilities

Your primary responsibility is to help the Energy Manager achieve the objective of an energy efficient installation without an adverse impact on the mission or quality of life. You need to work with the BEM Coordinator to help focus your efforts toward the goals of the Energy Manager. A team effort will yield far more benefits than individual action. Many of these energy responsibilities and goals are no longer an option. Several Mandates, Energy Policies and Executive Orders require the Federal Sector to reduce energy consumption though programs like this one. When initially appointed, you should discuss your duties with the appointing officer, BEM Coordinator and possibly Energy Manager. This can be done either one on one or in team building training or meetings. Transferring ideas is a great way to find solutions to common problems.

Some of your responsibilities will include:

· Serving as your building's point of contact

· Calling in Work orders for low cost maintenance and Energy Conservation Opportunities (ECO's)

· Monitoring the operation of your building

· Recommending energy savings changes to your building's operating procedures

· Meeting with your Energy Manger

· Reporting problems with the building's heating and cooling systems.

· Reporting Energy Use in your facility using Energy Star Portfolio Manger

Checklists can help you spot potential energy saving opportunities. There is a template in Chapter 12 of this manual. You will be sent an electronic version as well.

## 3. Energy Conservation Opportunities

If you find an energy conservation opportunity (ECO), you should discuss it with the DPW or your BEM Coordinator. You can and should also submit the idea through the incentive awards office in the form of a suggestion. If the ECO is technically sound, you might be requested to prepare and submit a work order. If the idea requires a capital investment or is applicable to a broad range of buildings, DPW may want you to prepare a project documentation to obtain funds through one of the various special funding programs. The checklists and concepts in this handbook will help you get some ideas for these recommendations.

## 4. How to carry out your responsibilities

To do your job as the Building Energy Monitor, you will need to know something about the energy consuming components of the building and how they can work more efficiently. This handbook helps you understand energy conservation and the types of things that you can recognize which will stop energy waste. These topics will cover proven energy saving techniques and principles which are based on scientific laws and real world application. Many times systems may seem broken or not functioning properly even though they are calibrated correctly or programmed according to the recommendations. This is primarily due to the concept that a building is a system working together at all times. If one aspect of the system is not working properly and goes undetected it can/will distort the balance of the whole system and can “throw off” the effectiveness of another aspect which may seem totally unrelated.

## 5. Checklist

| ITEM | CHECK POINT DESCRIPTION | YES | NO | CORRECTIVE ACTION |
|---|---|---|---|---|
| 1 | Are lights off in areas unoccupied for more than 5 minutes? | | | |
| 2 | Are exterior lights off during daytime hours? | | | |
| 3 | Is lighting on non-business hours and weekends used only when needed? | | | |
| 4 | Are A/C thermostats set to 74 degrees? | | | |
| 5 | Is air conditioning turned off in unoccupied workspaces? | | | |
| 6 | Are doors and windows for air conditioned areas closed? | | | |
| 7 | Are exhaust fans run only when required? | | | |

| | | | | |
|---|---|---|---|---|
| 8 | Are restroom fans and lights secured when unoccupied and at the close of business? | | | |
| 9 | Are there any leaking faucets or pipes? | | | |
| 10 | Are there any leaking toilet/urinals? | | | |
| 11 | Is watering done outside the hours of 0900 to 1700? | | | |
| 12 | Is watering limited to 15 minutes per area? | | | |
| 13 | Are sprinklers aimed only at grass? | | | |
| 14 | Are personnel advised in and practicing water conservation -full loads for laundry, not constantly running unused water? | | | |
| 15 | Is unused equipment turned off or in sleep mode during work hours? | | | |
| 16 | Is office equipment turned off at the close of business? | | | |
| 17 | Are the HVAC filters being replaced Monthly? | | | |

Meter Data

Date _____ _____

Inspected By _____

Comments _____

**Appendix 6: Retro-Commission Scope of Work**

ENGINEERING SERVICES TO RETRO-COMMISSION BUILDING [ # ]
Ft. Bragg, North Carolina
Directorate of Public Works

1.0 OBJECTIVE

Ft. Bragg has experienced numerous temperature and indoor environment complaints, increased energy usage, additional maintenance requests on the project building[s] This project will retro-commission BUILDING [ # ] utilizing LEED™ for Existing Buildings – O&M and Ft. Bragg Existing Building Commissioning Program requirements as a framework for technical requirements and implementation. Energy and water analysis and retro-commissioning will be performed to meet the requirements for LEED™-EB O&M. Projects that require significant construction, identified during survey and retro-commissioning, will be detailed and included in the documentation and final report. Retro-commissioning applies a systematic investigation process for improving and optimizing a building's operation and maintenance (O&M). Retro-commissioning occurs after construction, as an independent process. Retro-commissioning is typically applied to buildings that have *not* previously been commissioned. The expected outcomes are:

- Improved environmental conditions for the occupants
- Reduce complaints and break-down maintenance work orders
- Reduced energy/water usage
- Reduced facility life cycle operating cost and increased facility life

The Contractor will provide the following services as part of the project as detailed in the statement of services below:

- Existing Building Commissioning
- DDC repairs as needed (assume 20% of room thermostats are bad per Barracks)
- Mechanical repairs up to $50,000
- Construction Phase Services
- Facility Condition Assessment
- Building Systems Manual

2.0 GENERAL INFORMATION

2.1 Responsible officials: The Contracting Officer (KO) of U.S. Army Engineering and Support Center, Huntsville, is responsible for the administration of this contract. The Directorate of Public Works (DPW) at Ft. Bragg is designated as the technical surveillance representative of the KO. No change shall be made in the provisions of this contract without written authorization of the KO.

2.2 Channels for obtaining information: Except as specified herein, all requests for technical information necessary to do this work shall be made to the designated Contract Representative (COR) assigned by DPW. Maintain close liaison with the office by appropriate means to assure maximum coordination of the work.

2.3 Project Manager: Appoint a Project Manager for the project to serve as the single point of contact and liaison between the Contractor and the Government. Upon award of contract, advise the KO in writing of the name of the contact individual. The Contractor's Project Manager will be responsible for the complete coordination of all work required for this project.

2.3.1 The COR will serve as the point of contact for the Contractor on all technical matters. All work performed by the Contractor will be coordinated with the COR.

2.3.2 Mark all letters, meeting/phone records, reports, plans, sketches, specifications, estimates, computation sheets and other documents to identify the project name and number.

2.4 Government Furnished Information: The Government, through the COR, will furnish the best applicable data, information, and drawings as available. Field verification by Contractor of any Government furnished information is required.

## 3.0 FIELD WORK, SCHEDULE, AND SITE VISIT REQUIREMENTS

3.1 Notice: Report to the COR prior to each arrival for field investigation work and shall have made proper arrangements for identification badges, parking permits, and safety. See **Attachment A** for the Contractor checklist. Forty-eight (48) hour notice is required to allow the Government to arrange escorts, building access, or for interviews with Government employees.

3.2 Visits: Provide the appropriate personnel for site investigative work. The level of experience and expertise must be selected to ensure that all personnel making field investigations and determinations have the proper training and experience to make observations, opinions and reports of findings. It is the responsibility of the Contractor to determine the exact amount of fieldwork required and level of experience for each individual performing fieldwork prior to the Contractor commencing with the work.

3.3 Schedule: Prepare a detailed schedule establishing the dates and type of field investigation to be performed. This schedule shall be submitted for approval to the KO and revised as required. Do not commence with any work prior to approval of this schedule. Update the schedule as required and reissue any revised schedule for approval by the KO. As a minimum, this schedule shall provide:

3.3.1 Time line with dates, hours of proposed access to the site, building number and identification of personnel performing each work task.

3.3.2 Notification of any requested site investigation work that differs from regularly scheduled Ft. Bragg working hours (7:00 a.m. to 4:30 p.m., Monday through Friday, with exceptions of Government holidays).

3.3.3 Proposed utility outages or service interruptions that are required to perform the field investigation.

## 4.0 TASKS

The following sections are divided into 6 steps for purposes of phasing the retro-commissioning effort.

### 4.1 Existing Building Commissioning – Investigation phase

#### 4.1.1 EA Credit 2.1 Existing Building Commissioning, Investigation and Analysis – Option A: Commissioning Process

To meet the requirements of EA Credit 2.1, Option A, the Contractor shall, for each building:

1. Develop a retro-commissioning, re-commissioning or ongoing commissioning plan for the building's major energy-using systems.
2. Conduct the investigation and analysis phase.
3. Document the breakdown of energy use in the building.
4. List the operating problems that affect occupants' comfort and energy use, and develop potential operational changes that will solve them.
5. List the identified capital improvements that will provide cost-effective energy savings and document the cost/benefit analysis associated with each.
6. Prepare a detailed Systems Operating Manual for the building containing operational set-points, operating diagrams, and instructions for sustaining the operational and energy benefits achieved in the retro-commissioning process.
7. The Contractor shall have a kick-off meeting with DPW to discuss requirements of the project and get the names of key contacts for the project. The Contractor shall conduct a workshop with the DPW to document project requirements for retro-commissioning. The Contractor shall obtain available building utility information, mechanical/electrical drawings, test reports, current controls sequences, and HVAC operations and maintenance (O&M) data.

8. The Contractor shall document operational problems through interviews with staff.
9. The Contractor shall prepare a retro-commissioning performance testing plan for the investigation phase of the project and submit the plan to DPW for review and approval.

4.1.2 Establish Energy Baseline from Metered or Collected Data

The Contractor shall obtain from DPW the metered energy data from the building for the past 2 years. In the case where there is no metered data, incomplete data, or partial metered data, and energy savings are likely, the Contractor shall create a spreadsheet model, or build a more complete energy model to determine the baseline energy usage. If no energy savings are likely or the existing building commissioning goal is largely operational improvements vs. direct energy savings, then the energy consumption baseline will be stipulated from the measurements and data available. NOTE: on buildings with no metered data, DPW may elect to install adequate metering under another contract and the Contractor will coordinate the work in this scope to align with the installation of the new meters.

4.1.3 Controls Investigation**:**

The Contractor shall perform an investigation of the direct digital control (DDC) system for the HVAC equipment (AHUs, exhaust fans, chillers, boilers, associated pumps, etc.). Perform the investigation on a sample of [25%-100%] of the AHU's, 20% of VAV terminals, and the chiller & boiler plant equipment. The investigation shall include the following tasks:

- Functional test of the control loop sequence of operations
- Check and calibrate AHU, exhaust fan, and chiller, analog inputs and outputs (point-to-point)
- Check correct operation of digital points (point-to-point)
- Check actuators, valves, and dampers for proper operations.
- Check for valve leak through
- Check quality and condition of control dampers
- Validate the graphics on the host front end computer
- Setup start/stop schedules
- Trend 25% of major control loops for 24 hours to determine stability of control
- Randomly trend 25% of the room temperatures for one hour to determine stability of control
- Assess building level control system for compatibility of connection and integration with Ft Bragg UMCS per established standards provided by DPW

4.1.4 HVAC Investigation**:**

The Contractor shall inspect, assess, and document the condition of the AHU, exhaust, chiller and boiler systems. Any systems or subsystem parts that are broken will be identified immediately to DPW. A report of the equipment condition shall be provided. The Contractor shall perform the investigation on a sample of [ 25%-100%] of the AHU's & EFs, 10% of VAV terminals, and the chiller & boiler plant equipment.

The investigation will include the following tasks:

- Validate (not re-balance) the air and hydronic flows of the main HVAC systems. This will include AHUs, exhaust systems, chillers, pumps, air handler coils, circuit setters, valves and cooling towers.
- The Contractor shall make building pressurization tests to determine how the overall building pressure relationship is maintained (i.e., is it maintaining a slight positive pressure). This test shall be repeated for various control function modes of the AHUs (i.e., economizer, night setback, etc.).

4.1.5 EQ Prerequisite 1, Outside Air Introduction and Exhaust System**s**

To achieve EQ Prerequisite 1, the Contractor shall, for each building and central plant:

- Evaluate the existing ventilation distribution systems in accordance with ASHRAE 62.1-2007 Ventilation Rate Procedure under all normal operating conditions.
- The Contractor shall conduct a field survey of the existing air handlers in each building, review the design drawings, and compare to ASHRAE 62.1-2007 requirements to existing conditions.

4.1.6 Interim Report and Conference:

The Contractor shall submit an interim report of the findings of the investigations which contains:

- Deficiencies noted in existing systems
- Variance from design documents
- Summary of Energy Consumption

- Draft of the Systems Operating Manual
- Tabulation of System performance (as found)

4.2 Energy, Water and Carbon Audit –**TBD**

4.3 Final Retro-Commissioning Reports, Manuals and Review Meeting

The Contractor shall provide DPW with draft and final versions of the Retro-Commissioning report summarizing the results of the pre-requisite and credit as well as the results of the investigation and analysis phase. The report will include a list of the operating problems that affect occupants' comfort, energy use, and potential operational changes that will solve them. The estimated cost to correct these problems will be included in the report. The report will also include a list of the identified capital improvements that will provide cost-effective energy savings and document the cost/benefit analysis associated with each. The report will include a list of the operating problems that affect occupants' comfort, energy use, and potential operational changes that will solve them. The cost to correct these problems will be included in the report.

The Contractor shall attend a meeting with DPW to review the findings and recommendations in the final report.

4.4 Implementation Phase
**[This sub-section is included if capital or construction efforts are warranted in the corrective measures and funding is obtained, otherwise it may be omitted]**

4.4.1 Design Services

4.4.1.1 Site Survey - Provide site investigations as follows:

The Contractor shall amend and update field data about the project. The Contractor shall work with DPW to gather any additional drawings illustrating the existing installation.

4.4.1.2 Design – Major Retrofit Scope Package:

At the direction of the Government, The Contractor shall prepare a 35% preliminary design document package to correct the deficiencies noted in the investigation which require major alteration and/or construction services to correct. USAESC Huntsville and Ft. Bragg DPW will determine the specific repairs or retro-fits to be performed. The design shall include demolition, piping, HVAC, electrical, controls, and new equipment. The design shall include plans and specifications suitable for bidding and construction. The Contractor shall prepare (one) submittal for review and

comment: Schematic Design (35%). The Contractor may then be directed to complete the Construction Documents (100%). In this case, final bid documents shall be provided for review. The Contractor shall provide a written response to all review comments and incorporate comments into subsequent submittals. The submittals shall include drawings, specifications, a construction cost estimate, calculations, cut-sheets of equipment selections. The Contractor shall attend and on-site review meeting to discuss the 35% and 100% submittals.

4.4.2 Construction Phase Services – Provide the following engineering services during construction:

1. Attend construction kick-off meeting at DPW.
2. Review Contractor equipment submittals.
3. Answer Contractor questions and RFI's.
4. Make one trip during construction to review equipment and system installation.
5. Make one Final Inspection trip when construction is complete to verify the proper installation of all equipment and systems.
6. Review O&M manual submittals.
7. Prepare as-built drawings from red line drawings provided by the Contractor.

4.4.3 Project Commissioning for Implementation:

**Note:** This section is included as a follow on for the corrective measures made in the implementation phase and ensure that project construction and implementation measures are fully tested to the design documents or to the recommendations provided in the Investigation Phase [ edit to reflect appropriate project needs]

The Contractor will provide commissioning services for the project to integrate the Existing Building commissioning activities and any retro-fits or construction performed so as to provide Ft. Bragg with a fully operational and optimized facility. For this effort commissioning services will consist of:

1. Prepare Pre-Functional checklists for Contractors and ensure compliance
2. Monitor Start-Ups by the Contractor and ensure manufacturer requirements are met
3. Validate Test, Adjust and Balancing (TAB) by the Contractor
4. Verify calibration and tuning of controls modifications
5. Prepare revised FT procedures (post construction) and submit to the Contractor for review

6. Direct and witness functional testing by the Contractor
7. Update commissioning database and issues log
8. Provide commissioning progress reports
9. Update the building systems manual (final commissioning report) prepared in Para 4.1

## 5.0 WORK PHASES

### 5.1 PHASE I – Retro-Commissioning Investigation Phase:

- Coordinate and perform all necessary work to accomplish the scope of services identified in Paragraphs 4 through 4.2.

### 5.2 PHASE II – Energy Water and Carbon Audits:

- Energy, Water and Carbon Audits: Complete the appropriate level of Energy, Water and Carbon Audits and compile results for inclusion in the final report. Deliver Final Report(s)

### 5.3 PHASE III –Implementation

- Implement required changes via DPW resources locally or if capital or construction services are required to implement the corrective measures
- Initiate 35% Design. After review and approval of the Report by the Government, prepare and submit a 35% Design for review and comment and attend a review meeting with Government personnel at FT. Bragg.
- 100% Design: After review and approval of the 35% Design by the Government, prepare and submit a 100% Design for review and comment and attend a review meeting with Government personnel at Ft.Bragg. The 100% Design shall incorporate any corrections from the 35% Design review.
- Final Design: After review and approval of the 100% Design by the Government, prepare and submit a Final Design. The Final Design shall incorporate any corrections, comments, final documents, test results, final recommendations, and other final enclosures.
- Provide engineering support and commissioning during construction.

### 5.4 PHASE IV– Construction Services:

- Provide write-able compact disc containing all necessary reports and information to ensure conformance with **Attachment C** – Electronic Media Requirements.

- All meetings, conferences, interviews, and formal presentations shall be held at DPW, Ft. Bragg. NC.

***Note:** This section is typically outlined in COE project documentation.

6.0 PERIOD OF PERFORMANCE

6.1 Schedule:

| | | |
|---|---|---|
| 6.2 Phase I | Investigation Phase | [X] weeks after NTP |
| 6.3 Phase II | Audits | [X] weeks after NTP |
| 6.4 Phase III | Implementation | [X] weeks after NTP |
| 6.5 Phase IV | Construction Services | [TBD] |
| 6.6 Submit Final As-Built Documents | | [X] weeks after Construction |

6.7 The time required by the Government to review submissions made by the Contractor under this contract will vary with the workload. The review periods will generally begin within 1 week of receipt of the submittal and submittals will subsequently be reviewed within 1weeks. Within 7 calendar days of receipt of the submittal, the Contractor will be informed in writing as to whether or not the received submittal is considered sufficiently complete to be reviewed. There is no established maximum anticipated review period; however, should review period require more than six weeks, the KO will make a determination as to whether or not the Contractor contract should be modified. Every effort will be made to accomplish reviews within shorter periods.

***Note:** This section is typically outlined in COE project documentation.

7.0 DELIVERABLES

7.1 Phase I Deliverables:
Project Schedule
Abbreviated Safety Plan

7.2 Phase II Deliverables
Retro-Commissioning Plan
Interim Retro-Commissioning Report
Systems Operating Manual

7.3 Phase III Submittals:

Audit Report of Findings

7.4 Phase IV Deliverables
35% Design Drawings
Calculations
Equipment Cut Sheets/Drawings
Specifications
Construction Cost Estimate

7.5 Phase V Submittals:
100% Design Drawings
Calculations
Equipment Cut Sheets
Specifications
Construction Cost Estimate
Annotated Comments

7.6 Phase VI Submittals
Final Design Drawings
Annotated Comments
Final Baseline Report

7.7 Phase VII Deliverables
As-built Drawings
Reviewed O&M Manuals
Commissioning Report for Construction Phase

8.0 GOVERNMENT FURNISHED INFORMATION:

- Control system drawings notably including the Points Schedule drawing(s)
- Mechanical drawings
- Commissioned LNS database including XIF files and plug-ins
- Network Configuration Tool (NCT) licensing information including NCT model, manufacturer, revision and license status.
- DDC programming software and databases
- Floor plan drawings
- Ductwork layout drawings

* **Note**: If none or part of the above items cannot be furnished by the Government, the Contractor will provide pricing to the Government to reproduce, re-create or duplicate such information and/or provide alternate solutions.

**Appendix 7: Commission**

**Appendix 7.1: Commissioning Guide Specifications**

DEPARTMENT OF THE ARMY 01 46 00.00 06 (September 2008)
U.S. ARMY CORPS OF ENGINEERS ----------
LRL-01460L (September 2001)

GUIDE SPECIFICATION FOR CONSTRUCTION

SECTION 01 46 00.00 06

COMMISSIONING OF BUILDING ENERGY SYSTEMS
**09/08**

**NOTE: This guide specification covers the requirements for <SCP> commissioning of HVAC, lighting control, domestic hot water, renewable energy, and on-site power systems</SCP>. Lighting, domestic hot water, and on-site power systems are only REQUIRED to be commissioned for LEED projects. Delete references and checklists related to the Basis of Design; the Owner's Project Requirements; and the lighting, domestic hot water, renewable energy, and on-site power systems for projects not pursuing LEED-NC v2.2 Energy & Atmosphere prerequisite 1, Fundamental Commissioning of the Building Energy Systems. This guide specification is to be used in the preparation of project specifications in accordance with ER 1110-1-8155.**

PART 1 GENERAL

Commissioning of the HVAC [, Lighting Control, Domestic Hot Water, Renewable Energy, and On-Site Power] systems is the responsibility of the Contractor. The Contractor shall employ the services of an independent Commissioning Agent. The Commissioning Agent shall coordinate all aspects of the commissioning process. Commissioning procedures shall conform to the procedures outlined in this specification.

1.1 SUBMITTALS

**NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required. Indicate submittal classification in the blank space**

**following the name of the item requiring the submittal by using "G" when the submittal requires Government approval. Submittals not classified as "G" will show on the submittal register as "Information Only". For submittals requiring Government approval, a code of up to three characters should be used following the "G" designation to indicate the approving authority; codes of "RO" for Resident Engineer approval, "DO" for Engineering approval, and "AE" for Architect-Engineer approval are recommended.**

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-05 Design Data;

Design Review Report G, DO

**NOTE: Select first option for Design-Bid-Build projects or Design-Build projects not pursuing LEED-NC v2.2 Energy & Atmosphere credit 3, Enhanced Commissioning. Select the second option for Design-Build projects pursuing LEED-NC v2.2 EAc3, Enhanced Commissioning.**

Completed report individually listing each deficiency and the corresponding proposed corrective action shall be submitted [no later than 14 calendar days after approval of the Commissioning Agent.][ concurrent with the submission of the final design.]

Commissioning Plan; G, DO

Outline of the overall commissioning process; the schedule for Pre-Commissioning Checks, Functional Performance Tests, Training, Turn-Over Instruction, and Building Operation Review as applicable; list of team members who will represent the Contractor during Pre-Commissioning Checks and Functional Performance Tests; Pre-Commissioning Check lists and Functional Performance Tests lists for each building, each system, and each component; shall be submitted at least 14 calendar days prior to start of pre-commissioning checks.

SD-06 Test Reports

Final Commissioning Report Reports; G, DO.

**NOTE: Select the bracketed option for projects pursuing LEED-NC v2.2 EAp1,**

**Fundamental Commissioning of the Building Energy Systems.**

Completed pre-commissioning checklists and functional performance test checklists organized by system and by subsystem and submitted as one package. The results of failed tests shall be included along with a description of the corrective action taken. The report shall include an executive summary of the commissioning process and results and include any seasonal testing scheduled for a later date. [The report shall indicate whether systems meet the requirements of the Owner's Project Requirements and the Basis of Design. ]The training video shall be included. The report shall be submitted no later than 14 calendar days after completion of Functional Performance Testing.

SD-07 Certificates

Commissioning Agent; G, DO

**NOTE: Select bracketed option for Design-Build projects pursuing LEED-NC v2.2 EAc3, Enhanced Commissioning.**

The Commissioning Agent shall be a NEBB qualified Systems Commissioning Administrator (SCA) employed by a NEBB certified firm with a minimum of three years of HVAC commissioning experience and at least two projects of similar size and scope; or an AABC Certified Commissioning Agent (CCA) employed by an AABC certified firm with a minimum of three years of HVAC commissioning experience and at least two projects of similar size and scope; or a Professional Engineer (P.E.) with a minimum of five years of HVAC design experience who is not associated with the design of this project, is licensed in the state where this project is located, and has a minimum of three years of HVAC commissioning experience and at least two projects of similar size and scope. The Commissioning Agent's certification of qualifications including the Commissioning Agent's name and firm shall be submitted no later than 30 calendar days after Notice to Proceed.[The Commissioning Agent's contract including the Scope of Work for Building Operation Review shall be submitted with the Commissioning Agent's qualifications]

Certificate of Readiness; G, DO.

Statement issued by the Contractor and signed by the Contractor, the Commissioning Agent, and all other Contractor's Representatives on the Commissioning Team certifying that all equipment, systems, and controls are complete and ready for Functional Performance Tests. Includes start-up reports, completed Pre-Commissioning Checklists, Performance Verification Test Report, and the TAB Report. Submit no later than 14 calendar days prior to Functional Performance Tests.

**NOTE: Delete the Systems Manual submittal for projects not pursuing LEED-NC v2.2 EAc3, Enhanced Commissioning.**

SD-10 Operation and Maintenance Data

Systems Manual; G, DO

[Completed manual including the Basis of Design and, for all commissioned systems, the single line diagrams, the as-built sequences of operation, the control drawings, original setpoints, operating instructions, recommended schedule of maintenance if not in the O&M manual, and the recommended schedule for calibrating sensors and actuators. The Systems Manual shall be submitted no later than 14 calendar days after completion of Functional Performance Testing.]

1.2 Certificate of Readiness

The Contractor shall issue a Certificate of Readiness certifying that the building energy systems are ready for Functional Performance Testing. The Certificate of Readiness shall include all equipment and system start-up reports, Performance Verification Test Reports, Pre-Commissioning Checklists, TAB Report, and the Building Air Tightness Test Report. The Contractor, the Commissioning Agent, and the Contractor's Quality Control, Mechanical, Electrical, Controls, and Testing, Adjusting, and Balancing Representatives shall sign and date the Certificate of Readiness.

1.3 COMMISSIONING ACTIVITIES

**NOTE: The development and review of the Basis of Design (BOD) and the Owner's Project Requirements (OPR) documents is required for LEED-NC v2.2 Energy & Atmosphere prerequisite 1 compliance.**

**The design team develops the BOD in accordance with the requirements of LEED-NC v2.2 EAp1. The BOD must include a listing of the codes, guidelines, standards, and regulations applicable for the project. The BOD must include descriptions of the usage for each space or groups of spaces, climatic design conditions, space zoning, occupancy conditions, space environmental requirements (temperature, humidity, etc.), redundancy, and diversity. The BOD must include narrative descriptions for the HVAC, lighting systems, domestic hot water systems, renewable energy systems, or any other systems to be commissioned. The BOD should reflect the requirements stated in the OPR. Insert the BOD into this specification section as Appendix C.**

**The design team is responsible for the development of the OPR. The design team should consult with the program/project managers, users, operation/maintenance staff, base/military installation**

**personnel, etc. to obtain the specific requirements for the project. The OPR should be developed in accordance with the requirements of LEED-NC v2.2 EAp1. The OPR must describe the primary purpose and usage of the building, quality of materials, construction and operating costs, need for future expansion, and flexibility. The OPR must describe specific environmental and sustainability goals, energy efficiency goals relative to applicable energy codes, standards, or other requirements (ASHRAE, LEED, etc.). The OPR must include a description of any specific requirements that will impact energy usage (siting, fenestration, envelope, etc.). The OPR should describe anticipated occupancy schedules, space environmental requirements, desired level of occupant control of systems, specific lighting needs, accommodations for after-hour usage, and the usage for each space or groups of spaces. The OPR should describe the desired level of quality, reliability, flexibility, building automation, and maintenance requirements for each system. The OPR must describe how the facility will be operated and who will operate/maintain the building. The desired level of training for building users or operating/maintenance staff should be described. Insert the OPR into this specification as Appendix D. Delete Appendix C and D and any reference to them for projects not pursuing LEED-NC v2.2 EA prerequisite 1.**

**NOTE: The templates provided in Appendix C and Appendix D of this guide specification covers the requirements for the Basis of Design and the Owner's Project Requirements. These may be edited by the design team for use in this specification. In lieu of the templates provided, the design team may replace the templates with another form provided that all information required by LEED-NC v2.2 EAp1for these documents is included. Templates provided at http://en.sas.usace.army.mil, "Engineering Criteria" for the Basis of Design and Owner's Project Requirements may be used.**

The Contractor shall be responsible for the following procedures described in this specification:

a. Preconstruction Commissioning Meeting - The Commissioning Agent, the Contractor, the Contractor's Quality Control Representative, and the Government shall meet and discuss the commissioning process to include all requirements and submittals as specified in this section no later than 14 days after approval of the Commissioning Agent.

**NOTE: The following paragraph is applicable for Design-Build project pursuing LEED-NC v2.2Energy & Atmosphere credit 3, Enhanced Commissioning. For Design-Bid-Build project and/or projects that will not pursue LEED-NC v2.2 EA credit3, delete the paragraph.**

[b. Design Review (Design-Build) - The Commissioning Agent shall review the Design Plans and Specifications, the Basis of Design, and the Owner's Project Requirements prior to 60% completion of the design. The Commissioning Agent shall assess the completeness and clarity of the Owner's Project Requirements, verify that the requirements stated in the Owner's Project Requirements are addressed in the Basis of Design, and verify that the Design Plans and Specifications are prepared in accordance with the Basis of Design and the Owner's Project Requirements. The Commissioning Agent shall back check the reviewed documents at 95%completion of the design. The Commissioning Agent shall provide a Design Review Report which shall identify any discrepancies between the reviewed documents, deviations in the design from the Basis of Design or Owner's Project Requirements, or deficiencies that would prevent the building energy systems from operating effectively in accordance with the sequence of operation. The Design Review Report shall individually list each deficiency and the corresponding proposed corrective action necessary for proper system operation. The report shall be submitted with the final design submission to the Government. The Contracting Officer's Representative, the Commissioning Agent, and the Designers shall meet, discuss, and resolve any items contained in the report no later than 14calendar days after submission of the report.]

**NOTE: The following paragraph is applicable for Design-Bid-Build projects and Design-Build projects not pursuing LEED-NC v2.2 Energy &Atmosphere credit 3, Enhanced Commissioning. For Design-Build projects pursuing LEED-NC v2.2 EA credit 3, delete the paragraph.**

**Delete the bracketed option for projects not pursuing LEED-NC v2.2 Energy & Atmosphere prerequisite 1, Fundamental Commissioning of the Building Energy Systems.**

[b. Design Review (Design-Bid-Build) - The Commissioning Agent shall review the Contract Plans and Specifications and advise the Contracting Officer's Representative of any deficiencies that would prevent the building energy systems from operating effectively in accordance with the sequence of operation specified. [The Commissioning Agent shall review the Basis of Design and Owner's Project Requirements. The Basis of Design is shown in Appendix C. The Owner's Project Requirements is shown in Appendix D. The Commissioning Agent shall compare the Basis of Design and the Owner's Project Requirements against the Contract Plans and Specifications and advise the Contracting Officer of any discrepancies. The Design Review shall be performed before the first submission of building energy system related submittals. ]The Commissioning Agent shall provide a Design Review Report individually listing each deficiency and the corresponding proposed corrective action necessary for proper system operation. The report shall be submitted to the Contracting Officer no later than 14 days after approval of the Commissioning Agent. The Contracting Officer, the Commissioning Agent, and the Designer shall meet and discuss any items contained in the report no later than 7 calendar days after submission of the report. All items will be resolved at that meeting.]

c. Commissioning Plan - The Commissioning Agent shall prepare the Commissioning Plan. The Commissioning Plan shall outline the overall commissioning process, the commissioning schedule, the commissioning team members and responsibilities, and documentation requirements. The commissioning schedule shall include Pre-Commissioning Checks, Functional Performance Tests, Training, Turn-Over Instruction, and Building Operation Review as applicable. The Commissioning Agent shall prepare the Pre-Commissioning Checklists for each building, for each system, and for each component before the start of the checks. Appendix A provides examples of the minimum detail required for Pre-Commissioning Checklists. The Commissioning Agent shall prepare the Functional Performance Test lists for each building, for each system, and for each component before the start of the tests. Appendix B provides examples of the minimum detail required for Functional Performance Test Lists.

**NOTE: Delete bracketed options for projects not pursuing LEED-NC v2.2 Energy & Atmosphere prerequisite 1, Fundamental Commissioning of the Building Energy Systems.**

d. Construction - The Commissioning Agent shall review all building energy system related shop drawings and submittals and verify the submitted equipment complies with the contract requirements [ and the requirements of the Basis of Design and the Owner's Project Requirements]. The Commissioning Agent shall review the status of the Pre-Commissioning Checklists, and shall verify the items on the checklists conform to the submittals, are installed in accordance with the manufacturer's recommendations, and are installed in compliance with the contract requirements [ and the requirements of the Basis of Design and the Owner's Project Requirements]. The Commissioning Agent shall perform an onsite review and shall verify that the systems are in compliance with all specifications prior to the Functional Performance Tests.

e. Pre-Commissioning Checks - The Commissioning Agent, Contractor's Quality Control Representative, and the Government shall perform pre-commissioning checks and complete the Pre-Commissioning Checklists. Each applicable item in the checklist for each item of equipment shall be inspected and the checklist shall be initialed by the Commissioning Team. The Commissioning Team shall only initial items on the checklist that are complete and witnessed.

f. Testing, Adjusting, and Balancing (TAB) Verification Testing -After the TAB process is performed and the balance report is submitted, the Commissioning Agent shall perform a verification test. The extent of verification shall be to the discretion of the commissioning agent; however a minimum of 15% of all readings shall be verified. If readings deviate more than + or - 10% from the report the TAB contractor shall be directed to re-balance the system and submit new reports.

g. Pre-Functional Performance Test Meeting - The Commissioning Agent, the Contractor, the Contractor's Quality Control Representative, and the Government shall meet prior to Functional Performance Tests to determine if all Functional Performance Test Prerequisites have been completed and to discuss the reports submitted with the

Certificate of Readiness and the Functional Performance Test procedures.

h. Functional Performance Tests - The Commissioning Agent shall lead the Functional Performance Tests in accordance with the Commissioning Plan.

**NOTE: Delete the Systems Manual for projects not pursuing LEED-NC v2.2 Energy & Atmosphere credit 3, Enhanced Commissioning.**

[i. Systems Manual - The Commissioning Agent shall develop a system manual. The systems manual shall be a separate document from the Operating and Maintenance Manuals required by related sections. The system manual shall include the Basis of Design and, for all commissioned systems, the single line diagrams, the as-built sequences of operation, the control drawings, original setpoints, operating instructions, recommended schedule of maintenance if not in the O&M manual, and the recommended schedule for calibrating sensors and actuators.]

j. Training - The Commissioning Agent shall schedule, supervise and video all training of the owner's maintenance staff on all building energy equipment and systems. The video shall be turned over to the COR as part of the final commissioning report for future reference. The Commissioning agent shall provide the video on the appropriate media as directed by the Contracting Officer's Representative.

k. Operating and Maintenance Manuals Turn-over - The Commissioning Agent shall assist and schedule the submission of all O&M Manuals and Warranties.

l. Turn-over Instruction - When the building energy systems are ready to be turned-over to the owner, the Commissioning Agent shall schedule a final session for operation and maintenance personnel instruction. The system design engineers, installing contractors, major equipment suppliers and any other interested parties should be in attendance. This instruction shall include a review of all systems and equipment operations, additional hands-on instruction where required and a question and answer period.

**NOTE: Delete the bracketed option for projects not pursuing LEED-NC v2.2 Energy & Atmosphere prerequisite 1, Fundamental Commissioning of the Building Energy Systems.**

m. Final Commissioning Report - The Commissioning Agent shall prepare a Final Commissioning Report as required. The report shall include an executive summary of the commissioning process and results and include any seasonal testing scheduled for a later date. [The report shall indicate whether systems meet the requirements of the Owner's Project Requirements and the Basis of Design. ]The report shall detail any deficiencies found during the testing and the corrective actions taken. The report shall include all Pre-Commissioning Checklists and Functional Performance Test Checklists, and any substantiating information.

**NOTE: The following paragraph applies only to projects that pursue LEED-NC v2.2 Energy & Atmosphere credit 3, Enhanced Commissioning.**

[n. Building Operation Review - The Commissioning Agent shall visit the building and review building energy system operation with operating staff and users 8 to 10 months after substantial completion. The Commissioning Agent shall advise the Contracting Officer's Representative of any outstanding construction deficiencies. The Systems Manual shall be updated with the list of deficiencies that will not be corrected. The updated Systems Manual shall be submitted no later than 14 calendar days after completion of Building Operation Review.]

1.4 SEQUENCING AND SCHEDULING

The Functional Performance Tests described in this Section shall begin only after all work and testing required in related Sections, including Section 23 09 23 DIRECT DIGITAL CONTROL FOR HVAC AND OTHER LOCAL BUILDING SYSTEMS, LRL Section 07 25 00.00 06 BUILDING AIR BARRIER SYSTEM, and Section 23 05 93.00 10 TESTING, ADJUSTINGAND BALANCING FOR HVAC, have been successfully completed, and after all test and inspection reports and operation and maintenance manuals required in these Sections have been submitted and approved.

The following shall be completed prior to Functional Performance Tests:

a. All equipment and systems have been completed, calibrated, and operate in accordance with contract documents.
b. Performance Verification Tests have been completed and the Performance Verification Test Report has been submitted. Performance Verifications Tests shall [be as specified in Section 23 09 23.][ demonstrate that all physical and functional requirements of the contract have been met. The Contractor shall demonstrate that the control systems perform in accordance with the sequence of operations.]
c. Testing, Adjusting, and Balancing has been completed and the TAB Report has been submitted.
d. The Building Air Tightness Tests have been completed and the Building Air Tightness Test Reports have been submitted.
e. The Pre-Commissioning Checklists have been completed and submitted.
f. The Certificate of Readiness has been submitted.
g. The Pre-Functional Performance Test Meeting has occurred.

1.5 COMMUNICATION WITH THE GOVERNMENT

**NOTE: This paragraph is applicable only for Design-Build projects pursuing LEED-NC v2.2 Energy &Atmosphere credit 3, Enhanced Commissioning. Delete this paragraph for Design-Bid-Build projects or for Design-Build projects not pursuing LEED-NC v2.2 EAc3, Enhanced Commissioning.**

The Commissioning Agent shall submit all plans, schedules, reports, and

documentation directly to the Contracting Officer's Representative concurrent with submission to the CQC System Manager. The Commissioning Agent shall have direct communication with the Contracting Officer's Representative regarding all elements of the commissioning process.

PART 2 PRODUCTS (NOT APPLICABLE)

PART 3 EXECUTION

3.1 COMMISSIONING TEAM AND CHECKLISTS

**The "design Agent's Representative" will be a member of the HVAC design team, i.e. from the AE or from Engineering Division. Where possible the "Design Agent's Representative" should be included as a member of the commissioning team for the pre-commissioning checklists. The Design Agent's Representative will participate in functional performance tests. The planning and programming of either Title II services or in house support will be required for the participation of the Design Agent's Representative.**

**The checklists provided are to be used as guides for the preparation of project checklists. The appropriate checklist should be included in the project specification for each HVAC equipment component. The designer will add additional checklists for equipment or systems not included in this guide specification or modify the checklists where necessary for specific project requirements. If, for example, a system needs to be tested with certain internal load, each appropriate checklist should be modified to include this requirement along with specifics on how load should be generated.**

The Contractor shall designate team members to participate in the pre-commissioning checks and the functional performance testing specified herein.

The team members for pre-commissioning checks shall be as follows:

| Designation | Function |
|---|---|
| QA | Contracting Officer's Quality Assurance Representative |
| QC | Contractor's Quality Control Representative |
| CA | Commissioning Agent |

The team members for functional performance testing shall be as follows:

Contracting Officer's Quality Assurance Representative
Contractor's Quality Control Representative

Commissioning Agent
Contractor's Controls Representative
Contractor's Testing, Adjusting, and Balancing Representative
Design Agent's Representative

The following may be required to participate as team members during Pre-Commissioning Checks and Functional Performance Testing at the request of the Commissioning Agent:

Contractor's Mechanical Representative
Contractor's Electrical Representative
Using Agent's Representative

The commissioning team shall complete the Pre-Commissioning Check Lists and the Functional Performance Tests lists prepared by the Commissioning Agent. Acceptance by each commissioning team member of each pre-commissioning checklist item shall be indicated by initials and date. Acceptance by each commissioning team member of each functional performance test checklist shall be indicated by signature and date.

3.2 TESTS

**The use of the third and fourth sentences is optional for Army projects and mandatory for all Air Force projects.**

The pre-commissioning checks and functional performance tests shall be performed in a manner which essentially duplicates the checking, testing, and inspection methods established in the related Sections. Where checking, testing, and inspection methods are not specified in other Sections, methods shall be established to verify that the system is installed and performs in accordance with contract documents. Testing and verification shall demonstrate that all HVAC components have been installed, that each control device and item of equipment operates, and that the system operates in accordance with contract documents. Requirements in related Sections are independent from the requirements of this Section and shall not be used to satisfy any of the requirements specified in this Section. The Contractor shall provide all materials, services, and labor required to perform the pre-commissioning checks and functional performance tests. A pre-commissioning check or functional performance test shall be aborted if any system deficiency prevents the successful completion of the test or if any participating non-Government commissioning team member of which participation is specified is not present for the test. The Contractor shall reimburse the Government for all costs associated with effort lost due to tests that are aborted. These costs shall include salary, travel costs and per diem (where applicable) for Government commissioning team members.

3.2.1 Pre-Commissioning Checks

Pre-commissioning checks shall be performed for ductwork, piping, each major item of equipment, and the control systems. Deficiencies discovered during these checks shall be corrected and retested in accordance with the applicable contract requirements.

### 3.2.2 Functional Performance Tests

Functional performance tests shall be performed for each major item of equipment, each HVAC system, and the HVAC control systems. Functional performance tests shall verify all control responses, safeties, interlocks, operating modes, capacities, and all other relevant contract requirements comply with contract documents. Functional performance tests shall begin only after all pre-commissioning checks have been successfully completed, the Certificate of Readiness has been submitted, and the Pre-Functional Performance Test Meeting has occurred. Tests shall prove all modes of the sequences of operation, and shall verify all other relevant contract requirements. Tests shall begin with equipment or components and shall progress through subsystems to complete systems. Upon failure of any functional performance test checklist item, the Contractor shall correct all deficiencies in accordance with the applicable contract requirements. The checklist shall then be repeated until it has been completed with no errors. If TAB Verification has not been completed prior to Functional Performance Testing, it shall be verified during Functional Performance Testing. >

## 3.3 Building Operation Review

**NOTE: This paragraph is only applicable to projects pursuing LEED-NC v2.2 EAc3, Enhanced Commissioning.**

The Commissioning Agent shall visit the building site, inspect building energy system equipment, review building operation with the building operating/maintenance staff and/or users, and analyze control point trends. The operating staff shall have the responsibility for providing control point trends relevant to identified operating issues to the Commissioning Agent. The Commissioning Agent shall identify any deficiency of the building energy systems to operate in accordance with the Contract Plans and Specifications, the Basis of Design, and the Owner's Project Requirements. The Commissioning Agent shall advise the Contracting Officer's Representative of any identified deficiencies and the proposed corrective action. Any deficiency that will not be corrected, shall be documented. Documentation shall be provided to the Contracting Officer's Representative as an update to the Systems Manual.

## Appendix 7.2: Pre-Commissioning Checklist

### Pre-commissioning checklist - Piping

For [_____] Piping System

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Piping complete. | ___ | ___ | ___ |
| b. As-built shop drawings submitted. | ___ | ___ | ___ |
| c. Piping flushed and cleaned. | ___ | ___ | ___ |
| d. Strainers cleaned. | ___ | ___ | ___ |
| e. Valves installed as required. | ___ | ___ | ___ |
| f. Piping insulated as required. | ___ | ___ | ___ |
| g. Thermometers and gauges installed as required. | ___ | ___ | ___ |
| h. Verify operation of valves. | ___ | ___ | ___ |
| i. Air vents installed as specified. | ___ | ___ | ___ |
| j. Flexible connectors installed as specified | ___ | ___ | ___ |
| k. Verify that piping has been labeled and valves identified as specified. | ___ | ___ | ___ |
| Testing, Adjusting, and Balancing (TAB) | | | |
| a. Hydrostatic test complete. | ___ | ___ | ___ |
| b. TAB operation complete. | ___ | ___ | ___ |

### Pre-commissioning Checklist - Ductwork

For Air Handler: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Ductwork complete. | ___ | ___ | ___ |
| b. As-built shop drawings submitted. | ___ | ___ | ___ |
| c. Ductwork leak test complete. | ___ | ___ | ___ |
| d. Fire dampers, smoke dampers, and access doors installed as required. | ___ | ___ | ___ |

| | | | |
|---|---|---|---|
| e. Ductwork insulated as required. | ___ | ___ | ___ |
| f. Thermometers and gauges installed as required. | ___ | ___ | ___ |
| g. Verify open/closed status of dampers. | ___ | ___ | ___ |
| h. Verify smoke dampers operation. | ___ | ___ | ___ |
| i. Flexible connectors installed as specified. | ___ | ___ | ___ |

Testing, Adjusting, and Balancing (TAB)

| | | | |
|---|---|---|---|
| a. TAB operation complete. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Multizone Air Handling Unit**

For Air Handling Unit: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Vibration isolation devices installed [and freed to float with adequate movement and seismic restraint] as specified. | ___ | ___ | ___ |
| b. Inspection and access doors are operable and sealed. | ___ | ___ | ___ |
| c. Casing undamaged. | ___ | ___ | ___ |
| d. Insulation undamaged. | ___ | ___ | ___ |
| e. Condensate drainage is unobstructed. (Visually verify pan drains completely by pouring a cup of water into drain pan.) | ___ | ___ | ___ |
| f. Fan belt adjusted. | ___ | ___ | ___ |
| g. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |

Electrical

| | | | |
|---|---|---|---|
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Power available to unit control panel. | ___ | ___ | ___ |
| c. Proper motor rotation verified. | ___ | ___ | ___ |
| d. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |

| | | | |
|---|---|---|---|
| e. Power available to electric heating coil. | ___ | ___ | ___ |

Coils

| | | | |
|---|---|---|---|
| [a. Chilled water piping properly connected. | ___ | ___ | ___] |
| [a. Refrigerant piping properly connected. | ___ | ___ | ___] |
| [b. Chilled water piping pressure tested. | ___ | ___ | ___] |
| [b. Refrigerant piping pressure tested. | ___ | ___ | ___] |
| [c. Hot water piping properly connected. | ___ | ___ | ___] |
| [c. Steam and condensate piping properly connected. | ___ | ___ | ___] |
| [d. Hot water piping pressure tested. | ___ | ___ | ___] |
| [d. Steam and condensate piping pressure tested. | ___ | ___ | ___] |
| e. Air vents installed on water coils [with shutoff valves] as specified. | ___ | ___ | ___ |
| f. Any damage to coil fins has been repaired. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Control valves/actuators properly installed. | ___ | ___ | ___ |
| b. Control valves/actuators operable. | ___ | ___ | ___ |
| c. O.A. dampers/actuators properly installed. | ___ | ___ | ___ |
| d. O.A. dampers/actuators operable. | ___ | ___ | ___ |
| e. Zone dampers/actuators properly installed. | ___ | ___ | ___ |
| f. Zone dampers/actuators operable. | ___ | ___ | ___ |

Testing, Adjusting, and Balancing (TAB)

| | | | |
|---|---|---|---|
| a. Construction filters removed and replaced. | ___ | ___ | ___ |
| b. TAB report submitted. | ___ | ___ | ___ |
| c. TAB results within +10%/-0% of L/s cfm shown on drawings. | ___ | ___ | ___ |
| d. TAB results for outside air intake within +10%/-0% of L/s CFM shown on drawings. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Variable Volume Air Handling Unit**

For Air Handling Unit: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Vibration isolation devices installed. | ___ | ___ | ___ |
| b. Inspection and access doors are operable and sealed. | ___ | ___ | ___ |
| c. Casing undamaged. | ___ | ___ | ___ |
| d. Insulation undamaged. | ___ | ___ | ___ |
| e. Condensate drainage is unobstructed. | ___ | ___ | ___ |
| (Visually verify drainage by pouring a cup of water into drain pan.) | ___ | ___ | ___ |
| f. Fan belt adjusted. | ___ | ___ | ___ |
| g. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| Electrical | | | |
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Power available to unit control panel. | ___ | ___ | ___ |
| c. Proper motor rotation verified. | ___ | ___ | ___ |
| d. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| [e. Power available to electric heating coil. | ___ | ___ | ___] |
| Coils | | | |
| [a. Chilled water piping properly connected. | ___ | ___ | ___] |
| [a. Refrigerant piping properly connected. | ___ | ___ | ___] |
| [b. Chilled water piping pressure tested. | ___ | ___ | ___] |
| [b. Refrigerant piping pressure tested. | ___ | ___ | ___] |
| [c. Hot water piping properly connected. | ___ | ___ | ___] |
| [c. Steam and condensate piping properly connected. | ___ | ___ | ___] |
| [d. Hot water piping pressure tested. | ___ | ___ | ___] |
| [d. Steam and condensate piping pressure tested. | ___ | ___ | ___] |

| | | | |
|---|---|---|---|
| [e. Air vents installed on water coils [with shut-off valves] as specified. | ___ | ___ | ___] |
| f. Any damage to coil fins has been repaired. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Control valves/actuators properly installed. | ___ | ___ | ___ |
| b. Control valves/actuators operable. | ___ | ___ | ___ |
| c. Dampers/actuators properly installed. | ___ | ___ | ___ |
| d. Dampers/actuators operable. | ___ | ___ | ___ |
| e. Verify proper location, installation and calibration of duct static pressure sensor. | ___ | ___ | ___ |
| f. Fan air volume controller operable. | ___ | ___ | ___ |
| g. Air handler controls system operational. | ___ | ___ | ___ |

Testing, Adjusting, and Balancing (TAB)

| | | | |
|---|---|---|---|
| a. Construction filters removed and replaced. | ___ | ___ | ___ |
| b. TAB report submitted. | ___ | ___ | ___ |
| c. TAB results within +10%/-0% of L/s cfm shown on drawings. | ___ | ___ | ___ |
| d. TAB results for outside air intake within +10%/-0% of both the minimum and maximum L/s cfms shown on drawings. | ___ | ___ | ___ |

**Pre-commissioning Checklist - VAV Terminal**

For VAV Terminal: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. VAV terminal in place. | ___ | ___ | ___ |
| b. VAV terminal ducted. | ___ | ___ | ___ |
| c. VAV terminal connected to controls. | ___ | ___ | ___ |
| [d. Reheat coil connected to hot water pipe. | ___ | ___ | ___] |
| [e. Electric reheat coil connected to local disconnect. | ___ | ___ | ___] |

| | | | |
|---|---|---|---|
| f. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Cooling only VAV terminal controls set. | ___ | ___ | ___ |
| b. Cooling only VAV controls verified. | ___ | ___ | ___ |
| c. Reheat VAV terminal controls set. | ___ | ___ | ___ |
| d. Reheat terminal/coil controls verified. | ___ | ___ | ___ |

Testing, Adjusting, and Balancing (TAB)

| | | | |
|---|---|---|---|
| a. Verify terminal maximum air flow set. | ___ | ___ | ___ |
| b. Verify terminal minimum air flow set. | ___ | ___ | ___ |
| c. TAB operation complete. | ___ | ___ | ___ |

**Pre-commissioning Checklist - DX Air Cooled Condensing Unit**

For Condensing Unit: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| b. Refrigerant pipe leak tested. | ___ | ___ | ___ |
| c. Refrigerant pipe evacuated and charged in accordance with manufacturer's instructions. | ___ | ___ | ___ |
| d. Check condenser fans for proper rotation. | ___ | ___ | ___ |
| e. Any damage to coil fins has been repaired. | ___ | ___ | ___ |
| f. Manufacturer's required maintenance/operational clearance provided. | ___ | ___ | ___ |

Electrical

| | | | |
|---|---|---|---|
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Power available to unit control panel. | ___ | ___ | ___ |
| c. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Unit safety/protection devices tested. | ___ | ___ | ___ |
| b. Control system and interlocks installed. | ___ | ___ | ___ |
| c. Control system and interlocks operational. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Pumps**

For Pump: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Pumps grouted in place. | ___ | ___ | ___ |
| b. Pump vibration isolation devices functional. | ___ | ___ | ___ |
| c. Pump/motor coupling alignment verified. | ___ | ___ | ___ |
| d. Piping system installed. | ___ | ___ | ___ |
| e. Piping system pressure tested. | ___ | ___ | ___ |
| f. Pump not leaking. | ___ | ___ | ___ |
| g. Field assembled couplings aligned to meet manufacturer's prescribed tolerances. | ___ | ___ | ___ |
| Electrical | | | |
| a. Power available to pump disconnect. | ___ | ___ | ___ |
| b. Pump rotation verified. | ___ | ___ | ___ |
| c. Control system interlocks functional. | ___ | ___ | ___ |
| d. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| Testing, Adjusting, and Balancing (TAB) | | | |
| a. Pressure/temperature gauges installed. | ___ | ___ | ___ |
| b. Piping system cleaned. | ___ | ___ | ___ |
| c. Chemical water treatment complete. | ___ | ___ | ___ |
| d. Water balance complete. | ___ | ___ | ___ |
| e. Water balance with design maximum flow. | ___ | ___ | ___ |

| | | | |
|---|---|---|---|
| f. TAB Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Packaged Air Cooled Chiller**

For Chiller: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Chiller properly piped. | ___ | ___ | ___ |
| b. Chilled water pipe leak tested. | ___ | ___ | ___ |
| c. Verify that refrigerant used complies with specified requirements. | ___ | ___ | ___ |
| d. Any damage to coil fins has been repaired. | ___ | ___ | ___ |
| e. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| | | | |
| Electrical | | | |
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Power available to unit control panel. | ___ | ___ | ___ |
| c. Separate power is supplied to electric heating tape. | ___ | ___ | ___ |
| d. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| | | | |
| Controls | | | |
| a. Factory startup and checkout complete. | ___ | ___ | ___ |
| b. Chiller safety/protection devices tested. | ___ | ___ | ___ |
| c. Chilled water flow switch installed. | ___ | ___ | ___ |
| d. Chilled water flow switch tested. | ___ | ___ | ___ |
| e. Chilled water pump interlock installed. | ___ | ___ | ___ |
| f. Chilled water pump interlock tested. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Centrifugal Chiller**

For Chiller: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|

Installation

| | | | |
|---|---|---|---|
| a. Chilled water connections properly piped. | ___ | ___ | ___ |
| b. Condenser water connections properly piped. | ___ | ___ | ___ |
| c. Chilled water pipe leak tested. | ___ | ___ | ___ |
| d. Condenser water pipe leak tested. | ___ | ___ | ___ |
| e. High efficiency purge unit installed and operating as specified. | ___ | ___ | ___ |
| f. Refrigerant leak detector installed. | ___ | ___ | ___ |
| g. Oxygen sensor installed and tested. | ___ | ___ | ___ |
| h. Mechanical room ventilation installed as specified. | ___ | ___ | ___ |
| i. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| j. Field assembled couplings aligned to meet manufacturer's prescribed tolerances. | ___ | ___ | ___ |

Electrical

| | | | |
|---|---|---|---|
| a. Power available to unit starter. | ___ | ___ | ___ |
| b. Power available to unit control panel. | ___ | ___ | ___ |
| c. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Factory startup and checkout complete. | ___ | ___ | ___ |
| b. Chiller safety/protection devices tested. | ___ | ___ | ___ |
| c. Chilled water flow switch installed. | ___ | ___ | ___ |
| d. Chilled water flow switch tested. | ___ | ___ | ___ |
| e. Chilled water pump interlock installed. | ___ | ___ | ___ |
| f. Chilled water pump interlock tested. | ___ | ___ | ___ |
| g. Condenser water flow switch installed. | ___ | ___ | ___ |
| h. Condenser water flow switch tested. | ___ | ___ | ___ |
| i. Condenser water pump interlock installed. | ___ | ___ | ___ |
| j. Condenser water pump interlock tested. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Cooling Tower**

For Cooling Tower: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Cooling tower in place. | ___ | ___ | ___ |
| b. Cooling tower piped. | ___ | ___ | ___ |
| c. Cooling tower fan drive adjusted. | ___ | ___ | ___ |
| d. Cooling tower makeup water supply piped. | ___ | ___ | ___ |
| e. Verify makeup control valve shutoff. | ___ | ___ | ___ |
| f. Fan lubricated and blade pitch adjusted. | ___ | ___ | ___ |
| g. Manufacturer's required maintenance/operational clearance provided. | ___ | ___ | ___ |
| h. Cooling tower drain and overflow is piped. | ___ | ___ | ___ |
| Electrical | | | |
| a. Power available to tower disconnect. | ___ | ___ | ___ |
| b. Power available to electric sump heater. | ___ | ___ | ___ |
| c. Control system interlocks functional. | ___ | ___ | ___ |
| d. Motor and fan rotation checked. | ___ | ___ | ___ |
| e. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| Piping | | | |
| a. Tower basin is clean and filled. | ___ | ___ | ___ |
| b. Condenser water treatment functional. | ___ | ___ | ___ |
| c. Water balance with design flow verified. | ___ | ___ | ___ |
| d. Water distribution headers balanced. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Hot Water Boiler**

For Boiler: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|

Installation

| | | | |
|---|---|---|---|
| a. Boiler flue installed. | ___ | ___ | ___ |
| b. Boiler hot water piping installed. | ___ | ___ | ___ |
| c. Boiler hot water piping tested. | ___ | ___ | ___ |
| d. Boiler makeup water piping installed. | ___ | ___ | ___ |
| e. Boiler fuel oil piping installed. | ___ | ___ | ___ |
| f. Boiler fuel oil piping tested. | ___ | ___ | ___ |
| g. Boiler gas piping installed. | ___ | ___ | ___ |
| h. Boiler gas piping tested. | ___ | ___ | ___ |
| i. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |

Startup

| | | | |
|---|---|---|---|
| a. Boiler system cleaned and filled with treated water. | ___ | ___ | ___ |
| b. Boiler safety/protection devices, including high temperature burner shut-off, low water cutoff, flame failure, pre and post purge, have been tested. | ___ | ___ | ___ |
| c. Verify that PRV rating conforms to boiler rating. | ___ | ___ | ___ |
| d. Boiler water treatment system functional. | ___ | ___ | ___ |
| e. Boiler startup and checkout complete. | ___ | ___ | ___ |
| f. Combustion efficiency demonstrated. | ___ | ___ | ___ |

Electrical

| | | | |
|---|---|---|---|
| a. Verify that power disconnect is located within sight of the unit served. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Hot water pump interlock installed. | ___ | ___ | ___ |
| b. Hot water pump interlock tested. | ___ | ___ | ___ |
| c. Hot water heating system balanced. | ___ | ___ | ___ |
| d. Hot water heating controls operational. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Steam Boiler**

For Boiler: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Boiler flue installed. | ___ | ___ | ___ |
| b. Boiler steam piping installed. | ___ | ___ | ___ |
| c. Boiler steam piping tested. | ___ | ___ | ___ |
| d. Boiler makeup water piping installed. | ___ | ___ | ___ |
| e. Boiler makeup water piping tested. | ___ | ___ | ___ |
| f. Boiler fuel oil piping installed. | ___ | ___ | ___ |
| g. Boiler fuel oil piping tested. | ___ | ___ | ___ |
| h. Boiler gas piping installed. | ___ | ___ | ___ |
| i. Boiler gas piping tested. | ___ | ___ | ___ |
| j. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| Startup | | | |
| a. Boiler system cleaned and filled with treated water. | ___ | ___ | ___ |
| b. Boiler safety/protection devices, including high temperature burner shutoff, low water cutoff, flame failure, pre and post purge, have been tested. | ___ | ___ | ___ |
| c. Verify that PRV rating conforms to boiler rating. | ___ | ___ | ___ |
| d. Boiler feed water system operational. | ___ | ___ | ___ |
| e. Boiler water treatment system functional. | ___ | ___ | ___ |
| f. Boiler startup and checkout complete. | ___ | ___ | ___ |
| g. All steam traps operational. | ___ | ___ | ___ |
| h. All condensate return pumps operational. | ___ | ___ | ___ |
| i. Combustion efficiency demonstrated. | ___ | ___ | ___ |
| Electrical | | | |
| a. Verify that power disconnect is located within sight of the unit served. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Steam/Hot Water Converter**

For Converter: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Converter steam piping installed. | ___ | ___ | ___ |
| b. Converter steam piping tested. | ___ | ___ | ___ |
| c. Hot water piping installed. | ___ | ___ | ___ |
| d. Hot water piping tested. | ___ | ___ | ___ |
| e. Makeup water piping installed. | ___ | ___ | ___ |
| f. Vacuum breaker installed on shell of shell and tube unit. | ___ | ___ | ___ |
| g. Air vent installed as specified. | ___ | ___ | ___ |
| h. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| Startup | | | |
| a. Hot water system cleaned and filled. | ___ | ___ | ___ |
| b. All steam traps operational. | ___ | ___ | ___ |
| c. All condensate return pumps operational. | ___ | ___ | ___ |
| d. Converter safety/protection devices tested. | ___ | ___ | ___ |
| e. Converter startup and checkout complete. | ___ | ___ | ___ |
| Controls | | | |
| a. Control valves/actuators properly installed. | ___ | ___ | ___ |
| b. Control valves/actuators operable. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Fan Coil Unit**

For Fan Coil Unit: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Vibration isolation devices installed. | ___ | ___ | ___ |
| b. Access doors/removable panels are operable and sealed. | ___ | ___ | ___ |
| c. Casing undamaged. | ___ | ___ | ___ |

| | | | |
|---|---|---|---|
| d. Insulation undamaged. | ___ | ___ | ___ |
| e. Condensate drainage is unobstructed. | ___ | ___ | ___ |
| f. Fan belt adjusted. | ___ | ___ | ___ |
| g. Any damage to coil fins has been repaired. | ___ | ___ | ___ |
| h. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |

Electrical

| | | | |
|---|---|---|---|
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Power available to unit control panel. | ___ | ___ | ___ |
| c. Proper motor rotation verified. | ___ | ___ | ___ |
| d. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| [e. Power available to electric heating coil. | ___ | ___ | ___] |

Coils

| | | | |
|---|---|---|---|
| [a. Dual temperature piping properly connected. | ___ | ___ | ___] |
| [a. Chilled water piping properly connected. | ___ | ___ | ___] |
| [b. Dual temperature piping pressure tested. | ___ | ___ | ___] |
| [b. Chilled water piping pressure tested. | ___ | ___ | ___] |
| [c. Hot water piping properly connected. | ___ | ___ | ___] |
| [d. Hot water piping pressure tested. | ___ | ___ | ___] |

Controls

| | | | |
|---|---|---|---|
| a. Control valves/actuators properly installed. | ___ | ___ | ___ |
| b. Control valves/actuators operable. | ___ | ___ | ___ |
| c. Verify proper location and installation of thermostat. | ___ | ___ | ___ |

Testing, Adjusting, and Balancing (TAB)

| | | | |
|---|---|---|---|
| a. Construction filters removed and replaced. | ___ | ___ | ___ |
| b. TAB results +10%/-0% of L/s (cfm) shown on drawings | ___ | ___ | ___ |
| c. TAB Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Unit Heater**

For Electric Cabinet or Unit Heater: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| [a. Hot water piping properly connected. | ___ | ___ | ___] |
| [a. Steam and condensate piping properly connected. | ___ | ___ | ___] |
| [b. Hot water piping pressure tested. | ___ | ___ | ___] |
| [b. Steam and condensate piping pressure tested. | ___ | ___ | ___] |
| c. Air vent installed on hot water coil with shutoff valve as specified. | ___ | ___ | ___ |
| d. Any damage to coil fins has been repaired. | ___ | ___ | ___ |
| e. Manufacturer's required maintenance/operational clearance provided. | ___ | ___ | ___ |
| | | | |
| Electrical | | | |
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Proper motor rotation verified. | ___ | ___ | ___ |
| c. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| d. Power available to electric heating coil. | ___ | ___ | ___ |
| | | | |
| Controls | | | |
| a. Control valves properly installed. | ___ | ___ | ___ |
| b. Control valves operable. | ___ | ___ | ___ |
| c. Verify proper location and installation of thermostat. | ___ | ___ | ___ |
| | | | |
| Testing, Adjusting, and Balancing (TAB) | | | |
| a. TAB Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Exhaust Fan**

For Exhaust Fan: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Fan belt adjusted. | ___ | ___ | ___ |
| | | | |
| Electrical | | | |
| a. Power available to fan disconnect. | ___ | ___ | ___ |
| b. Proper motor rotation verified. | ___ | ___ | ___ |
| c. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| | | | |
| Controls | | | |
| a. Control interlocks properly installed. | ___ | ___ | ___ |
| b. Control interlocks operable. | ___ | ___ | ___ |
| c. Dampers/actuators properly installed. | ___ | ___ | ___ |
| d. Dampers/actuators operable. | ___ | ___ | ___ |
| e. Verify proper location and installation of thermostat. | ___ | ___ | ___ |
| | | | |
| Testing, Adjusting, and Balancing (TAB) | | | |
| a. TAB results +10%/-0% to L/s (cfm) shown on drawings. | ___ | ___ | ___ |
| b. TAB Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Computer Room Unit**

For Computer Room Unit: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Unit properly supported. | ___ | ___ | ___ |
| b. Access doors are operable and sealed. | ___ | ___ | ___ |
| c. Casing undamaged. | ___ | ___ | ___ |
| d. Insulation undamaged. | ___ | ___ | ___ |

| | | | |
|---|---|---|---|
| e. Condensate drainage is unobstructed and routed to floor drain. | ___ | ___ | ___ |
| f. Fan belt adjusted. | ___ | ___ | ___ |
| g. Manufacturer's required maintenance operational clearance provided. | ___ | ___ | ___ |

Electrical

| | | | |
|---|---|---|---|
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Proper motor rotation verified. | ___ | ___ | ___ |
| c. Proper motor rotation verified. | ___ | ___ | ___ |
| d. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| [e. Power available to reheat coils. | ___ | ___ | ___] |

Coils/Humidifier

| | | | |
|---|---|---|---|
| [a. Chilled water piping properly connected. | ___ | ___ | ___] |
| [a. Refrigerant piping properly connected. | ___ | ___ | ___] |
| [b. Chilled water piping pressure tested. | ___ | ___ | ___] |
| [b. Refrigerant piping pressure tested. | ___ | ___ | ___] |
| [c. Hot water piping properly connected. | ___ | ___ | ___] |
| [c. Steam piping properly connected. | ___ | ___ | ___] |
| [d. Hot water piping pressure tested. | ___ | ___ | ___] |
| [d. Steam piping pressure tested. | ___ | ___ | ___] |
| e. Humidifier makeup water connected. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Control valves operable. | ___ | ___ | ___ |
| b. Unit control system operable and verified. | ___ | ___ | ___ |
| c. Verify proper location and installation of thermostat. | ___ | ___ | ___ |

Testing, Adjusting, and Balancing (TAB)

| | | | |
|---|---|---|---|
| a. Construction filters removed and replaced. | ___ | ___ | ___ |
| b. TAB results +10%/-0% L/s (cfm) shown on drawings. | ___ | ___ | ___ |
| c. TAB Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - HVAC System Controls**

For HVAC System Control Including the Central Equipment

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. As-built shop drawings submitted. | ___ | ___ | ___ |
| b. Layout of control panel matches drawings. | ___ | ___ | ___ |
| c. Framed instructions mounted in or near control panel. | ___ | ___ | ___ |
| d. Components properly labeled (on inside and outside of panel). | ___ | ___ | ___ |
| e. Control components piped and/or wired to each labeled terminal strip. | ___ | ___ | ___ |
| f. EMCS connection made to each labeled terminal strip as shown. | ___ | ___ | ___ |
| g. Control wiring and tubing labeled at all terminations, splices, and junctions. | ___ | ___ | ___ |
| h. Shielded wiring used on electronic sensors. | ___ | ___ | ___ |
| i. Air dryer installed as specified. | ___ | ___ | ___ |
| j. Water drain installed as specified. | ___ | ___ | ___ |
| Main Power and Control Air | | | |
| a. 110 volt AC power available to panel. | ___ | ___ | ___ |
| b. 138 kPa gauge (20 psig) 20 psig compressed air available to panel. | ___ | ___ | ___ |
| Testing, Commissioning, and Balancing | | | |
| a. Testing, Commissioning, and Balancing | ___ | ___ | ___ |
| Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Single Zone or Outdoor Air Handling Unit**

For Air Handling Unit: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Vibration isolation devices installed. | ___ | ___ | ___ |
| b. Inspection and access doors are operable and sealed. | ___ | ___ | ___ |
| c. Casing undamaged. | ___ | ___ | ___ |
| d. Insulation undamaged. | ___ | ___ | ___ |
| e. Condensate drainage is unobstructedand trap is installed in accordance with the details. | ___ | ___ | ___ |
| f. Fan belt adjusted. | ___ | ___ | ___ |
| g. Any damage to coil fins has been repaired. | ___ | ___ | ___ |
| h. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| Electrical | | | |
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Power available to unit control panel. | ___ | ___ | ___ |
| c. Proper motor rotation verified. | ___ | ___ | ___ |
| d. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| e. Power available to electric heating coil. | ___ | ___ | ___ |
| Coils | | | |
| [a. Chilled water piping properly connected. | ___ | ___ | ___] |
| [a. Refrigerant piping properly connected. | ___ | ___ | ___] |
| [b. Chilled water piping pressure tested. | ___ | ___ | ___] |
| [b. Refrigerant piping pressure tested. | ___ | ___ | ___] |
| [c. Hot water piping properly connected. | ___ | ___ | ___] |
| [c. Steam and condensate piping properly connected. | ___ | ___ | ___] |
| [d. Hot water piping pressure tested. | ___ | ___ | ___] |
| [d. Steam and condensate piping pressure tested. | ___ | ___ | ___] |

| | | | |
|---|---|---|---|
| [e. Air vents installed on water coils [with shutoff valves] as specified. | ___ | ___ | ___] |
| f. Any damage to coil fins has been repaired. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Control valves/actuators properly installed. | ___ | ___ | ___ |
| b. Control valves/actuators operable. | ___ | ___ | ___ |
| c. Dampers/actuators properly installed. | ___ | ___ | ___ |
| d. Dampers/actuators operable. | ___ | ___ | ___ |
| e. Verify proper location and installation of thermostat. | ___ | ___ | ___ |

Testing, Adjusting, and Balancing (TAB)

| | | | |
|---|---|---|---|
| a. Construction filters removed and replaced. | ___ | ___ | ___ |
| b. TAB results +10%/-0% L/s (cfm) shown on drawings. | ___ | ___ | ___ |
| c. TAB Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Energy Recovery System**

For Energy Recovery System: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Recovery system piping installed. | ___ | ___ | ___ |
| b. Recovery system piping tested. | ___ | ___ | ___ |
| c. Air vent installed as specified. | ___ | ___ | ___ |
| d. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| Startup | | | |
| a. Recovery system piping cleaned and filled. | ___ | ___ | ___ |
| b. Converter startup and checkout complete. | ___ | ___ | ___ |
| Controls | | | |
| a. Control valves/actuators properly installed. | ___ | ___ | ___ |

| | | | |
|---|---|---|---|
| b. Control valves/actuators operable. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Geothermal Well Field**

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Vault inspection and access doors are operable. | ___ | ___ | ___ |
| c. All vault supply and return valves operate full open and full closed. | ___ | ___ | ___ |
| d. The vault contains no water and has no leaks. | ___ | ___ | ___ |
| e. TAB report submitted. | ___ | ___ | ___ |
| f. TAB results within +10%/-0% of the flow shown on drawings | ___ | ___ | ___ |
| g. Verify the flow. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Heat Exchanger**

For Heat Exchanger: [____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Piping installed and connections are per manufacturers diagrams. | ___ | ___ | ___ |
| b. Piping tested. | ___ | ___ | ___ |
| c. Makeup water piping installed. | ___ | ___ | ___ |
| d. Air vent installed as specified. | ___ | ___ | ___ |
| e. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |
| Startup | | | |
| a. System cleaned and filled. | ___ | ___ | ___ |
| b. Strainer is clean. | ___ | ___ | ___ |

Pre-commissioning Checklist - Heat Pump Unit

For Heat Pump Unit: _____

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Unit properly supported. | ___ | ___ | ___ |
| b. Access doors are operable and sealed. | ___ | ___ | ___ |
| c. Casing undamaged. | ___ | ___ | ___ |
| d. Insulation undamaged. | ___ | ___ | ___ |
| e. Condensate drainage is unobstructed and trap is as detailed. | ___ | ___ | ___ |
| g. Manufacturer's required maintenance operational clearance provided. | ___ | ___ | ___ |
| h. Loop water piping connected as detailed. | ___ | ___ | ___ |
| Electrical | | | |
| a. Power available to unit disconnect. | ___ | ___ | ___ |
| b. Proper fan motor rotation verified. | ___ | ___ | ___ |
| c. Verify that power disconnect is located within sight of the unit it controls. | ___ | ___ | ___ |
| Controls | | | |
| a. Control valve is operates properly. | ___ | ___ | ___ |
| b. Unit control system operable and verified. | ___ | ___ | ___ |
| c. Verify proper location and installation of thermostat. | ___ | ___ | ___ |
| Testing, Adjusting, and Balancing (TAB) | | | |
| a. Construction filters removed and replaced. | ___ | ___ | ___ |
| b. TAB results +10%/-0% L/s (cfm) shown on drawings. | ___ | ___ | ___ |
| c. TAB Report submitted. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Domestic Hot Water Heater**

For Water Heater: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|

Installation

| | | | |
|---|---|---|---|
| a. Water Heater flue installed. | ___ | ___ | ___ |
| b. Water Heater hot water piping installed. | ___ | ___ | ___ |
| c. Water Heater hot water piping tested. | ___ | ___ | ___ |
| d. Water Heater makeup water piping installed. | ___ | ___ | ___ |
| e. Water Heater fuel oil piping installed. | ___ | ___ | ___ |
| f. Water Heater fuel oil piping tested. | ___ | ___ | ___ |
| g. Water Heater gas piping installed. | ___ | ___ | ___ |
| h. Water Heater gas piping tested. | ___ | ___ | ___ |
| i. Water Heater insulation installed as required. | ___ | ___ | ___ |
| j. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |

Startup

| | | | |
|---|---|---|---|
| a. Domestic water system cleaned, flushed, and filled with water. | ___ | ___ | ___ |
| b. Water Heater safety/protection devices, including high temperature burner shut-off, low water cutoff, flame failure, have been tested. | ___ | ___ | ___ |
| c. Water Heater startup and checkout complete. | ___ | ___ | ___ |
| f. Combustion efficiency demonstrated. | ___ | ___ | ___ |

Electrical

| | | | |
|---|---|---|---|
| a. Verify that power disconnect is located within sight of the unit served. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Domestic water heating controls operational. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Steam/Domestic Hot Water Heat Exchanger**

For Heat Exchanger: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|

Installation

| | | | |
|---|---|---|---|
| a. Heat Exchanger steam piping installed. | ___ | ___ | ___ |
| b. Heat Exchanger steam piping tested. | ___ | ___ | ___ |
| c. Domestic hot water piping installed. | ___ | ___ | ___ |
| d. Domestic hot water piping tested. | ___ | ___ | ___ |
| e. Makeup cold water piping installed. | ___ | ___ | ___ |
| f. Vacuum breaker installed on shell of shell and tube unit. | ___ | ___ | ___ |
| g. Air vent installed as specified. | ___ | ___ | ___ |
| h. Insulation installed as required. | ___ | ___ | ___ |
| h. Manufacturer's required maintenance clearance provided. | ___ | ___ | ___ |

Startup

| | | | |
|---|---|---|---|
| a. Hot water system cleaned, flushed, and filled. | ___ | ___ | ___ |
| b. All steam traps operational. | ___ | ___ | ___ |
| c. All condensate return pumps operational. | ___ | ___ | ___ |
| d. Heat Exchanger safety/protection devices tested. | ___ | ___ | ___ |
| e. Heat Exchanger startup and checkout complete. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Control valves/actuators properly installed. | ___ | ___ | ___ |
| b. Control valves/actuators operable. | ___ | ___ | ___ |

**Pre-commissioning Checklist - Lighting System**

For Lighting System: [_____]

| Checklist Item | QA | QC | CA |
|---|---|---|---|
| Installation | | | |
| a. Light fixtures installed and . | ___ | ___ | ___ |
| | | | |
| Electrical | | | |
| a. Power available to light fixtures. | ___ | ___ | ___ |

| | | | |
|---|---|---|---|
| b. Power available to light sensors. | ___ | ___ | ___ |
| c. Power available to occupancy sensors. | ___ | ___ | ___ |

Controls

| | | | |
|---|---|---|---|
| a. Controls operable. | ___ | ___ | ___ |
| c. Verify proper location and installation of light sensors. | ___ | ___ | ___ |
| d. Verify proper location and installation of occupancy sensors. | ___ | ___ | ___ |

## Appendix 7.3: Functional Performance Testing Checklist

### Functional Performance Test Checklist - Pumps

For Pump: [_____]
Prior to performing this checklist, ensure that for closed loop systems, system is pressurized and the make-up water system is operational or, for open loop systems, that the sumps are filled to the proper level.

1. Activate pump start using control system commands (all possible combination, on/auto, etc.). ON_____ AUTO_____ OFF_____

a. Verify pressure drop across strainer:
Strainer inlet pressure _____ kPa (_____ psig)
Strainer outlet pressure _____ kPa (_____ psig)
Strainer inlet pressure _____ psig
Strainer outlet pressure _____ psig

b. Verify pump inlet/outlet pressure reading, compare to Testing, Adjusting, and Balancing (TAB) Report, pump design conditions, and pump manufacturer's performance.

DESIGN TAB ACTUAL
Pump inlet pressure (kPa gauge) _____ _____ _____
Pump outlet pressure (kPa gauge) _____ _____ _____

DESIGN TAB ACTUAL
Pump inlet pressure (psig) _____ _____ _____
Pump outlet pressure (psig) _____ _____ _____

c. Operate pump at shutoff and at 100 percent of designed flow when all components are in full flow. Plot test readings on pump curve and compare results against readings taken from flow measuring devices.

SHUTOFF 100 percent
Pump inlet pressure (kPa gauge) _____ _____
Pump outlet pressure _____ _____
Pump flow rate (L/s) _____ _____
SHUTOFF 100 percent
Pump inlet pressure (psig) _____ _____
Pump outlet pressure _____ _____
Pump flow rate (gpm) _____ _____

d. Operate pump at shutoff and at minimum flow or when all components are in full by-pass. Plot test readings on pump curve and compare results against readings taken from flow measuring devices.

SHUTOFF 100 percent
Pump inlet pressure (kPa gauge) _____ _____
Pump outlet pressure _____ _____
Pump flow rate (L/s) _____ _____
SHUTOFF 100 percent
Pump inlet pressure (psig) _____ _____
Pump outlet pressure _____ _____
Pump flow rate (gpm) _____ _____

2. Verify motor amperage each phase and voltage phase to phase and phase to ground for both the full flow and the minimum flow conditions.

a. Full flow:
PHASE 1 PHASE 2 PHASE 3
Amperage _____ _____ _____
Voltage _____ _____
Voltage _____
Voltage to ground _____ _____ _____

b. Minimum flow:
PHASE 1 PHASE 2 PHASE 3
Amperage _____ _____ _____
Voltage _____ _____
Voltage _____
Voltage to ground _____ _____ _____

3. Unusual vibration, noise, etc.
_____
_____
_____

4. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Centrifugal Chiller**
For Chiller: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of chilled water system as per specifications including the following: Start building air handler to provide load for chiller. Activate controls system chiller start sequence as follows:

a. Time of day startup program initiates chiller start: _____

b. Start condenser water pump and establish condenser water flow. Verify chiller condenser water proof-of-flow switch operation. _____

c. Start chilled water pump and establish chilled water flow. Verify chiller chilled water proof-of-flow switch operation. _____

d. Verify control system energizes chiller start sequence. _____

e. Verify chiller senses chilled water temperature above set point and control system activates chiller start. _____

f. Verify functioning of "soft start" sequence. _____

g. Shut off air handling equipment to remove load on chilled water system. Verify chiller shutdown sequence is initiated and accomplished after load is removed.
_____

h. Restart air handling equipment one minute after chiller shut down. Verify condenser water pump, cooling tower, and chiller restart sequence.
_____

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Cooling Tower**
For Cooling Tower: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of the cooling tower as per specification and the following:

a. Activate cooling tower fan start using control system command. This should first start [condenser][tower] water pump, establish flow, delay fan start, as specified, to equalize flow in distribution basin and sump. Verify fan start after timed delay.
_____

b. After chiller startup, control system should modulate [bypass valve and two-speed fan motor][fan speed] to maintain [condenser][loop] water set point. Verify function of bypass valve under varying loads._____

c. Verify cooling tower operates in accordance with the sequence of control.
_____

d. Verify makeup water [float][fill] valve is functioning: _____

e. Verify bleed valve is functioning:
_____
Activate chemical treatment feed valve, verify makeup of chemical treatment system, pump, and controls: _____

e. Entering water temperature [_____] degrees C
Leaving water temperature: [_____] degrees C
Air volume measured: [_____] L/s
Air volume calculated: [_____] L/s
Entering wet bulb temperature: [_____] degrees C
Measured water flow: [_____] L/s
e. Entering water temperature [_____] degrees F
Leaving water temperature: [_____] degrees F
Air volume measured: [_____] cfm
Air volume calculated: [_____] cfm
Entering wet bulb temperature: [_____] degrees F
Measured water flow: [_____] gpm

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____

Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - VAV Terminals**
The Contracting officer will select VAV terminals to be spot-checked during the functional performance test. The number of terminals shall not exceed [2] [10] [10 percent].

1. Functional Performance Test: Contractor shall demonstrate operation of selected VAV boxes as per specifications including the following:

a. Cooling only VAV boxes:
(1) Verify VAV box response to room temperature set point adjustment. Turn thermostat to 5 degrees F above ambient and measure maximum air flow. Turn thermostat to 5 degrees F below ambient and measure minimum air flow.
Maximum flow [_____] L/s
Minimum flow [_____] L/s
Maximum flow [_____] cfm
Minimum flow [_____] cfm

(2) Check damper maximum/minimum flow settings.
Maximum flow setting [_____] L/s
Minimum flow setting [_____] L/s
Maximum flow setting [_____] cfm
Minimum flow setting [_____] cfm

b. Cooling with reheat VAV boxes:
(1) Verify VAV box response to room temperature set point adjustment. Turn thermostat to 3 degrees C 5 degrees F above ambientand measure maximum air flow. Turn thermostat to 3 degrees C 5 degrees F below ambient and measure minimum air flow.
Maximum flow [_____] L/s
Minimum flow [_____] L/s
Maximum flow [_____] cfm
Minimum flow [_____] cfm

(2) Check damper maximum/minimum flow settings.
Maximum flow setting [_____] L/s
Minimum flow setting [_____] L/s
Maximum flow setting [_____] cfm
Minimum flow setting [_____] cfm

Reheat coil operation range (full open to full closed) _____

c. Fan powered VAV boxes:

(1) Verify VAV box response to sensor call for heating via set point adjustment. Changes to be cooling setpoint to heating set point and return to cooling set point. _____
Verify cooling damper closes to minimum position, blower fan energizes according to sequence of operation, and upon further drop in space temperature, heating coil activation and deactivation. _____

(2) Check primary air damper maximum/minimum flow settings.
Maximum flow setting [_____] L/s
Minimum flow setting [_____] L/s

(3) Check blower fan flow. [_____] L/s
Maximum flow setting [_____] cfm
Minimum flow setting [_____] cfm

(3) Check blower fan flow. [_____] cfm

(4) Verify free operation of fan backdraft damper (insure no primary air is being discharged through the recirculated air register).
_____

(5) Verify that no recirculated air is being induced when box is in full cooling.
_____

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Variable Volume Air Handling Unit**
For Air Handling Unit: [_____]

Ensure that a slight negative pressure exists on inboard side of the outside air dampers throughout the operation of the dampers. Modulate OA, RA, and EA dampers from fully open to fully closed positions.

1. Functional Performance Test: Contractor shall verify operation of air handling unit as per specification including the following:

a. The following shall be verified when the [supply fan operating] [supply and return fans operating] mode is initiated:
(1) All dampers in normal position [and fan inlet vanes modulate to maintain the required static pressure]. _____
(2) All valves in normal position. _____
(3) System safeties allow start if safety conditions are met. _____
(4) VAV fan controller shall "soft-start" fan. _____
(5) Modulate all VAV boxes to minimum air flow and verify that the static pressure does not exceed the design static pressure Class shown.
_____

b. Occupied mode of operation - economizer de-energized.
(1) Outside air damper at minimum position. _____
(2) Return air damper open. _____
(3) Relief air damper [at minimum position] [closed]. _____
(4) Chilled water control valve modulating to maintain leaving air temperature set point.
_____
(5) Fan VAV controller receiving signal from duct static pressure sensor and modulating fan to maintain supply duct static pressure set point.
_____

c. Occupied mode of operation - economizer energized.
(1) Outside air damper modulated to maintain mixed air temperature set point.
_____
(2) Relief air damper modulates with outside air damper according to sequence of operation. _____
(3) Chilled water control valve modulating to maintain leaving air temperature set point.
_____
(4) Hot water control valve modulating to maintain leaving air temperature set point.
_____
(5) Fan VAV controller receiving signal from duct static pressure sensor and modulating fan to maintain supply duct static pressure set point.
_____

d. Unoccupied mode of operation
(1) All dampers in normal position. _____

(2) Verify low limit space temperature is maintained as specified in sequence of operation. _____

e. The following shall be verified when the [supply fan off] [supply and return fans off] mode is initiated:
(1) All dampers in normal position. _____
(2) All valves in normal position. _____
(3) Fan de-energizes. _____

f. Verify the chilled water coil control valve operation by setting all VAV's to maximum and minimum cooling.
Max cooling Min cooling
Supply air volume (_____ L/s) _____ _____
Supply air temp. (_____ degrees C) _____ _____
Max cooling Min cooling
Supply air volume _____ cfm) _____ _____
Supply air temp. (_____ degrees F) _____ _____

g. Verify safety shut down initiated by smoke detectors. _____

h. Verify safety shut down initiated by low temperature protection thermostat.
_____

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Single Zone Air Handling Unit**
For Air Handling Unit: [_____]

1. Functional Performance Test: Contractor shall verify operation of air handling unit as per specification including the following:

a. The following shall be verified when the [supply fan operating] [supply and return fans operating] mode is initiated:
(1) All dampers in normal position. _____
(2) All valves in normal position. _____
(3) System safeties allow start if safety conditions are met. _____

b. Occupied mode of operation - economizer de-energized.
(1) Outside air damper at minimum position. _____
(2) Return air damper open. _____
(3) Relief air damper [at minimum position] [closed]. _____
(4) Chilled water control valve modulating to maintain space cooling temperature set point. _____
(5) Hot water control valve modulating to maintain space heating temperature set point input from outside air temperature controller. _____

c. Occupied mode of operation - economizer energized.
(1) Outside air damper modulated to maintain mixed air temperature set point.
_____
(2) Relief air damper modulates with outside air damper according to sequence of operation. _____
(3) Chilled water control valve modulating to maintain space cooling temperature set point. _____

d. Unoccupied mode of operation
(1) All dampers in normal position. _____
(2) Verify low limit space temperature is maintained as specified in sequence of operation. _____

e. The following shall be verified when the [supply fan off] [supply and return fans off] mode is initiated:
(1) All dampers in normal position. _____
(2) All valves in normal position. _____
(3) Fan de-energizes. _____

f. Verify cooling coil and heating coil operation by varying thermostat set point from cooling set point to heating set point and returning to cooling set point.
_____

g. Verify safety shut down initiated by smoke detectors. _____

h. Verify safety shut down initiated by low temperature protection thermostat.
_____

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Single Zone Outdoor Air Handling Unit**
For Air Handling Unit: [____]_____

1. Functional Performance Test: Contractor shall verify operation of air handling unit as per specification including the following:

a. The following shall be verified when the supply fan is commanded off or manually set to OFF:
(1) Outdoor air damper is closed. _____
(2) Automatic Water Valve is closed. Verify no water flow.
_____

b. The following shall be verified when the supply fan is commanded on or manually set to ON:
(1) Outside air damper at full open position. _____
(2) Automatic Water Valve is open. Verify full flow. _____
(3) Verify safety shut down initiated by smoke detectors. _____

c. Cooling mode of operation:
(1) Note the outdoor air temperature. _____
(2) Verify that the cooling coil leaving air temperature is as scheduled.
_____
(3) Verify that the reheat coil leaving temperature is as scheduled.
_____

d. Heating mode of operation:
(1) Verify that the cooling coil leaving air temperature is as scheduled.
_____
(2) Verify that the heating section leaving air temperature is as scheduled.
_____

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Multizone Air Handling Unit**
For Air Handling Unit: [_____]
Ensure that a slight negative pressure exists on inboard side of the outside air dampers throughout the operation of the dampers. Modulate OA,RA, and EA dampers from fully open to fully closed positions.

1. Functional Performance Test: Contractor shall verify operation of air handling unit as per specification including the following:

a. The following shall be verified when the supply and return fans operating mode is initiated:
(1) All dampers in normal position. _____
(2) All valves in normal position. _____
(3) System safeties allow start if safety conditions are met. _____

b. Occupied mode of operation - economizer de-energized.
(1) Outside air damper at minimum position. _____
(2) Return air damper open. _____
(3) Relief air damper [at minimum position] [closed]. _____
(4) Chilled water control valve modulating to maintain cold deck supply air temperature set point. _____
(5) Hot water control valve modulating to maintain hot deck supply air temperature set point input from outside air temperature controller.
_____
_____

c. Occupied mode of operation - economizer energized.
(1) Outside air damper modulates to maintain mixed air temperature set point.
_____
(2) Relief air damper modulates with outside air damper according to sequence of operation. _____

(3) Chilled water control valve modulating to maintain cold deck supply air temperature set point. _____
(4) Hot water control valve modulating to maintain hot deck supply air temperature set point input from outside air temperature controller.
_____
_____

d. Unoccupied mode of operation
(1) All dampers in normal position. _____
(2) Verify low limit space temperature is maintained as specified in sequence of operation. _____

e. The following shall be verified when the supply and return fans off mode is initiated:
(1) All dampers in normal position. _____
(2) All valves in normal position. _____
(3) Fan de-energizes. _____

f. Verify zone damper operation by varying zone thermostat set points from cooling set point to heating set point and returning to cooling set point.
_____

g. Verify safety shut down initiated by smoke detectors. _____

h. Verify safety shut down initiated by low temperature protection thermostat.
_____

i. Index room thermostats to full cooling then to full heating.
Measure and record cold deck, hot deck, and supply air temperatures and determine damper leakage for a minimum of 2 zones.
Cold deck temperature _____ degrees C (_____ degrees F)
Hot deck temperature _____ degrees C (_____ degrees F)
Cold deck temperature _____ degrees F
Hot deck temperature _____ degrees F
Zone _____
Cooling temperature _____ degrees C (_____ degrees F)
Heating temperature _____ degrees C (_____ degrees F)
Damper leakage cooling ____ degrees C (_____ degrees F)
Damper leakage heating ____ degrees C (_____ degrees F)
Zone _____
Cooling temperature _____ degrees F
Heating temperature _____ degrees F
Damper leakage cooling ____ degrees F
Damper leakage heating ____ degrees
Zone _____
Cooling temperature _____ degrees C (_____ degrees F)
Heating temperature _____ degrees C (_____ degrees F)

Damper leakage cooling ____ degrees C (_____ degrees F)
Damper leakage heating ____ degrees C (_____ degrees F)
Zone _____
Cooling temperature _____ degrees F
Heating temperature _____ degrees F
Damper leakage cooling ____ degrees F
Damper leakage heating ____ degrees F

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Packaged Air Cooled Chiller**
For Chiller: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of chilled water system as per specifications including the following: Start building air handler to provide load for chiller. Activate controls system chiller start sequence as follows.

a. Start chilled water pump and establish chilled water flow. Verify chiller-chilled water proof-of-flow switch operation. _____

b. Verify control system energizes chiller start sequence. _____

c. Verify chiller senses chilled water temperature above set point and control system activates chiller start. _____

d. Verify functioning of "soft start" sequence. _____

e. Shut off air handling equipment to remove load on chilled water system. Verify chiller shutdown sequence is initiated and accomplished after load is removed.
_____

f. Restart air handling equipment one minute after chiller shut down. Verify chiller restart sequence. _____

2. Verify chiller inlet/outlet pressure reading, compare to Testing, Adjusting, and Balancing (TAB) Report, chiller design conditions, and chiller manufacturer's performance data.
DESIGN TAB ACTUAL
Chiller inlet pressure (kPa gauge) _____ _____ _____
Chiller inlet pressure (psig) _____ _____ _____
Chiller outlet pressure (kPa gauge) _____ _____ _____
Chiller outlet pressure (psig) _____ _____ _____

3. Verify chiller amperage each phase and voltage phase-to-phase and phase-to-ground.
PHASE 1 PHASE 2 PHASE 3
Amperage _____ _____ _____
Voltage _____ _____
Voltage _____
Voltage to ground _____ _____ _____

4. Record the following information:
Ambient dry bulb temperature _____ degrees C
Ambient wet bulb temperature _____ degrees C
Entering chilled water temperature _____ degrees C
Leaving chilled water temperature _____ degrees C
Ambient dry bulb temperature _____ degrees F
Ambient wet bulb temperature _____ degrees F
Entering chilled water temperature _____ degrees F
Leaving chilled water temperature _____ degrees F

5. Unusual vibration, noise, etc.
_____
_____

6. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____

Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Air Cooled Condensing Unit**
For Condensing Unit: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of refrigeration system as per specifications including the following: Start building air handler to provide load for condensing unit. Activate controls system start sequence as follows.

a. Start air handling unit. Verify control system energizes condensing unit start sequence. _____

b. Shut off air handling equipment to verify condensing unit de-energizes.
_____

c. Restart air handling equipment one minute after condensing unit shut down. Verify condensing unit restart sequence. _____

2. Verify condensing unit amperage each phase and voltage phase to phase and phase to ground.

| | PHASE 1 | PHASE 2 | PHASE 3 |
|---|---|---|---|
| Amperage | _____ | _____ | _____ |
| Voltage | _____ | _____ | |
| Voltage | _____ | | |
| Voltage to ground | _____ | _____ | _____ |

3. Record the following information:
Ambient dry bulb temperature _____ degrees C
Ambient wet bulb temperature _____ degrees C
Suction pressure _____ kPa gauge
Discharge pressure _____ kPa gauge
Ambient dry bulb temperature _____ degrees F
Ambient wet bulb temperature _____ degrees F
Suction pressure _____ psig
Discharge pressure _____ psig

4. Unusual vibration, noise, etc.
_____
_____

5. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing _____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Hot Water Boiler**
For Boiler: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of hot water system as per specifications including the following: Start building heating equipment to provide load for boiler. Activate controls system boiler start sequence as follows.

a. Start hot water pump and establish hot water flow. Verify boiler hot water proof-of-flow switch operation. _____

b. Verify control system energizes boiler start sequence. _____

c. Verify boiler senses hot water temperature below set point and control system activates boiler start. _____

d. Shut off building heating equipment to remove load on hot water system. Verify boiler shutdown sequence is initiated and accomplished after load is removed.
_____

2. Verify boiler inlet/outlet pressure reading, compare to Test and Balance (TAB) Report, boiler design conditions, and boiler manufacturer's performance data.
DESIGN TAB ACTUAL
Boiler inlet pressure (kPa gauge) _____ _____ _____
Boiler outlet pressure (kPa gauge) _____ _____ _____
Boiler flow rate (L/s) _____ _____ _____
Flue-gas temperature at boiler outlet _____ _____
Percent carbon dioxide in flue-gas _____ _____
Draft at boiler flue-gas exit _____ _____
Draft or pressure in furnace _____ _____
Stack emission pollutants _____ _____ _____
concentration
Fuel type _____ _____ _____
Combustion efficiency _____ _____ _____
DESIGN TAB ACTUAL

Boiler inlet pressure (psig) _____ _____ _____
Boiler outlet pressure (psig) _____ _____ _____
Boiler flow rate (gpm) _____ _____ _____
Flue-gas temperature at boiler outlet _____ _____
Percent carbon dioxide in flue-gas _____ _____
Draft at boiler flue-gas exit _____ _____
Draft or pressure in furnace _____ _____
Stack emission pollutants _____ _____ _____
concentration
Fuel type _____ _____ _____
Combustion efficiency _____ _____ _____

3. Record the following information:
Ambient temperature _____ degrees C
Entering hot water temperature _____ degrees C
Leaving hot water temperature _____ degrees C
Ambient temperature _____ degrees F
Entering hot water temperature _____ degrees F
Leaving hot water temperature _____ degrees F

4. Verify temperatures in item 3 are in accordance with the reset schedule.
_____

5. Verify proper operation of boiler safeties. _____

6. Unusual vibration, noise, etc.
_____
_____

7. Visually check refractory for cracks or spalling and refractory and tubes for flame impingement. _____

8. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____

Commissioning Agent _____

**Functional Performance Test Checklist - Steam Boiler**
For Boiler: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of steam heating system as per specifications including the following: Start building heating equipment to provide load for boiler. Activate controls system boiler start sequence as follows.

a. Start steam heating system. Verify control system energizes boiler start sequence. _____

b. Verify boiler senses steam pressure below set point and control system activates boiler start. _____

c. Shut off building heating equipment to remove load on steam heating system. Verify boiler shutdown sequence is initiated and accomplished after load is removed. _____

d. Verify that water level and makeup water system are operational. _____

2. Verify boiler inlet/outlet pressure reading, compare to boiler design conditions and manufacturer's performance data.
DESIGN TAB ACTUAL
Boiler inlet water temp (degrees F) _____ _____ _____
Boiler outlet pressure (kPa gauge) _____ _____ _____
Flue-gas temperature at boiler outlet (degrees C) _____ _____
Percent carbon dioxide in flue-gas _____ _____
Draft at boiler flue-gas exit _____ _____
Draft or pressure in furnace _____ _____
Stack emission pollutants _____ _____ _____
concentration
Fuel type _____ _____ _____
Combustion efficiency _____ _____ _____
DESIGN TAB ACTUAL
Boiler inlet water temp (degrees F) _____ _____ _____
Boiler outlet pressure (psig) _____ _____ _____
Flue-gas temperature at boiler outlet (degrees F) _____ _____
Percent carbon dioxide in flue-gas _____ _____
Draft at boiler flue-gas exit _____ _____
Draft or pressure in furnace _____ _____
Stack emission pollutants _____ _____ _____
concentration

Fuel type _____ _____ _____
Combustion efficiency _____ _____ _____

3. Record the following information:
Ambient temperature _____ degrees C
Ambient temperature _____ degrees F

4. Verify proper operation of boiler safeties. _____

5. Unusual vibration, noise, etc.
_____
_____

6. Visually check refractory for cracks or spalling and refractory and tubes for flame impingement. _____

7. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Fan Coil Units**
The Contracting Officer will select fan coil units to be spot-checked during the functional performance test. The number of terminals shall not exceed [2] [10] [10 percent].

1. Functional Performance Test: Contractor shall demonstrate operation of selected fan coils as per specifications including the following:

a. Cooling only fan coils:
(1) Verify fan coil unit response to room temperature set point adjustment. Changes to be cooling set point to cooling set point minus 10 degrees and return to cooling set point.
_____
(2) Check blower fan air flow. _____ L/s
Check blower fan air flow. _____ cfm
(3) Check cooling coil water flow. _____ L/s

Check cooling coil water flow. _____ gpm
(4) Verify proper operation of cooling water control valve. _____

b. Cooling/heating fan coils:
(1) Verify fan coil unit response to room temperature set point adjustment. Changes to be cooling set point to heating set point and return to cooling set point.
_____
(2) Check blower fan air flow. _____ L/s
Check blower fan air flow. _____ cfm
(3) Check cooling coil water flow. _____ L/s
Check cooling coil water flow. _____ cfm
(4) Verify proper operation of cooling water control valve. _____
(5) Check cooling mode inlet air temperature. _____ degrees C
Check cooling mode inlet air temperature. _____ degrees F
(6) Check cooling mode outlet air temperature. _____ degrees C
Check cooling mode outlet air temperature. _____ degrees F
(7) Check heating coil water flow. _____ L/s
Check heating coil water flow. _____ gpm
(8) Verify proper operation of heating water control valve. _____
(9) Check heating mode inlet air temperature. _____ degrees C
Check heating mode inlet air temperature. _____ degrees F
(10) Check heating mode outlet air temperature. _____ degrees C
Check heating mode outlet air temperature. _____ degrees F

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Unit Heaters**
The Contracting Officer will select unit heaters to be spot-checked during the functional performance test. The number of terminals shall not exceed [2] [10] [10 percent].

1. Functional Performance Test: Contractor shall demonstrate operation of selected unit heaters as per specifications including the following:

a. Verify unit heater response to room temperature set point adjustment. Changes to be heating set point to heating set point minus 10 degrees and return to heating set point. _____

b. Check blower fan speed. _____rpm

c. Check heating mode inlet air temperature. _____ degrees C Check heating mode inlet air temperature. _____ degrees F

d. Check heating mode outlet air temperature. _____ degrees C Check heating mode outlet air temperature. _____ degrees F

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

Functional Performance Test Checklist - Heat Exchanger
For Converter: HX-1

1. Functional Performance Test: Contractor shall demonstrate operation of heat exchanger as per specifications including the following:

a. Verify proper flow. _____

b. Verify that the building controls open the valve allowing flow to the heat exchanger according the the sequence of control. _____

c. Shut off building cooling equipment to remove load on system. Verify that the valve allowing flow to the heat exchanger closes. _____

2. Verify converter inlet/outlet pressure reading, compare to converter design conditions and manufacturer's performance data.

DESIGN ACTUAL
Hot Side inlet water temp (degrees F) _____ _____
Hot Side outlet water temp (degrees F) _____ _____
Cold Side inlet water temp (degrees F) _____ _____
Cold Side outlet water temp (degrees F) _____ _____
Hot side inlet pressure (psig) _____ _____
Hot Side outlet pressure (psig) _____ _____
Hot Side Water flow rate based
on pressure drop. _____ _____
Hot Side Water flow rate based on flow
measuring device. _____ _____
Cold side inlet pressure (psig) _____ _____
Cold Side outlet pressure (psig) _____ _____
Cold Side Water flow rate based
on pressure drop. _____ _____
Cold Side Water flow rate based on flow
measuring device. _____ _____

3. Check and report unusual vibration, noise, etc.
_____
_____

4. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Heat Pump Unit**
For Heat Pump: _____

1. Functional Performance Test: Contractor shall verify operation of each heat pump as per specification including the following:

a. System safeties allow start if safety conditions are met. _____

b. Verify cooling and heating operation by varying thermostat set point from space set point to space set point plus 10 degrees, space set point minus 10 degrees, and returning to space set point. _____

c. Verify that airflow is within +10/-0 percent of design airflow.
_____

d. Command all units off, then command all the units on. Verify that units start in a staggered manner and that all units do not start at once._____

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Commissioning Agent _____

Functional Performance Test Checklist - Steam/Hot Water Converter
For Converter: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of heating system as per specifications including the following: Start building heating equipment to provide load for converter.

a. Verify control system energizes. _____

b. Verify converter senses hot water temperature below set point and control system modulates steam valve. _____

c. Shut off building heating equipment to remove load on heating system. Verify converter steam valve closes after load is removed. _____

2. Verify converter inlet/outlet pressure reading, compare to converter design conditions and manufacturer's performance data.
DESIGN ACTUAL
Converter inlet water temp (degrees C) _____ _____
Converter outlet water temp (degrees F) _____ _____

Converter inlet steam pressure (psig) _____ _____
Determine water flow rate based on pressure drop through converter _____
_____
Determine water flow rate with flow measuring device _____ _____
Verify that temperature of water is in accordance with outdoor air reset schedule
_____ _____
DESIGN ACTUAL
Converter inlet water temp (degrees F) _____ _____
Converter outlet water temp (degrees F) _____ _____
Converter inlet steam pressure (psig) _____ _____
Determine water flow rate based on pressure drop through converter _____
_____
Determine water flow rate with flow measuring device _____ _____
Verify that temperature of water is in accordance with outdoor air reset schedule
_____ _____

3. Verify proper operation of converter safeties. _____

4. Check and report unusual vibration, noise, etc.
_____
_____

5. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Computer Room Unit**
For Computer Room Unit: [_____]

1. Functional Performance Test: Contractor shall verify operation of computer room unit as per specification including the following:

a. System safeties allow start if safety conditions are met. _____

b. Verify cooling and heating operation by varying thermostat set point from space set point to space set point plus 10 degrees, space set point minus 10 degrees, and returning to space set point. _____

c. Verify humidifier operation by varying humidistat set point from space set point to space set point plus 20 percent RH, and returning to space set point.
_____

d. Verify that airflow is within +10/-0 percent of design airflow.
_____
_____

e. Verify unit shut down during fire event initiated by smoke/heat sensors.
_____

2. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Geothermal Well Field**

1. Functional Performance Test: Contractor shall demonstrate operation of the system as per specifications including the following: Start equipment to provide energy source for the geothermal well field.

2. Verify the geothermal well field inlet/outlet readings, compare to design conditions and manufacturer's performance data.

Design Actual
Loop inlet temp (degrees F) _____ _____
Loop outlet temp (degrees F) _____ _____
Loop flow rate _____ _____
Loop pressure drop _____ _____
Energy transfered (BTU/hr) _____ _____

3. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing , Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - HVAC Controls**
For HVAC System: [_____]
The Contracting Officer will select HVAC control systems to undergo functional performance testing. The number of systems shall not exceed [2] [10] [10 percent].

1. Functional Performance Test: Contractor shall verify operation of HVAC controls by performing the following tests:

a. Verify that controllers are maintaining the set points by manually measuring the controlled variables with a thermometer, sling psychrometer, inclined manometer, etc.

b. Verify sensor/controller combination by manually measuring the controlled medium. Take readings from control panel display and compare readings taken manually. Record all readings for all sensors on a separate form.
Sensor - _____
Manual measurement _____
Panel reading value _____

c. Verify system stability by changing the controller set point as follows:
(1) Air temperature - 10 degrees F
(2) Water temperature - 10 degrees F
(3) Static or Differential pressure - 10 percent of set point
(4) Relative humidity - percent (RH)
(5) Flow - 10 percent
The control system shall be observed for 10 minutes after the change in set point. Instability or excessive hunting will be unacceptable.

d. Verify interlock with other HVAC controls.

e. Verify interlock with fire alarm control panel.

f. Verify interlock with EMCS.

g. Verify all points are available at the EMCS..

[h. Change controller set point 10 percent with EMCS and verify correct response.]

2. Verify that operation of control system conforms to that specified in the sequence of operation.

3. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Energy Recovery System**
For Energy Recovery System: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of energy recovery system as per specifications including the following: Start equipment to provide energy source for recovery system.

a. Verify energy source is providing recoverable energy. _____

b. Verify recovery system senses available energy and activates. ____

c. Verify that recovery system deactivates when recoverable energy is no longer available. _____

2. Verify recovery system inlet/outlet readings, compare to design conditions and manufacturer's performance data.
Design Actual
Primary loop inlet temp (degrees C) _____ _____
Primary loop outlet temp (degrees F) _____ _____
Primary loop flow rate _____ _____

Secondary loop inlet temp (degrees) _____ _____
Secondary loop outlet temp (degrees C) _____ _____
Energy recovered (kJ) _____ _____
Design Actual
Primary loop inlet temp (degrees F) _____ _____
Primary loop outlet temp (degrees F) _____ _____
Primary loop flow rate _____ _____
Secondary loop inlet temp (degrees F) _____ _____
Secondary loop outlet temp (degrees F) _____ _____
Energy recovered BTU's) _____ _____

3. Check and report unusual vibration, noise, etc.
_____
_____

4. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing , Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Domestic Hot Water Heater**
For Water Heater: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of domestic hot water system as per specifications including the following:

a. Run domestic hot water at all plumbing fixtures. Determine flow rate of hot water at fixtures. Verify hot water heater burners fire to maintain hot water temperature._____

b. Shut off domestic hot water at plumbing fixtures. Verify hot water heater burners shut off when load is satisfied.
_____

c. Put building into unoccupied mode and verify that domestic hot water recirculating pump shuts off and hot water heater controls are disabled.
_____

d. Put building into occupied mode and verify that domestic hot water recirculating pump starts and hot water heater controls are enabled.
_____

2. Record the following information:
Entering hot water temperature _____ degrees C
Leaving hot water temperature _____ degrees C
Domestic hot water flow rate _____ L/s
Entering hot water temperature _____ degrees F
Leaving hot water temperature _____ degrees F
Domestic hot water flow rate _____ gpm

3. Verify capacity of water heater from data in item 2.
_____

4. Verify proper operation of water heater safeties.
_____

5. Unusual vibration, noise, etc.
_____
_____

6. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Steam/Domestic Hot Water Heat** Exchanger
For Heat Exchanger: [_____]

1. Functional Performance Test: Contractor shall demonstrate operation of the domestic hot water system as per specifications including the following:

a. Run domestic hot water at all plumbing fixtures. Determine flow rate of hot water at fixtures._ _____

b. Verify heat exchanger senses hot water temperature below set point and control system modulates steam valve.
_____

c. Shut off domestic hot water at plumbing fixtures. Verify heat exchanger steam valve closes after load is removed.

d. Put building into unoccupied mode and verify that domestic hot water recirculating pump shuts off and heat exchanger controls are disabled.
_____

e. Put building into occupied mode and verify that domestic hot water recirculating pump starts and heat exchanger controls are enabled.
_____

2. Verify heat exchanger inlet/outlet temperature readings and pressures and compare to heat exchanger design conditions and manufacturer's performance data.
DESIGN ACTUAL
Converter inlet water temp (degrees C) _____ _____
Converter outlet water temp (degrees F) _____ _____
Converter inlet steam pressure (psig) _____ _____
Determine water flow rate based on pressure drop through heat exchanger _____
_____
Determine water flow rate with flow measuring device or from plumbing fixture flow rate
_____ _____
DESIGN ACTUAL
Converter inlet water temp (degrees F) _____ _____
Converter outlet water temp (degrees F) _____ _____
Converter inlet steam pressure (psig) _____ _____
Determine water flow rate based on pressure drop through converter _____
_____
Determine water flow rate with flow measuring device or from plumbing fixture flow rate
_____ _____

3. Verify proper operation of heat exchanger safeties.
_____

4. Check and report unusual vibration, noise, etc.
_____
_____

5. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Electric Instantaneous**
Point-of-Use Water Heaters

1. Functional Performance Test: Contractor shall demonstrate operation of electric instantaneous point-of-use water heaters as per specifications including the following:

a. Run domestic hot water at all connected plumbing fixtures.
Determine flow rate of hot water at fixtures. _____

b. Check water heater inlet water temperature. _____ degrees C _____ degrees F

c. Check water heater outlet water temperature. _____ degrees C _____ degrees F

2. Verify capacity of water heater from data in item 1.
_____

3. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____

Design Agency's Representative _____
Commissioning Agent _____

**Functional Performance Test Checklist - Lighting System**

1. Functional Performance Test: Contractor shall demonstrate operation of lighting system for 10% of sensors, devices, or spaces as applicable including the following:

a. Occupancy Sensors - Enter room to turn on lights and leave room. Record time to lights off. _____

b. Occupancy Sensors - Verify manual switch operation.
_____

c. Night Shutoff - Verify lighting system shuts off at specified time._____

d. Night Shutoff - Verify occupancy sensors override night shutoff._____

e. Automatic Lighting Dimmers - Verify light dimmers increase light output from fixtures by blocking daylight from windows.
_____

f. Automatic Lighting Dimmers - Verify light dimmers decrease light output from fixtures by allowing daylight into space._____

2. Record illumination level in footcandles at 30 inches above the floor at 10 ft intervals for all spaces with automatic lighting dimmers.
_____

3. Certification: We the undersigned have witnessed the above functional performance tests and certify that the item tested has met the performance requirements in this section of the specifications.

Signature and Date
Contractor's Quality Control Representative _____
Contractor's Mechanical Representative _____
Contractor's Electrical Representative _____
Contractor's Testing, Adjusting and Balancing Representative
_____
Contractor's Controls Representative _____
Government Representative _____
Using Agency's Representative _____
Design Agency's Representative _____
Commissioning Agent _____

Project: Project, Location, PN ######
Approved:
Name Design Agent's Representative Date Instructions: Each bullet point describes information that should be inputted. Replace the explanation of the bullet point with the appropriate information. Add fields or additional spaces as necessary to provide all pertinent information to the commissioning of the building energy-related systems. Matrices may be provided to describe Primary Design Assumptions for redundant space types rather than listing per the outline.

**Appendix 7.4 Basis of Design Document for LEED Fundamental Commissioning**

Contents

1. Primary Design Assumptions
    a. Climatic Design Conditions
    b. Space Type 1
        i. Space Use
        ii. Redundancy
        iii. Diversity
        iv. Space Zoning
        v. Occupancy
        vi. Operations
        vii. Space Environmental Requirements
    c. Space Type 2
        i. Space Use
        ii. Redundancy
        iii. Diversity
        iv. Space Zoning
        v. Occupancy
        vi. Operations
        vii. Space Environmental Requirements
    d. Space Type 3
        i. Space Use
        ii. Redundancy
        iii. Diversity
        iv. Space Zoning
        v. Occupancy
        vi. Operations
        vii. Space Environmental Requirements
2. Applicable Standards
3. System Narratives
    a. HVAC&R Systems
        i. System 1
        ii. System 2
        iii. System 3
    b. Lighting Systems
        i. System 1
        ii. System 2
        iii. System 3
    c. Domestic Hot Water Systems
        i. System 1
        ii. System 2
        iii. System 3
    d. On-site Power Systems
        i. System 1
        ii. System 2

iii. System 3

e. Other Systems

i. System 1

ii. System 2

iii. System 3

1. Primary Design Assumptions

a. Climatic Design Conditions Identify Source of Design Condition Data. (Example: Design Criteria Data is obtained from the Air Force Combat Climatology Center in accordance with UFC 3-400-02, Design: Engineering Weather Data.)

Location Information. (Example: Ft. Drum, NY; Latitude 44.05 N, Longitude 75.73 W, Elevation 679 ft)

Summer Hot Design Condition (Example: 1.0% Dry Bulb Temperature Occurrence 84 deg F / 70 deg F mean coincident wet bulb temperature)

Winter Design Condition
(Example: 99.6% Dry Bulb Temperature Occurrence -11 deg F/ -11 deg F mean coincident wet bulb temperature)
Summer Humid Design Condition
(Example: 1.0% Wet Bulb Temperature Occurrence 73 deg F/ 79 deg F mean coincident dry bulb temperature)

Cooling and Heating Degree Days and Base Temperature
(Example: Cooling Degree Days 584 Heating Degree Days 6901 Base 65 deg F)

b. Space Type 1
Space Use: Explain how the space(s) will be used (Example: Classroom occasionally used as conference room).
Redundancy: Identify whether and why the systems serving the space(s) require redundancy. (Example: Systems serving spaces will use hydronic heating system with two boilers minimum.)
Diversity: Identify whether and why diversity may be applied to the determination of block cooling/heating loads, ventilation rates, lighting, electrical circuit capacity, etc. (Example: Applied population diversity to ventilation system in accordance with ASHRAE 62.1-2004. Applied diversity to VAV system by setting airflow at value needed to satisfy total block load.)
Space Zoning: Describe how spaces will be zoned. (Example: No more than 3 private offices will be grouped together on one VAV box and thermostat. Commander offices will have its own VAV box and thermostat.) (Example: External open office spaces [within 15 ft of wall] will be separately zoned from interior open office spaces.) (Example: Each office is its own zone.)
Occupancy: Describe the occupancy including number of people at various times (i.e. drill weekend-maximum capacity, weekdays-20%; or 0700-0900 - none, 0900-1400 - 30 people, 1400-1600 - none; 1 person per 100 sqft.).

Operations: Describe how space(s) are operated. (Example: Building is operated 24 hrs 7 days a week; Building systems are controlled from DDC system to switch modes based on occupancy schedule or sensor input.) (Example: The classroom is used occasionally as a conference room.)
Space Environmental Requirements: Describe the environmental requirements of the space(s). Include description of temperatures, humidity levels, ventilation rates, air quality, lighting levels, or any other specific parameters (i.e. 75 deg F, 50% rh, 30 fc, etc.).

c. Space Type 2

2. Applicable Standards
List standards, codes, design guides, and other references used for the design and installation of the building energy systems. (Example:

- ASHRAE Standard 90.1-2004 Energy Standard for Buildings Except Low-Rise Residential
- ASHRAE Standard 62.1-2004 Ventilation for Acceptable Indoor Air Quality
- ASHRAE Standard 52.2-1999 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
- LEED-NC Green Building Rating System for New Construction & Major Renovations v2.2
- LEED for New Construction & Major Renovation v 2.2 Reference Guide
- International Mechanical Code
- International Plumbing Code
- NFPA 54 National Fuel Gas Code
- NFPA 90A Standard for the Installation of Air-Conditioning and Ventilating Systems
- NFPA 90B Standard for the Installation of Warm Air Heating and Air-Conditioning Systems
- UFC 4-171-05 Design: Guide for Army Reserve Facilities
- UFC 3-400-01 Energy Conservation
- UFC 3-400-02 Design: Engineering Weather Data
- UFC 3-410-01 Heating, Ventilating, and Air Conditioning)

3. System Narratives

a. HVAC&R Systems
i. System 1 (Examples: Office Area VAV Air Distribution System, Hydronic Heating System, Geothermal Systems, Control Systems, Unit Heating)
Insert narrative of system.
ii. System 2
Insert narrative of system.

b. Lighting Systems
i. System 1 (Examples: High-efficiency fluorescent lamps with high-efficiency ballasts. A daylight harvesting system with automatic dimming of the

fluorescent fixtures based on the amount of natural sunlight in the area will be specified in the open office areas.)
Insert narrative of system.
ii. System 2
Insert narrative of system.

c. Domestic Hot Water Systems
i. System 1 (Examples: Gas-fire Water Heater with External Storage Tank, Recirculation Loop, Instantaneous Electric Water Heaters)
Insert narrative of system.
ii. System 2
Insert narrative of system.

d. On-site Power Systems
i. System 1 (Examples: Hydro-power Units, etc.)
Insert narrative of system.
ii. System 2
Insert narrative of system.

e. Other Systems
i. System 1
Insert narrative of system.
ii. System 2
Insert narrative of system.

**APPENDIX D**
**OWNER'S PROJECT REQUIREMENTS**
**OWNER'S PROJECT REQUIREMENTS DOCUMENT FOR LEED FUNDAMENTAL COMMISSIONING**
Project: Project, Location, PN #####
Approved:
Name Design Agent's Representative Date
Name Owner's Representative Date
Instructions: Each bullet point describes information that should be inputted. Replace the explanation of the bullet point with the appropriate information. Add fields or additional spaces as necessary to provide all pertinent information to the commissioning of the building energy-related systems. Matrices may be provided to describe Indoor Environmental Quality Requirements rather than listing per the outline.

**OWNER'S PROJECT REQUIREMENTS DOCUMENT FOR LEED FUNDAMENTAL COMMISSIONING**

Contents
1. Owner and User Requirements
a. Primary Purpose, Program, and Use
b. Project History

- c. Broad Goals
    - i. Future Expansion
    - ii. Flexibility
    - iii. Quality of Materials
    - iv. Construction Costs
    - v. Operational Costs

2. Environmental and Sustainability Goals
    - a. LEED Goal
    - b. Other
3. Energy Efficiency Goals
    - a. Compliance with Energy Policy Act of 2005
    - b. Envelope or Site Feature Energy Impact
4. Indoor Environmental Quality Requirements
    - a. Space Type 1
        - i. Intended Use
        - ii. Occupancy Schedule
        - iii. Environmental Requirements
        - iv. Occupant System Control Ability
        - v. Type of Lighting
        - vi. After-hour Use Accommodation
    - b. Space Type 2
        - i. Intended Use
        - ii. Occupancy Schedule
        - iii. Environmental Requirements
        - iv. Occupant System Control Ability
        - v. Type of Lighting
        - vi. After-hour Use Accommodation
5. Equipment and System Expectations
    - a. HVAC Systems
        - i. Quality and Reliability
        - ii. Type
        - iii. Automation
        - iv. Flexibility
        - v. Maintenance Requirements
    - b. Lighting Systems
        - i. Quality and Reliability
        - ii. Type
        - iii. Automation
        - iv. Flexibility
        - v. Maintenance Requirements
    - c. Domestic Hot Water Systems
        - i. Quality and Reliability
        - ii. Type
        - iii. Automation
        - iv. Flexibility
        - v. Maintenance Requirements

d. On-site Power Systems
i. Quality and Reliability
ii. Type
iii. Automation
iv. Flexibility
v. Maintenance Requirements
e. Other Systems
i. Quality and Reliability
ii. Type
iii. Automation
iv. Flexibility
v. Maintenance Requirements
6. Building Occupant and O&M Personnel Requirements
a. Facility Operation
b. UMCS (EMCS or FMCS)
c. Occupant Training and Orientation
d. O&M Staff Training and Orientation

1. Owner and User Requirements
a. Primary Purpose, Program, and Use Explain the purpose, program, and use of the facility. (i.e. Army Reserve Center used for training reserve units. Training includes weapons, medical, vehicle repair, cooking, etc.)
b. Project History: Explain the history of the project related to design/construction (i.e. D/B/B, D/B, IDIQ, JOC, COE in-house, A/E, etc.). Explain any additional project background that would impact energy/sustainability goals.
c. Broad Goals
i. Future Expansion: Explain goals related to potential future expansion.
ii. Flexibility: Explain goals related to flexibility for layout and use of the building. (i.e. high rate of office churn, expected frequency of renovation, etc.)
iii. Quality of Materials: Explain goals related to quality of materials. (i.e. highest quality materials, 50 yr life, 25 yr life, highest quality within budget, etc.)
iv. Construction Costs: Explain goals related to construction costs. (i.e. how low can you go, set project amount, select simplest systems for low cost, etc.)
v. Operational Costs: Explain goals related to operational costs. (i.e. low utilities based on water and energy conservation, trade-off allowable on maintenance costs to reduce utility cost, utility cost unimportant compared to construction cost, etc.)
2. Environmental and Sustainability Goals
a. LEED Goal: Set LEED goal and explain sustainable features permissible or preferred to be incorporated. Explain relative importance of LEED goal within project scope. Set LEED goal. Indicate requirement by Army Sustained Design and Development Policy.
b. Other: Explain any special sustainability or environmental goals associated with the project. Identify specific sustainability features that may be required or desired. (i.e. hydro-power, solar power, on-site water treatment, on-site water infiltration, impervious cover reduction, parking capacity, etc.)

3. Energy Efficiency Goals

a. Compliance with the Energy Policy Act of 2005

It is mandatory that all federal buildings designed after January 2007 meet the requirements of the Energy Policy Act of 2005. This act requires that the building energy consumption level be reduced by 30% compared to the baseline building performance per ASHRAE Standard 90.1-2004, Appendix G if Life Cycle Cost Effective. If 30% reduction is not life-cycle cost effective, the most energy efficient design that is life cycle cost effective must be evaluated. Federal agencies are required to specify FEMP-designated or ENERGY STAR equipment, including building mechanical and lighting equipment and builder-supplied appliances.

b. Envelope or Site Feature Energy Impact

Identify and explain envelope or site features that will be incorporated to maximize energy efficiency. Identify features that must be incorporated that will reduce or limit energy efficiency.

4. Indoor Environmental Quality Requirements

a. Space Type 1

i. Intended Use: Explain how the space will be used (i.e. classroom occasionally used as conference room).

ii. Occupancy Schedule: Describe the occupancy including number of people at various times (i.e. drill weekend-maximum capacity, weekdays-20%; or 0700-0900 - none, 0900-1400 - 30 people, 1400-1600 - none).

iii. Environmental Requirements: Describe the environmental requirements of the space. Include description of temperatures, humidity levels, ventilation rates, air quality, lighting levels, or any other specific parameters desired (i.e. 75 deg F, 50% rh, 30 fc, etc.).

iv. Occupant System Control Ability: Describe the desired level of control the occupants will have over the thermal comfort and lighting systems. (i.e. adjustable thermostat for every person, adjustable thermostat in all private offices, no adjustable thermostats, adjustable thermostat in senior rank also controlling other offices, occupancy sensors for lighting, adjustable dimming, etc.)

v. Type of Lighting: Describe the type of lighting desired (i.e. task lighting with minimal overhead, maximize daylight with dimming on overhead, accent lighting, particular fixtures, etc.).

vi. After-hour Use Accommodations: Describe whether and how often the space may be used after hours. Describe the systems that activate when an occupant uses the building after-hours. Describe the level of control of after-hour use HVAC. (Example: Space is rarely used after-hours by few occupants. HVAC and lighting system should activate. The HVAC operation will be limited to that required to provide heating, A/C, and ventilation to the occupied space alone.) (Example: Space is rarely used after-hours by few occupants. Lighting and heating systems should activate. Ventilation and cooling should remain in normal after-hour operation.)

b. Space Type 2

5. Equipment and System Expectations

a. HVAC Systems

i. Quality and Reliability: Explain the level of quality and reliability required of the HVAC systems. (Example: Equipment efficiency should meet ASHRAE and EPACT requirements. Due to critical nature of facility, additional redundancy in the cooling and heating systems is required, i.e. multiple chillers, boilers, and pumps.) (Example: No specific quality or reliability requirements specified. Equipment should remain serviceable over life of building or to the extent typical of the type of equipment.)

ii. Type: Explain the type of equipment desired. (Example: Boilers and water heaters should be XXXX manufacturer. Boilers should be condensing type. Use hydronic heating and cooling. Use self-contained A/C units in computer rooms.)

iii. Automation: Explain the level of automation in the HVAC System desired. (Example: Single loop HVAC systems permissible. Use packaged controls only.) (Example: Control HVAC systems from DDC system connected to the base UMCS.) (Example: Boilers should have packaged controls connected to the DDC system.)

iv. Flexibility: Describe the desired level of flexibility of the HVAC system. (Example: System should accommodate frequent office layout changes including private office wall movement.) (Example: Layout will remain mostly unchanged; no flexibility required.) (Example: Accommodate potential for conference and classrooms to change to offices.)

v. Maintenance Requirements: Describe the level of maintenance available or the requirements of the equipment regarding maintainability. (Example: Equipment should be located to allow easy maintenance access. Equipment vendors or repair service should be able to respond within 24 hrs.)

b. Lighting Systems

i. Quality and Reliability: Explain the level of quality and reliability required of the lighting system controls. (Example: The building lighting system should meet ASHRAE/IESNA Standard 90.1 requirements.)

ii. Type: Explain the type of lighting or control equipment desired. (Example: High-efficiency fluorescent lamps with high-efficiency ballasts will be specified. Indirect lighting will be used in all office and classroom spaces. Foot-candle levels may be reduced to 45 in lieu of the typical 50 foot-candles when indirect lighting is used.)

iii. Automation: Explain the level of automation in the lighting control system desired. (Example: Provide occupancy sensors in restrooms, corridors, and storage areas.)

iv. Flexibility: Describe the desired level of flexibility of the lighting system and control systems. (Example: Provide dual level switching in classrooms and conference rooms.)

v. Maintenance Requirements: Describe the level of maintenance available or the requirements of the equipment regarding maintainability.

c. Domestic Hot Water Systems

i. Quality and Reliability: Explain the level of quality and reliability required of the domestic hot water systems. (Example: Equipment efficiency should meet ASHRAE and EPACT requirements. Due to critical nature of facility, additional redundancy in the water heating systems is required, i.e. multiple hot water heaters and circulation pumps.) (Example: No specific quality or reliability requirements specified. Equipment should remain serviceable over life of building or to the extent typical of the type of equipment.)

ii. Type: Explain the type of equipment desired. (Example: Gas-fired storage tank water heater with mixing valve for temperature control.) (Example: Instantaneous electric water heater at lavatories.) (Example: Instantaneous electric water heater with integral control system for eyewash/showers.)

iii. Automation: Explain the level of automation in the domestic hot water control system desired. (Example: Occupancy schedule control for recirculation loop and gas burner. Connect package controls to DDC system.)

iv. Flexibility: Describe the desired level of flexibility of the domestic hot water systems. (Example: No anticipated changes to restroom layout; no additional flexibility required.)

v. Maintenance Requirements: Describe the level of maintenance available or the requirements of the equipment regarding maintainability. (Example: Equipment should be located to allow easy maintenance access. Equipment vendors or repair service should be able to respond within 24 hrs.)

d. On-site Power Systems

i. Quality and Reliability: Explain the level of quality and reliability required of the on-site power system.

ii. Type: Explain the type of on-site power system desired.

iii. Automation: Explain the level of automation in the on-site power system desired.

iv. Flexibility: Describe the desired level of flexibility of the on-site power system.

v. Maintenance Requirements: Describe the level of maintenance available or the requirements of the on-site power system regarding maintainability.

e. Other Systems

i. Quality and Reliability: Explain the level of quality and reliability required of the system.

ii. Type: Explain the type of system desired.

iii. Automation: Explain the level of automation in the system desired.

iv. Flexibility: Describe the desired level of flexibility of the system.

v. Maintenance Requirements: Describe the level of maintenance available or the requirements of the system regarding maintainability.

6. Building Occupant and O&M Personnel Requirements

a. Facility Operation

Describe how the facility will be operated. Who operates the facility? Who maintains the facility? Who pays the utility bills?

b. UMCS (EMCS or FMCS)

Will the building be tied to an EMCS? What system will be connected to? Provide information regarding connection requirements, protocols, and control, scheduling and monitoring points.

c. Occupant Training and Orientation

How much training and orientation is desired for building occupants? Will training need to be provided for all systems? To what extent do the occupants need to understand and use the systems?

d. O&M Staff Training and Orientation

How much training and orientation is desired for building occupants? Will training need to be provided for all systems? To what extent do the occupants need to understand and use the systems?

**Appendix 7.5: Re-Commissioning (TBD)**

**Appendix 7.6: Contract Language**

- MTRFP Chapter 5
  - 5.8.5. Commission all HVAC systems and equipment, including controls, and all systems requiring commissioning for LEED Fundamental commissioning, in accordance with ASHRAE Guideline 1.1 and LEED. The Contractor shall hire the Commissioning Authority, certified as a Commissioning Authority by AABC, NEBB, or TABB, as described in Guideline 1.1. The Contracting Officer's Representative will act as the Owner's representative in performance of duties spelled out under OWNER in Annex A2 of ASHRAE Guideline 1.1.
- EO 13423, sec 2(f)(i), HPSB MOU (2006). Employ total building commissioning practices tailored to the size and complexity of the building.

## Appendix 8: General Building Guidelines

### Appendix 8.1: Office Equipment

1. All new and replacement office equipment, whether owned or leased, shall comply with EPACT 05 Energy Star® requirements. Reference (9) is a good source of Energy Star® information. New, leased, and purchased office equipment shall have power saving features and those features shall be enabled at delivery as specified.
2. The "sleep mode" shifts office equipment into a low- energy mode when not in use for a period of time, reducing energy use by up to 90%. Check equipment manuals to ensure all sleep modes are enabled and set to activate after ten minutes of inactivity. All computers in common use on Base shall be set to put monitor in sleep mode after 20 minutes and off after 60 minutes. All personnel shall ensure that sleep mode is set accordingly. Contact your computer help desk if you need assistance.
3. All personal computer (PC) monitors, dedicated printers, and ancillary equipment shall be shut down at the end of the workday. Your personal workstation may represent 400 to 600 watts of power and is a significant load.
4. Turn off common copiers and printers at the close of business unless there is an operational need to keep them on.
5. Where possible, turn off the power to small transformers attached to office equipment. Small transformers consume up to five watts of power even when the equipment is turned off. This represents a significant load when multiplied by the thousands of units on Base.
6. Turn off all PC speakers, scanners and ancillary equipment when not in use.
7. Fax machines are authorized to be left on 24 hours a day, but users are requested to determine whether this is cost- effective for their office. If leaving a fax machine on is not mission essential, it should be turned off.
8. Office equipment shall be secured to the greatest degree possible over weekends, holidays, leave periods, and other periods when they are not needed.
9. Ensure that all office appliances like coffee machines, hot plates, and toaster ovens, are turned off when not in use.
10. Personal and government-owned portable resistive electric heaters are prohibited in areas that are centrally heated. Electric resistance space heating is not authorized except in unique circumstances and where specifically authorized by the PWO. These heaters must be inspected and approved by the Base Safety Office and the Base Fire Inspector where authorized. Approved portable heaters must meet current energy efficiency, safety, and electrical circuit loading standards.

**Appendix 8.2: Refrigeration**

1. Defrost manual refrigerators quarterly to avoid ice build-up, which retards the unit's efficiency. Wipe dust build- up off from coils also.
2. Replace worn or improper sized door seals. If needed, tighten door latches and realign doors for a better fit.
3. Install thermo-strip door curtains in all walk-in freezers and refrigerators where doors must be open for extended periods.
4. Replace light switches with 15-minute delay timers on all walk-in refrigerators where cost-effective.
5. Install door buzzer with door switch on all walk-in refrigerators and freezers as a reminder for all personnel to close doors.
6. New and replacement refrigerators and freezers shall meet or exceed the most current appliance energy efficiency requirements as identified by Energy Star.
7. Procurement of new and replacement refrigerators and water coolers shall specify R-134a refrigerant.

## Appendix 9: Solar Domestic Hot Water (SDHW)

### Appendix 9.1: Solar Domestic Hot Water Overview

1. Points of Contact
    a. Jennifer McKenzie, Fort Bragg Energy Manager, 910-396-6371, Jennifer.McKenzie@us.army.mil.
    b. Jim Peedin, Subject Matter Expert (SME), 910-396-5970 office, james.f.peedin@us.army.mil

2. Solar Thermal (Hot water) Description
    a. Ft. Bragg Solar Thermal (hot water) installations are glazed flat plate collector, active, indirect, drain back type systems. The working fluid is potable water.
    b. Below is a brief overview of the major parts of the Solar Thermal system. A more detailed description can be found in **Appendix C**, page 10.
        i. Collectors
        ii. Collector mounts
        iii. Drain back tank/solar water storage tank
        iv. Heat exchangers
        v. Piping systems
        vi. Pumps
        vii. Working fluid
        viii. Control panel
        ix. Metering and Remote monitoring
    c. The solar thermal system generates hot water for medium temperature domestic hot water or process hot water application (160F maximum) within each facility.

3. Guidance and References
        i. North American Board of Certified Energy Practitioners (NABCEP). NABCEP provides certification programs for solar electric and thermal system installers. A NABCEP-certified installer provides for an extra level of assurance as to the qualifications of the installer. However, because the solar thermal certification is a relatively recent development, NABCEP-certified installers are not especially common. Certified installers can be found on the website, http://www.nabcep.org/installer-locator-agreement
        ii. Florida Solar Energy Center (FSEC). Mandated by the state of Florida to perform testing of solar energy products, FSEC is a good source for performance characteristics on both solar thermal collectors and entire solar thermal systems. Although specifically geared towards the solar industry in Florida, the FSEC is a good resource for the Southeast region as a whole. This is a well-established organization that has been producing literature for these systems for several years. FSEC Standard 101-09, which was

revised May 2009, is the institute's solar collector certification. It supersedes FSEC Standard 102-05. Website: http://www.fsec.ucf.edu/en/industry/testing/index.htm

iii. Solar Rating and Certification Corporation (SRCC). This is the principle rating entity for SDHW collectors and is highly trustworthy. The SRCC offers OG-100 certification for solar collectors and OG-300 for entire systems. OG-300 certification is for smaller residential systems. Website: http://www.solar-rating.org/ratings/ratings.htm

iv. Energy Star. Energy Star evaluates residential solar water heaters and has criteria for achieving an Energy Star rating. To qualify, at least half the energy generated by the "qualifying property" must come from the sun. The credit is not available for pools or hot tubs. Website: http://www.energystar.gov/index.cfm?c=solar_wheat.pr_solar_wheat

4. Contract Language

**Please reference the appropriate Appendix for specific contract language**

a. Solar Thermal Specification **Appendix F,** page 19.

b. MCA Projects

i. MT RFP Chapter 5

1. 5.9.4. Solar Hot Water Heating. Provide at least 30% of the domestic hot water requirements through solar heating methodologies, unless the results of a Life Cycle Cost Analysis (LCCA) developed utilizing the Building Life Cycle Cost Program (BLCC) or the Life Cycle Cost in Design (LCCID) Program which demonstrates that the solar hot water system is not life cycle cost effective in comparison with other hot water heating systems. The type of system will be established during the contract or task order competition and award phase, including submission of an LCCA for government evaluation to justify non-selection of solar hot water heating. The LCCA uses a study period of 25 years and the **Appendix K** (MTRFP) utility cost information. The LCCA shall include life cycle cost comparisons to a baseline system to provide domestic hot water without solar components, analyzing at least three different methodologies for providing solar hot water to compare against the baseline system.

ii. MT RFP Chapter 6 **Appendix G**, page 43: Provides guidance for Fort Bragg.

c. SRM Projects

i. New construction and/or renovation/retrofit projects that will include major HVAC changes/upgrades should use the Solar Thermal specifications located in the Installation Design Guide (IDG) located in **Appendix G,** page 43***.***

d. Solar Thermal Installation Scope of Work: **Appendix D**, page 15

5. Warranty Process
   a. Following final acceptance of the installation, Government will take responsibility for operation and maintenance of the new system. Should a warranty claim arise, Government agrees to troubleshoot the system to identify the failure, if the failure is deemed to be a warranty issue, a warranty Service Order will be created for the installation vendor to respond.

6. Subject Matter Expert (SME) Assistance
   a. The SME will help your team make Solar Thermal systems a successful alternative energy solution at Fort Bragg. To make this happen the SME should be involved in the total process of these projects.

   b. Provide information for existing buildings and like facilities for buildings equipped with Solar thermal.

   c. DD1391 development to include solar technologies

   d. RFP and Design review; The SME should be added to your email list for distribution of review material and meeting schedules.
      i. The SME will make comments directly into Dr. Checks.
      ii. The project timeline is a concern to the SME as it is to the Project Managers. All reviews and comments will be made in a timely matter.

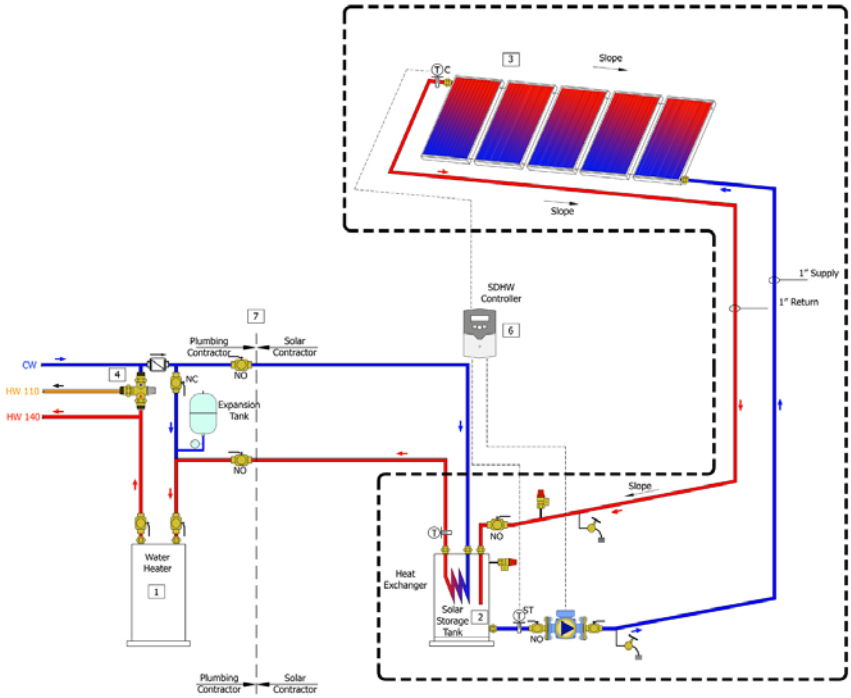
   e. During construction, the SME is available to provide assistance with any questions, issues, or concerns including submittal review.

   f. The SME should be invited to any Pre-Final inspection meetings

   g. Commissioning, the SME should be involved with the Performance Verification Test to track and record any problems found during the test.

   h. Submittal / Turnover procedure
      i. The SME shall receive, at a minimum, 1 copy of the submittal documentation. The information should include the items listed in the SOW located in **Appendix D,** page 15**.**
      ii. The SME should be invited to turnover meetings

iii. The SME can assist in tracking warranty dates for the solar thermal system
iv. SME will ensure Operations and Maintenance Department (OMD) receives information needed to service the solar thermal system



## Appendix 9.2: Solar Thermal Guidelines

### 1.1 General:

- Fixed solar array.
- Flat plate, single cover, tempered glass glazed collectors, See guide specification for more detail.
- Drain back system – Drain working fluid from the solar array to prevent freezing and over temperature in accordance with the sequence of operation.
- Indirect system – Use a heat exchanger to separate the solar array working fluid from domestic hot water.
- Active system – pump required to circulate working fluid through the collector array.
- Working fluid – Potable water. [Water and food grade Propylene Glycol used for the working fluid, 30% glycol, 70% water if greater freeze protection is warranted.]

### 1.2 Application:

The solar hot water system is generally intended for production of domestic hot water. Although there will be other applications where solar hot water generation should be considered for process heat loads. Process applications will be evaluated on a case by case basis.

Buildings considered for SDHW should have an un-shaded, south-facing (or nearly south-facing) surface on or near the building. In addition, the building candidate should have the following attributes:

- Hot water heating from electricity.
- Highly-occupied buildings, such as
    - Hospitals
    - Schools
    - Child Development Centers (CDC) , Youth Centers
    - Company Operation Facility (COF)
    - Fire and police stations
    - Barracks, lodging
    - Administration
    - Clinics, including for animals
    - PX, BX
    - AAFES
    - Some MWR facilities (bowling alley, etc.)
- Buildings with high hot water usage, such as
    - Fitness centers
    - Dining facilities and clubs
    - Hospitals
    - Laundry facilities
    - Bath houses, if regularly used.
    - Car washes
    - Central heating plants
    - Pools

**1.3 Integration with existing DHW system:**
The SDHWS is intended to preheat cold makeup water for domestic hot water production. During periods of low or no hot water demand, the hot water generated by the SDHWS can offset tank and hot water recirculation circuit standby losses. The new SDWHS storage tank will be located near the existing hot water storage tank inside the existing mechanical room. Cold water makeup will be diverted to pass through the solar hot water storage tank heat exchanger before being introduced to the existing hot water heater storage tank.

Existing domestic hot water systems may include storage tanks with integral heat exchanger elements or separate heat exchangers and storage tanks. The type of heat used may be electric, hot water (sourced from the building heating hot water system), steam, or direct gas fired burners.

**1.4 Sizing criteria:**
- Goal: Solar system to provide a minimum of 30% of DHW demand.
- Use F-Chart or NREL software sizing tool to select optimum system size.

**1.5 Remote Monitoring/controls:**
All new SDHW systems shall be remotely monitored by the base Utility Monitoring & Control System (UMCS). The intent of monitoring the SDHWS is to collect operational data to track the energy contributed by the SDHWS, and to monitor the health of the system. Using the UMCS for monitoring the SDWHS allows Ft Bragg to:
- Increase consistency across many different installations.
- Provide a robust centrally managed vehicle to collect trend data, monitor alarms, and dispatch service personnel.
- Maximize effectiveness of service personnel by using familiar hardware and software.

With this goal, each new SDHWS installation shall be provided with the following minimum monitored points. See Appendix X for Point Schedules:

SDHWS operation:
- Tank temperature
- Solar array circulating pump start/stop
- Solar array circulating pump status
- Solar controller alarm
- Solar array inlet temperature
- Solar array discharge temperature
- Solar array discharge temperature alarm high limit
- Solar array stagnation temperature (via temperature sensor mounted to the flat plate collector)

The solar controller provided with the system shall be Lonworks compatible either directly or via an approved Lonworks gateway. The solar controller shall have a local

display panel (LDP) capable of showing the status of each point as outlined by **Appendix X** (not yet defined)Point Schedules. SRCC certification is preferred.

SDHWS shall be graphically represented at the UMCS. All integration shall be performed by Fort Bragg's System Integration Contractor as per the Fort Bragg Integration SOW. Contact UMCS Manager for details. Coby Jones, joseph.c.jones4@us.army.mil 910-396-1868.

**1.6 Energy Monitoring:**
The intent of the energy monitoring BTU/electric/gas meters is to document the amount of energy captured from the solar system and to determine what the solar fraction is of the total hot water load. All meters shall be monitored by the UMCS.

BTU meter on SDHWS production.
This BTU meter application captures the energy produced by the SDHWS.

- Solar array circulation loop flow.
- Solar array inlet temperature (provided above)
- Solar array discharge temperature (provided above)

BTU meter on existing hot water heater.
This BTU meter application captures the energy consumed by the existing hot water heater. Knowing this value allows determination of the solar fraction. This installation assumes the existing domestic hot water tank is heated with a liquid to liquid heat exchanger element tied to the building heating hot water system.

- HHWR or HHWS flow
- HHWS temperature
- HHWR temperature

Alternatives for electric or gas fired hot water heaters;

- If the existing hot water tank uses an electrical heating element, provide a totalizing electrical meter on the circuit feeding the heating element.
- If the existing hot water tank uses a gas burner, provide a totalizing gas meter on the gas line to burner.

**1.7 Trend data:**
Standard trend data collection:

- Days: 7 days per week, 365 days per year.
- Interval: 15 minutes
- Hardware points:
  - Solar array inlet temperature
  - Solar array discharge temperature
  - Solar array flow
  - HHWR or HHWS flow
  - HHWS temperature
  - HHWR temperature
- Virtual points:

- o BTUs, SDHWS - totalize for monthly.
- o BTUs, existing hot water heater - totalize monthly.

**1.8 Roofing:**

- The solar collector panels will be mounted to a frame which is in turn mounted to the building structure (roof or walls). Where the collector array is mounted to the roof, the intent is to minimize the number of roof penetrations. Roof penetrations will be required for piping and possibly for the frame supports.
- Wherever possible the roofing company that installed the roof should be engaged to perform this work to preserve any remaining roof warranty. The Government shall furnish the contact information for the original roofer to the contractor.

**1.9 Solar array roof orientation:**

- Fixed solar array.
- Solar array ideally tilted at 36 degrees from horizontal (tilt angle acceptable range is 21 to 51 degrees).
- Solar array azimuth aligned with due south +/- 10 degrees.
- Locate to prevent shading.
- Ensure location of rack will not block, or otherwise interfere with any existing roof elements including, but not limited to, roof drains, maintenance access to roof mounted equipment, HVAC intake and exhaust flows, plumbing vents, flues, or chimneys, antennas, etc.

**1.10 Solar panel array rack frame:**

- Rack shall be constructed of a non-corrosive metal. Aluminum is preferred. Connections may be shop welded or bolted.
- Design for the rack and collector assembly shall be stamped by a registered professional engineer in the state of North Carolina.
- Design shall account for all applicable static, wind, snow, and seismic loads.

**1.11 Mechanical Transport system:**

- Copper piping with soldered joints shall be used.
- All piping shall be insulated, exterior insulated piping shall have aluminum or stainless steel outer insulation cover. Insulation shall be rated for the intended service temperatures.
- All piping serving the collector array shall have horizontal runs sloped back to the drain back tank a minimum of ¼” per foot. High points in the lines shall be avoided.
- Use reverse return piping configuration for the collector array. If reverse return piping configuration is not practical, provide manual balancing valves for each collector circuit.
- Use combination automatic air vent valve/vacuum breaker(s) at the high points of the system. Discharge of automatic air vents shall be piped back to the drain back tank and be provided with an in-line sight glass.

- Use seal-less magnetic drive pumps with high efficiency motors for the solar array circulation circuit.

**1.12 Storage tanks:**

- Tanks shall be SRCC certified.
- Drain back tank shall have an overflow drain line piped to the nearest floor drain.
- Tanks shall be lined with glass or other corrosion resistant material rated for the highest system temperature and working fluid. Alternatively, stainless steel tanks may be provided.
- Tanks shall be ASME rated in accordance with the maximum possible pressures and temperatures. (System designer to reference the requirements of the ASME boiler and pressure vessel Code for determination of requirements.)
- Preference will be given to tank/heat exchanger designs that allow scale build up on exterior surfaces of the heat exchange elements to shed and fall to the bottom of the tank without further fouling of heat exchange elements.

**1.13 Heat Exchangers:**

- Heat exchangers shall be SRCC certified.
- Single wall
- Heat exchange elements constructed from stainless steel or copper.
- Heat exchanger may be integrated with the solar storage tank.

**1.14 Sequence of Operation**

Proposed solar thermal sequences of operation:

- **System run command:**
  If solar array stagnation temperature is above the solar tank temperature by 10 F, energize solar circulation pump P-1. Pump shall be energized during daylight hours only. Upon command to start, pump must remain energized for an adjustable period of time (initial setting of 20 minutes).
- **System stop command (high temperature):**
  If solar circulation pump P-1 is energized and if solar array discharge temperature rises above 185F (adjustable), activate a high temperature alarm. If solar array discharge temperature rises above 195F (adjustable), de-energize solar circulation pump P-1.
- **System stop command (low temperature):**
  If solar circulation pump P-1 is energized and solar array discharge temperature falls below the solar tank temperature for a period of 10 minutes (adjustable), solar circulation pump shall de-energize.
- **Thermal shock prevention:**
  If solar circulation pump P-1 is de-energized during daylight hours and if solar array stagnation temperature is below 180 F (adjustable), solar circulation pump shall be enabled. If solar circulation pump P-1 is de-energized and if solar array

stagnation temperature is 180F or above (adjustable), solar circulation pump P-1 shall be disabled for an adjustable time period (8 hr initial setting).

- **Notes:**
  The solar array stagnation temperature sensor is critical to these sequences. The installation of the stagnation temperature sensor may take one of two different forms:
  - Option 1: Install the stagnation temperature sensor directly to the absorber surface on the backside, inside the insulation.
  - Option 2: Provide a separate small (approx 1 ft x 1 ft) solar collector mounted to the array without piping it into the hydronic loop. This “dry” collector will provide a representative temperature without the effects of the fluid flow through the collector. This method is preferred to prevent short cycling the pump during conditions where introducing fluid to the collector would cool it below the run command threshold.

**Appendix 9.3: Fort Bragg Specification Overview for SDHW**

*Note: Reference UFGS XX XX XX Fort Bragg edited version for more detailed specifications. The UFGS can be requested from the Fort Bragg Energy Manager.

**Part 1**

**1.1 References**-ASHRAE, ASSE, AWS, ASME, ASTM, CDA, MSS, SMACNA, SRCC, NABCEP, US Dept of Defense, GSA

**1.2 Related Requirements** –list of other specification sections that may have content related to the installation of solar thermal systems. Division 01 – General requirements, Division 05 – Metals, Division 07-Thermal and Moisture protection, Division 09-Finishes, Division 13-Special Construction (Seismic), Division 22-Plumbing, Division 23 – HVAC (DDC systems), Division 26 – Electrical

**1.3 Submittals**-Shop Drawings, Product Data, Certificates, Manufacturer's instructions, O&M manuals, Closeout Submittals.

**1.4 Quality Assurance** – Install piping systems in conformance with ASME and CDA recommendations. Provide troubleshooting guide and maintenance schedule.

**1.5 Solar Collector Warranty** – One year parts and labor. After warranty period expires, all remaining warranties transfer to the Government. Minimum 5 year warranty on solar collectors.

**1.6 Posted Operating Instructions-**Provide with closeout submittals.

**Part 2**

**2.1 Solar Energy Systems** - Provide necessary materials to fabricate solar energy systems in accordance with this section. At the Contractor's option, provide factory-prefabricated solar equipment packages which include heat exchanger, compression and storage tanks, pumps and controls and which meet the requirements of this section. In general, the system shall have the following attributes:

- Fixed solar array.
- Flat plate, single cover, tempered glass glazed collectors
- Drain back system – Drains working fluid from the solar array to prevent freezing and fluid over temperature.
- Indirect system – Use a heat exchanger to separate the solar array working fluid from domestic hot water.
- Active system – pump required to circulate working fluid through the collector array.
- Working fluid – Potable water.

**2.2 Piping** – Copper, Type L, soldered joints.

**2.3 Valves**-Ball, gate, globe, mixing/anti-scald, pressure/temperature relief, flow balancing, check, automatic air vent/vacuum breaker. Comply with MSS.

**2.4 Piping specialties**-Bolts and nuts, gaskets, solder metal, strainers, labels, hangers and supports.

**2.5 Pumps**-Centrifugal, seal-less magnetic drive, high efficiency motor.

**2.6 Compression tanks**-ASME labeled, 125 psig working pressure, hot dip galvanized tank, drain, fill, air charge connections, and level gauge.

**2.7 Solar storage tanks**-SRCC certified, insulated, galvanized steel with glass lining or stainless steel. ASME rated for design temperatures and pressures.

**2.8 Heat exchangers**-SRCC certified, Single wall, copper tubes preferred, exchanger may be immersed inside the solar hot water storage tank.

**2.9 Solar collectors**-SRCC and or FSEC certified, flat plate, single glazed, tempered glass, absorber plate coated in black chrome (minimum absorptivity of 0.9 and maximum emissivity of 0.12) , casing fabricated from 20 ga. Minimum aluminum or galvanized steel.

**2.10 Solar collector supports**-design stamped by a professional engineer. Fabricate from metal, aluminum preferred. Shop welded or bolted connections. Roof penetrations to be performed by original roofer where possible.

**2.11 Collector heat transfer fluid**-Potable water.

**2.12 Solar-boosted Domestic Water Heaters**-SRCC certified, insulated, galvanized steel with glass lining or stainless steel. ASME rated for design temperatures and pressures.

**2.13 Insulation**-Minimum wall thickness of 1.5” fiberglass with all service jacket and PVC fitting covers for indoor piping systems. Minimum wall thickness of 2” for tanks and equipment. Provide aluminum or stainless steel cover with waterproof vapor barrier for all outdoor piping systems.

**2.14 Instrumentation**-the following points are recommended as the minimum:

1. Tank temperature
2. Solar array circulating pump start/stop
3. Solar array circulating pump status
4. Solar controller alarm
5. Solar array inlet temperature
6. Solar array discharge temperature
7. Solar array discharge temperature alarm high limit

8. Solar array stagnation temperature (via temperature sensor mounted to the center back of a flat plate collector inside the insulation)

- The solar controller provided with the system shall be Lonworks compatible either directly or via an approved Lonworks gateway. SRCC certification is preferred.
- Provide BTU meter on solar circulation loop and on existing hot water heater

**2.15 Solar Collector Control Sequences**-The following sequences are to be used as a guide:

- **System run command:**
  If solar array stagnation temperature is above the solar tank temperature by 10 F, energize solar circulation pump. Pump shall be energized during daylight hours only. Upon command to start, pump must remain energized for an adjustable period of time (initial setting of 20 minutes).
- **System stop command (high temperature):**
  If solar circulation pump is energized and if solar array discharge temperature rises above 185F (adjustable), activate a high temperature alarm. If solar array discharge temperature rises above 195F (adjustable), de-energize solar circulation pump.
- **System stop command (low temperature):**
  If solar circulation pump is energized and solar array discharge temperature falls to within 4F (adjustable) of the solar tank temperature for a period of 10 minutes (adjustable), solar circulation pump shall de-energize.
- **Thermal shock prevention:**
  If solar circulation pump is de-energized during daylight hours and if solar array stagnation temperature is below 180 F (adjustable), solar circulation pump shall be enabled. If solar circulation pump is de-energized and if solar array stagnation temperature is 180F or above (adjustable), solar circulation pump shall be disabled for an adjustable time period (8 hr initial setting).

**<u>Part 3</u>**

**3.1 Installation**-Install per approved submittals and in accordance with manufacturer's instructions. Use NABCEP certified installers. If NABCEP certified installers are not available, installers shall have a minimum of 2 years experience installing solar thermal systems. Provide references on at least 5 similar installations within the last 2 years of similar size and scope. Protect collectors from sunlight until system is ready for operation.

**3.2 Field quality control**- Hydro test all new piping to 1.5x working pressure, perform leak down test for 1 hour. Provide training to at least four Government personnel. Training shall use approved closeout submittals as the basis for the training.

**Appendix 9.4: SDHW Installation SOW**

1.0 SYNOPSIS: The Contractor shall provide the materials and labor required to design and install a Solar Domestic Hot Water System (SDHWS) in the Fort Bragg building identified below.

2.0 PRICE PROPOSAL: The Contractor shall provide a firm fixed price proposal for installation of a SDHWS specified below for the building identified.

3.0 SPECIFIC WORK TO BE ACCOMPLISHED: The Contractor shall provide materials and labor required to design, and install a new SDHWS specified below for the building specified. All work shall be in accordance with the Fort Bragg Installation Design Guide, Fort Bragg Installation Design Guide (IDG) **http://www.bragg.army.mil/dpw/idg/index.htm,** Unified Facilities Guide Specification (UFGS) 22 33 30 "Solar Water Heating Equipment" http://wbdg.org/ and this Statement of Work (SOW).

3.1 The contractor shall provide SDHWS for the following building(s):

3.1.1 Buildings **< Number>**

3.2 For each system the contractor shall perform all tasks required to fully integrate the system into the Solar thermal including but not limited to:

3.2.1 Pre-Design

3.2.1.1 Measure Domestic Hot Water (DHW) demand – add metering as required to hot water tank heater element serving the load in the mechanical room(s).

3.2.1.2 System sizing – Use F-chart or NREL tool to select solar system size that best fits the application once the DHW demand is known.

3.2.1.2.1 Tank size

3.2.1.2.2 Collector array size

3.2.2 Design

3.2.2.1 Collector array configuration and rack/support design.

3.2.2.2 Structural analysis of collector frame (static load, seismic, wind, and snow loading).

3.2.2.3 Roof penetration design.

3.2.2.4 Piping sizing and routing.

3.2.2.5 Pump selection.

3.2.2.6 Drain back tank size.

3.2.2.7 Solar tank/heat exchanger size and configuration.

3.2.2.8 Mechanical room equipment layout.

3.2.2.9 Controls/instrumentation/sequence of operation.

3.2.2.10 Electrical Power plan.

3.2.3 Submittals

3.2.3.1 Product data (SRCC certified solar equipment).
3.2.3.2 Shop drawings (wiring diagram, plumbing riser diagram, mechanical plans, structural plans, roof support and penetration details, sequence of operation.).
3.2.3.3 Engineering calculations (stamped structural calcs, stamped mechanical and electrical design).
3.2.3.4 Training.
3.2.3.5 O&M manual.
3.2.3.6 As-builts.

3.2.4 Installation
3.2.4.1 NABCEP certified installers.

3.2.5 Contractors Field Test (CFT)
3.2.5.1 QC checklist completed.

3.2.6 Performance Verification Test (PVT)
3.2.6.1 QC checklist completed.
3.2.6.2 Punch list signed off.
3.2.6.3 Operational test-trend system operation for a week then analyze results, manually demonstrate sequences for Government.

3.2.7 Training
3.2.7.1 Four hour training for system installation for a group of 4 people.
3.2.7.2 Use approved as-builts and O&M manuals for the training program.

3.2.8 Warranty
3.2.8.1 One year parts and labor. The warranty period starts upon Final Acceptance.

3.3 Contractor shall demonstrate completed installation to the Government during the PVT. This demonstration shall show all work performed and shall be sufficient to familiarize the Government with the installed system.

3.4 Prior to contract award, contractor must meet the following requirements:
3.4.1 The solar contractor shall be NABCEP certified.
3.4.2 The solar contractor shall have successfully completed at least five similar systems within the last 2 years.

4.0 GOVERNMENT FURNISHED INFORMATION:

4.1 Building type and occupancy.
4.2 Building drawings * to the extent available (architectural, structural, mechanical, electrical, DDC controls).
4.3 Roof type and original installer if information is available.

* Note: If none or part of the above items cannot be furnished by the Government, the Contractor will provide pricing to the Government to reproduce, re-create or duplicate such information and/or provide alternate solutions.

5.0 DELIVERABLES:

5.1 Submittals per the SOW.

6.0 SCHEDULE: The performance period shall be as mutually agreed. Notice of demonstration of completed system shall be given to [point of contact] no less than one week before demonstration. Schedule impacts, for any cause, will be brought to the attention of the COR and the Contracting Officer immediately. The contractor shall provide a proposed resolution and basis for delay.

7.0 Warranty: The SDHWS contractor will warrant the system including parts and labor for one year. Warranties for system components extending beyond the warranty period shall be transferred to the Government. The warranty shall cover the following items:

7.1 SDHWS components including solar collectors, collector supports, heat exchangers, tanks, controls, remote monitoring, pumps, and piping systems. (exceptions; Damage by others, communication issues not controlled by contractor)

7.2 Roof integrity related to solar thermal installation.

**Table: 1 QC Checklist**

| Instructions: Initial each item, sign and date verifying that the requirements have been met. | | |
|---|---|---|
| # | Description | Initials |
| | | |
| 1 | All solar thermal monitoring points and all energy monitoring devices are installed. All sensors and devices are calibrated and communicating on the UMCS system and the information is shown correctly both locally and at the UMCS monitoring head end. | |
| 2 | All piping has been leak tested and passed the leak down test. | |
| 3 | All sequences are performed using the solar controller. System functions according to the sequences. | |
| 4 | All software and associated licenses have been submitted to the Government. | |
| 5 | Final As-built Drawings accurately representing the final installed system submitted and approved. | |
| 6 | O&M manuals have been submitted and approved. | |
| 7 | All warranty certificates submitted to the Government. | |
| 8 | All punch list items have been completed. | |
| 9 | Training for Government personnel complete. | |
| 10 | Final Completion notice received. | |

By signing below I verify that all requirements of the contract, including but not limited to the above, been met. Signature:_____ Date:_____

**Appendix 9.5: Contract Language**

- MTRFP Chapter 4
    - UFC 3-400-01 Energy Conservation
- MTRFP Chapter 5
    - 5.9.4. Solar Hot Water Heating. Provide at least 30% of the domestic hot water requirements through solar heating methodologies, unless the results of a Life Cycle Cost Analysis (LCCA) developed utilizing the Building Life Cycle Cost Program (BLCC) or the Life Cycle Cost in Design (LCCID) Program which demonstrates that the solar hot water system is not life cycle cost effective in comparison with other hot water heating systems. The type of system will be established during the contract or task order competition and award phase, including submission of an LCCA for government evaluation to justify non-selection of solar hot water heating. The LCCA uses a study period of 25 years and the Appendix K utility cost information. The LCCA shall include life cycle cost comparisons to a baseline system to provide domestic hot water without solar components, analyzing at least three different methodologies for providing solar hot water to compare against the baseline system.

**Appendix 10: Solar Heating for Indoor Pools**

Solar water heaters can be used to heat swimming pools and spas. In a solar pool-heating system, the existing pool filtration system pumps pool water through the solar collector, and the collected heat is transferred directly to the pool water. Solar pool-heating collectors operate just slightly warmer than the surrounding air temperature and typically use inexpensive, unglazed, low-temperature collectors made from specially formulated plastic materials. Glazed (glass-covered) solar collectors are not typically used in pool-heating applications, except for indoor pools, hot tubs, or spas in colder climates. In some cases, unglazed copper or copper-aluminum solar collectors are used. In residential applications where the goal is usually to extend the swimming season into spring and fall, heating a swimming pool with solar energy requires a solar collector that is 50% to 100% of the surface area of the pool. In general, adding more square footage lengthens the swimming season and allows owners to use the pool in colder weather. A pool cover or blanket significantly reduces heat loss in a cost-effective manner and helps maintain warm temperatures for long periods.

A solar pool-heating system costs between $2,000 and $10,000 to buy and install, depending on size. Costs run between $7 - $12 per square foot depending on system design and collection type. This provides a return on investment between 1.5 and 7 years, depending on the cost of the auxiliary energy being displaced.

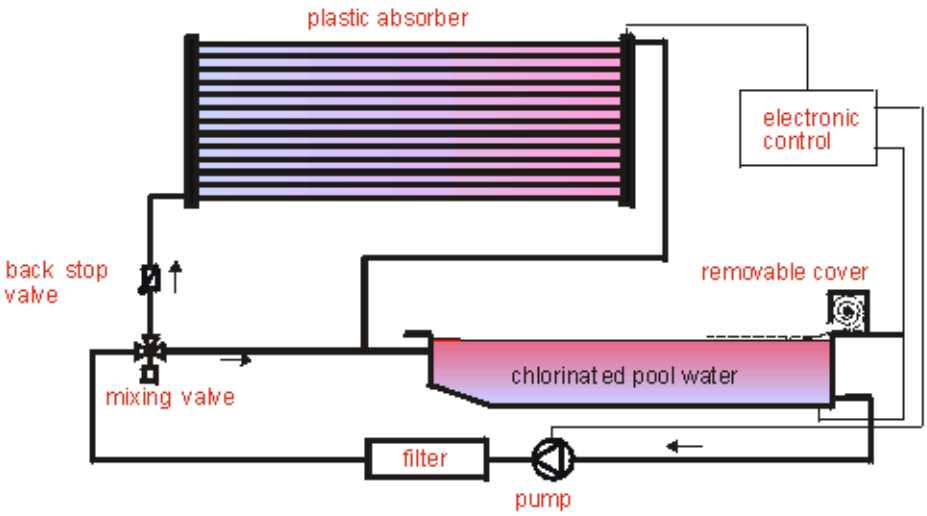
Maintenance of solar pool-heating systems is minimal. The systems are pre-engineered and can be sized for any pool by simply adding additional solar panels to obtain an adequate solar collector area.

The only moving part on a solar pool-heating system is the diverting valve. This valve controls when the water circulates through the collector loop. If the collector temperature is sufficiently higher than the temperature of the water in the pool, water is diverted from the filter systems through the collector loop. The water bypasses the solar collectors during the night or cloudy periods. Some smaller systems are operated manually or with timers. Larger systems are operated by electronic sensors and controls.

Above, 29 year old solar system for an indoor pool at Fort Huachuca.  It is the ground mounted system to the right side of the photo.

Due to their limited pressure and temperature durability, plastic absorbers are mainly used for heating pool water. In this case, the desired temperature level is only a few degrees higher than the ambient temperature. Thus, simple plastic absorbers, which can usually be mounted uncovered on a flat roof due to their low operating temperature, are sufficient. Since they consist entirely of plastic, they have the advantage of single-circuit operation. The chlorinated pool water is directly pumped through the absorbers by a circulation pump and no heat exchanger is needed.

If a filter pump already exists, it can also be used for the solar circuit. In this case, the adequate dimensioning of the pump is very important. Plastic collectors are only operated during the summer months and have to be emptied before the first frost sets in. http://energytech.at/solar/portrait_kapitel-5.html



**Appendix 11: Transpired Solar Collector (Solar Wall)**

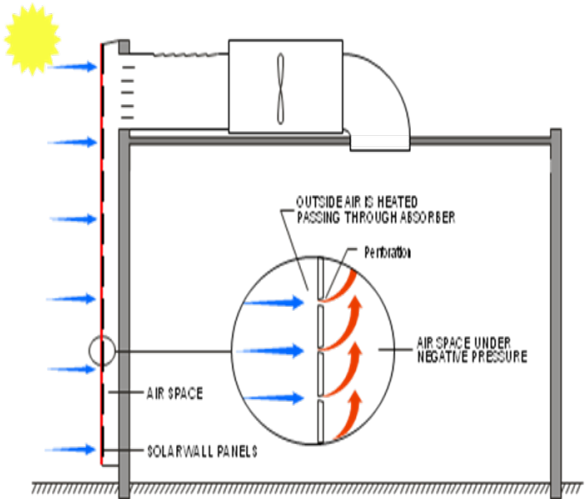
This?

- Transpired solar collectors (solar walls) preheats fresh air to building as passive solar heating.
- Solar wall replaces building cladding or other exterior finish
- Locating fresh air intake near solar wall location eliminates separate fan for solar wall
- Integrate operation of solar wall with building controls
- Solar wall cost range between $40-$50 per square foot
- Life-cycle cost effectiveness depends on many factors but will probably be a 7-8 year simple payback in new construction

In a typical application, a large portion of the building's south facing-wall is clad with dark-colored, perforated metal sheeting, which performs as a large solar collector. The sheeting is mounted to the building's structural wall, creating a 2-4" gap between the two. As outside air is drawn through the collector's perforations by ventilation fans, its temperature increase by as much as 40°F. The heated air flows to the top of the wall, where it is distributed to the building's interior through conventional ductwork.

Research at the NREL on transpired solar collectors shows that:

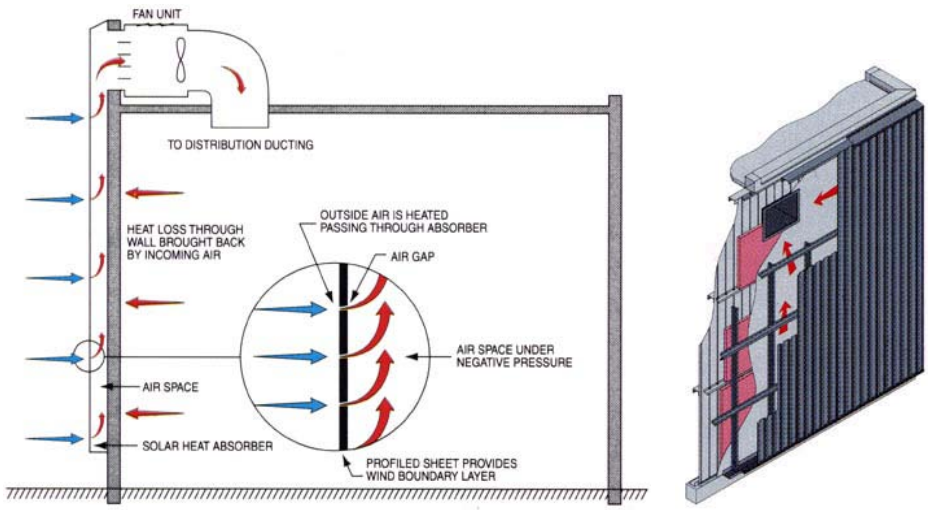
- Converts as much as 80% of available solar radiation to heat



Or This?

**Description:**

An unglazed "solar wall" preheats ventilation air by drawing make-up air through a perforated steel or aluminum plate that is warmed by solar radiation. The solar wall consists of perforated steel or aluminum cladding attached to the south façade of a building with an air gap between the existing wall and the cladding. The solar wall is dark-colored to absorb the maximum amount of solar radiation. Air is drawn through the small holes in the wall and heated at the same time. The warm air rises to the top of the wall and is drawn into the building's ventilation system as shown in the figure below.

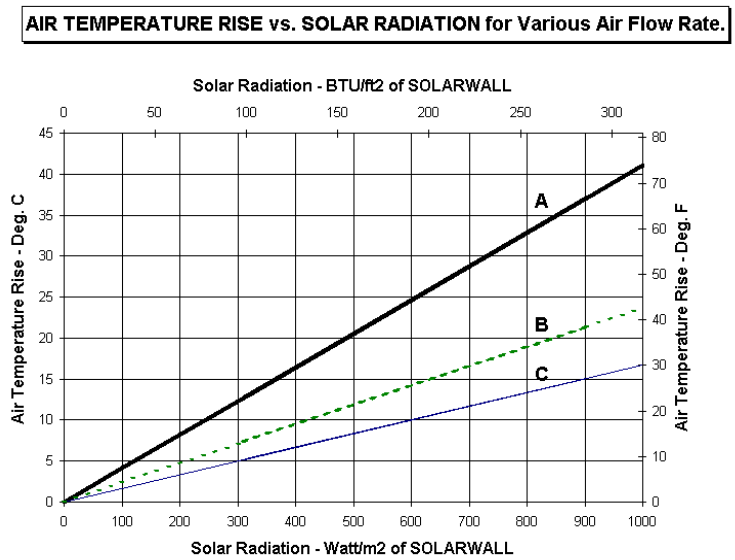



Schematic of air flows through a solar wall (a) and typical installation (b). (*www.solarwall.com*)

**Concept:**

The performance of an unglazed, perforated ('transpired') solar wall depends primarily on four parameters: the solar reflectance of the wall, the orientation of the wall, the size and spacing of the perforations in the wall and the pressure drop maintained by the ventilation system across the wall. The solar reflectance is primarily affected by the coating applied to the solar wall. In general, darker colors have a lower reflectance, and thus absorb a greater fraction of incident solar radiation. The orientation of the wall also greatly affects its performance. The intensity of the incident solar radiation is dependent on the cosine of the 'angle of incidence', the angle between the outward facing normal of the surface and the 'line of sight' to the sun. Walls that more directly face the sun will receive more solar radiation. In winter months in the northern hemisphere, south facing walls perform best. The cost effectiveness of applying solar collectors to East and West facing walls (to catch morning and afternoon sun) must be analyzed on a case by case basis.

The size and spacing of the perforations along with the pressure drop across the wall due to the operation of the ventilation system largely determines the impact of wind speed and wind direction on the solar wall performance. For a properly designed wall with small closely spaced perforations and a relatively high pressure drop, the laminar boundary layer created by suction at the wall will largely negate the effects of changing wind speed and wind direction. Below in the figure is a graph showing the temperature rise of incoming air versus solar radiation intensity for different airflow rates. It can be seen that for low ventilation airflow rates, the temperature rise can be as large as 75□F. For high airflow rates, the temperature rise can be as large as 30□F.




**Graph illustrating temperature rise vs. solar radiation intensity. A low flow rate, C high flow rate.** (www.solarwall.com)

## Potential Energy Savings (Qualitative)

Transpired solar wall technology is beneficial in applications where heating loads exist, a high ventilation flow rate is required and a large south-facing facade is available for cladding. The shortest payback is achieved by designing a system that will maintain an adequate pressure drop across the wall during all or most hours of operation. In the summer, the ventilation air is drawn directly into the HVAC system, bypassing the solar wall. The air in the cavity behind the solar wall naturally flows through holes at the top of the cladding.

## Potential Energy Savings (Qualitative)

The installed cost of a transpired solar wall system varies from \$20/ $ft^2$ for a basic industrial application (left below) to \$25/ $ft^2$ for an architecturally designed façade (right below)

a. Typical Industrial Application

b. Architecturally Designed Façade

Transpired Solar Wall Applications

**Energy Savings and Payback Calculation Assumptions**

A 50,000 sq. ft. (4645.152 $m^2$) typical metal building with 20 ft. (6.1 m) high walls are used for the study. The work zones consist of a high thermal heat gain area, a high ventilation area, a light fabrication area and a loading dock area are single story with 20 ft. (6.1 m) high walls. Typical light industrial wall and roof constructions are used in modeling the building. The walls are insulated metal construction (R-4) and the roof is a standard built up bitumen roof . The building is heated and ventilated, with no air-conditioning in the work areas. The high thermal heat gain and high ventilation area operate with 100% outside air year-round. The other areas operate with an economizer cycle with a minimum of 30% outside air.

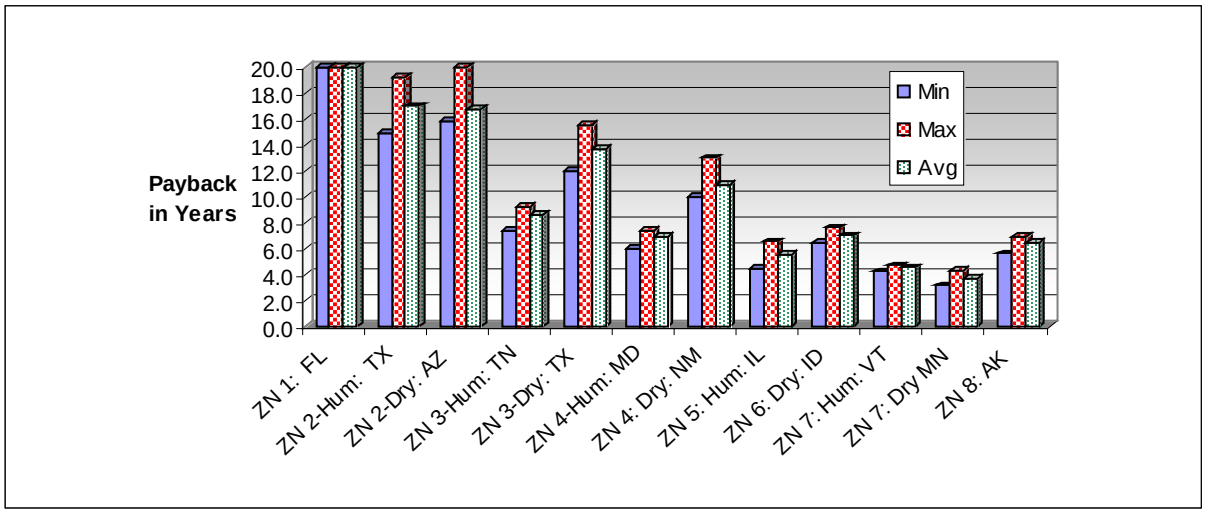
The solar wall was evaluated by direct comparison of the total building energy use reported by the base-case EnergyPlus simulation program output with the total building energy use reported by the solar wall-case simulation output. The solar wall-case results were generated by changing only those input parameters in the base case input file that were directly related to the solar wall. 1937 $ft^2$ (180 $m^2$) of solar wall was added to the south wall of the building The collector preheated outside air delivered to the light fabrication zone. The transpired collector had the following properties:

- Diameter of Perforations: 0.00525 ft (0.0016 m)
- Perforation Pitch: 0.055 ft (0.01689 m)
- Perforation Pattern: Triangle
- Thermal Emissivity: 0.9
- Solar Emissivity: 0.9
- Thickness of Plenum: 0.328 ft (0.1 m)
- Collector Thickness: 0.00282 ft (0.00086 m)

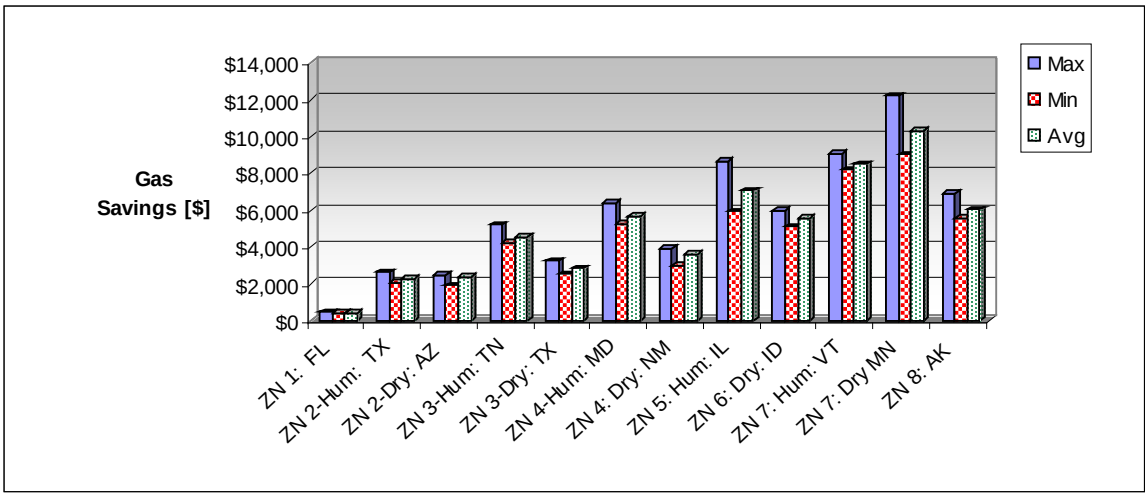
A cost of $20/sq. ft. which is a typical new construction cost for industrial buildings was assumed.

## Energy Savings and Payback Calculation Results

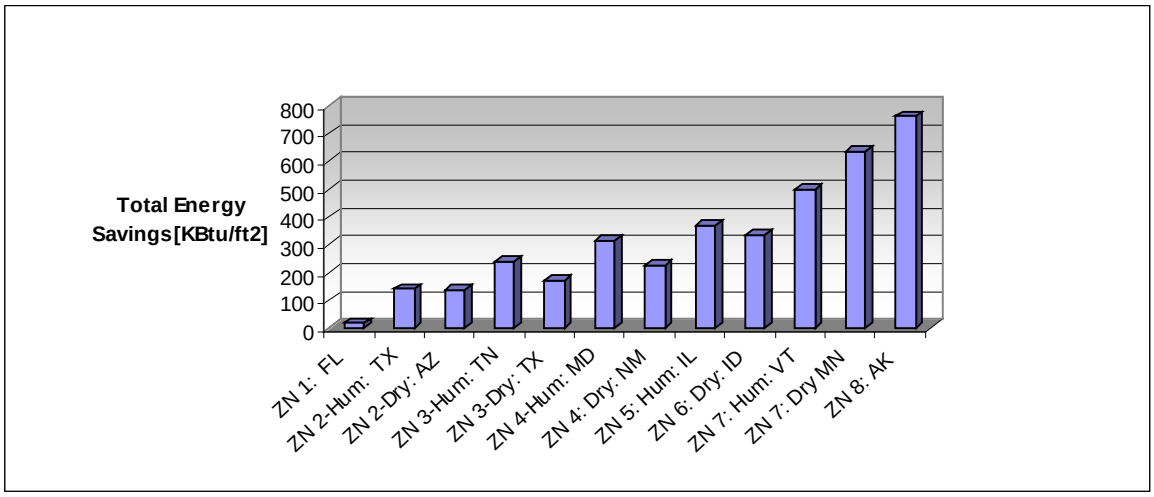
The results show that savings were significant in every climate that required heating. For the industrial building with high ventilation flow rates, the average payback was under six years for all heating dominated climates.




Transpired Solar Wall Estimated Payback Shown for High, Medium and Low Energy Rates




Transpired Solar Wall Estimated Gas Savings Shown for High, Medium and Low Energy Rates




Transpired Solar Wall Total Annual Energy Savings per Square Foot of Collector Area

**Level of Maturity:** The technology was first proposed in the early 1990's and is supported by research results from the National Renewable Energy Laboratory and field experience.

**Impact on Indoor Air Quality:** None.

**Climatic Conditions Necessary:** The technology works equally well in any climate, however it is a heating technology which will find its major application in cold and temperate climates. The typical number of clear days in a climatic region should also be considered in the application of the technology.

## Appendix 11.1: Scope of Work for Solar Wall Installation

Optional text is indicated by brackets [ ]; delete optional text in final copy of specification. Specifier Notes typically precede specification text; delete notes in final copy of specification. Trade/brand names with appropriate symbols typically are used in Specifier Notes; symbols are not used in specification text. Metric conversion, where used, is soft metric conversion.

**APPLICABLE UNDER SECTIONS:**
**23 56 00 SOLAR ENERGY HEATING EQUIPMENT**
**23 56 13 SOLAR HEATING COLLECTORS**
**07 42 13 METAL WALL PANELS**

### PART 1 GENERAL

1.01 SUMMARY

A. Section Includes: Perforated metal wall system or perforated modular rooftop system that uses solar energy as fuel to heat or ventilate indoor spaces.

Specifier Note: Revise paragraph below to suit project requirements.

B. Related Sections:

1. Sealants: Division 07 sealant sections.
2. Connections to Ventilation Fans: Division 23 HVAC sections.

Specifier Note: Article below may be omitted when specifying manufacturer's proprietary products and recommended installation. Retain Reference Article when specifying products and installation by an industry reference standard. If retained, list standard(s) referenced in this section. Indicate issuing authority name, acronym, standard designation and title. Establish policy for indicating edition date of standard referenced. Conditions of the Contract or Section 01 42 19 - Reference Standards may establish the edition date of standards. This article does not require compliance with the standard, but is merely a listing of references used. Article below should list only those industry standards referenced in this section.

1.02 REFERENCES

A. ASTM International (ASTM):

1. ASTM A653 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
2. ASTM A755 Standard Specification for Steel Sheet, Metallic Coated by the Hot-Dip Process and Prepainted by the Coil-Coating Process for Exterior Exposed Building Products.
3. ASTM B209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.

B. American Architectural Manufacturers Association (AAMA):

1. AAMA 2605 Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels.

## 1.03 SYSTEM DESCRIPTION

A. Performance Requirements:

Specifier Note: Insert cfm requirement below. (Typical range 2 - 8 cfm/ft$^2$. See 10-Part Specifications document for application.)

1. Air Intake: Provide a solar panel system that will provide for heating [_____] cubic feet per minute of fresh air per square foot of panel, or, provide a solar air heating system designed to handle a total of [_____] cubic feet per minute of fresh air.

Specifier Note: If loads are not indicated on the drawings, insert below.

2. Structural: Provide a panel system that will safely withstand dead and live loads [Indicated on the drawings] [ ].
3. Expansion and Contraction: Provide a panel system that will accommodate expansion and contraction due to solar heat gain and ambient temperatures without damaging panel system performance.

Specifier Note: Insert temperature values below.

a. Design Ambient Temperature Range: Minus [ ] to plus [ ] degrees F or C.

Specifier Note: Article below includes submittal of relevant data to be furnished by the Contractor, either before, during or after construction. Coordinate this article with Architect's and Contractor's duties and responsibilities in Conditions of the Contract and Section [01 33 00 - Submittals Procedures] [_____].

## 1.04 SUBMITTALS

A. General: Submit listed submittals in accordance with Conditions of the Contract and Section [01 33 00 - Submittal Procedures] [_____].

B. Product Data: Submit product data, including manufacturer's Specifications sheet, for specified products.

C. Shop Drawings: Submit installation drawings that show the arrangement and orientation of panels. Include details of stand-off components, panel joints, flashing and trim for closures.

D. Samples:

1. Submit color chart of manufacturer's full range of standard colors for specified finish.
2. Submit color chip of color to be selected.

E. Test Reports: Submit certified performance results from an independent and accredited laboratory testing facility, such as the National Solar Test Facility, that is capable of testing an unglazed solar air collector.

Specifier Note: Article below should include prerequisites, standards, limitations and criteria that establish an overall level of quality for products and workmanship for this section. Coordinate article below with Division 01 Quality Assurance Section.

1.05 QUALITY ASSURANCE

Specifier Note: Paragraph below should list obligations for compliance with specific code requirements particular to this section. General statements to comply with a particular code are typically addressed in Conditions of the Contract and Section 01 41 00 - Regulatory Requirements. Repetitive statements should be avoided.

A. Regulatory Requirements: In accordance with Section [01 41 00 - Regulatory Requirements] [_____].

B. Manufacturer Qualifications: Minimum of 10 years experience in the design and manufacture of solar air heating systems and whose solar panels have been independently tested by a laboratory accredited by [SRCC (for USA installations)]; [CSA (for Canadian installations)].

Specifier Note: Article below should include special and unique requirements. Coordinate article below with Division 01 Product Requirements Section.

1.06 DELIVERY, STORAGE & HANDLING

A. General: Comply with Division 01 Product Requirements Section.

B. Delivery: Deliver materials in manufacturer’s original, unopened, undamaged containers with identification labels intact.

C. Storage and Protection: Store materials protected from exposure to harmful environmental conditions.

Specifier Note: Coordinate article below with Conditions of the Contract and with Section 01 78 36 - Warranties.

1.07 WARRANTY

A. Project Warranty: Refer to Conditions of the Contract for project warranty provisions.

B. Manufacturer’s Warranty: Submit in accordance with Section [01 78 36 - Warranties] [_____] for Owner’s acceptance manufacturer’s standard warranty document executed by authorized company official. Manufacturer’s warranty is in addition to, and not a limitation of, other rights Owner may have under Contract Documents.

1. Warranty Period:

a. System: 12 months from the date of installation.

b. Panel: 12 months from the date of installation.

c. Paint: 40 years for silicon modified polyester. 20 years performance specification for fluoropolymer finish against peeling, chipping and fading.

## PART 2 PRODUCTS

Specifier Note: Retain article below for proprietary method specification. Add product attributes, performance characteristics, material standards and descriptions as applicable. Use of such phrases as “or equal” or “or approved equal” or similar phrases may cause ambiguity in specifications. Such phrases require verification (procedural, legal, and regulatory) and assignment of responsibility for determining “or equal” products.

2.01 SOLAR ENERGY HEATING EQUIPMENT; SOLAR HEATING COLLECTORS; METAL ROOF & WALL PANELS

Specifier Note: Retain or delete paragraph below per project requirements and specifier’s practice.

A. Manufacturer:

1.

B. SolarWall® System:

Specifier Note: Select type, metal and color below.

1. Type: [SW150] [SW250].
2. Metal: [Galvanized steel, 26 gauge, ASTM A653 and ASTM A775]; [Galvanized steel, 24 gauge, ASTM A653 and A775]
3. Configuration: 1 1/4 inch (32 mm) ribs with 35.44 inch (900 mm) coverage.
4. Finish: [Silicon modified polyester (SMP**)** with inorganic and ceramic pigmentation]. [Polyvinylidene with 70% Kynar 500 or Hylar 5000 **(**fluoropolymer) resins].
   a. Color: [Antique Linen] [Black] [Bone White] [Bright Red] [Cambridge White] [Charcoal] [Dark Brown] [Dark Green] [Deep Water Green] [Gold] [Green] [Heron Blue] [Ivory] [Metro Brown] [Navy Blue] [Pacific Turquoise] [Regent Grey] [Royale Blue [Slate Blue] [Stone Grey] [Tan] [Tile Red] [White White].

2.02 ACCESSORIES

A. Stand-Off Components: Provide galvanized steel components to support the panels in a manner as recommended by the manufacturer.

B. Flashing: Provide flashing materials to match the metal and finish of the panels.

C. Fasteners: Provide corrosion resistant self-drilling screws and rivets as recommended by the manufacturer. Exposed fasteners must be finished to match the panels.

2.03 FABRICATION

A. Factory Finishing:

1. Silicon modified polyester (SMP**)** with inorganic and ceramic pigmentation.

2.04 PRODUCT SUBSTITUTIONS

A. Substitutions: [Substitutions in accordance with Section [01 25 13 - Product Substitution Procedures] [No substitutions permitted] [_____].

**PART 3 EXECUTION**

Specifier Note: Retain or delete paragraph below per project requirements and specifier's practice.

3.01 MANUFACTURER'S INSTRUCTIONS

A. Compliance: Comply with manufacturer's product data, including product technical bulletins, product catalog installation drawings and instructions.

B. Coordinate with mechanical to ensure SolarWall system is connected to fan inlet and ventilation system.

3.02 EXAMINATION

A. Site Verification of Conditions: Verify that substrate conditions [For substrates that have been previously installed under other sections] are acceptable for product installation in accordance with manufacturer's instructions.

3.03 PREPARATION

A. Prepare surfaces using the methods recommended by the manufacturer for achieving the best result for the substrate under the project conditions.

**END OF SECTION**

## Appendix 12: Photovoltaic (PV)

### Appendix 12.1: PV Overview

1. **Points of Contact**
    a. Jennifer McKenzie, Fort Bragg Energy Manager, 910-396-6371, Jennifer.McKenzie@us.army.mil.
    b. Jim Peedin, Subject Matter Expert (SME), 910-396-5970 office, james.f.peedin@us.army.mil

2. **Solar PV (photovoltaic) Description**
    a. Ft. Bragg Solar PV (photovoltaic) installations are utility connected systems using fixed DC solar collectors, an inverter, and utility (revenue) grade metering.
    b. Below is a brief overview of the major parts of the Solar PV system. A more detailed description can be found in **Appendix C**, page 10.
        i. Collectors
        ii. Collector mounts
        iii. DC disconnect/combiner box
        iv. Inverter/control panel
        v. Metering and Remote monitoring
    c. The solar PV system generates electricity for use within each facility or for direct injection into the utility grid.

3. **Guidance and References**
    a. North American Board of Certified Energy Practitioners (NABCEP). NABCEP provides certification programs for solar electric and PV system installers. A NABCEP-certified installer provides for an extra level of assurance as to the qualifications of the installer. However, because the solar PV certification is a relatively recent development, NABCEP-certified installers are not especially common. Certified installers can be found on the website, http://www.nabcep.org/installer-locator-agreement
    b. Florida Solar Energy Center (FSEC). Mandated by the state of Florida to perform testing of solar energy products, FSEC is a good source for performance characteristics on both solar PV collectors and entire solar PV systems. Although specifically geared towards the solar industry in Florida, the FSEC is a good resource for the Southeast region as a whole. This is a well-established organization that has been producing literature for these systems for several years. FSEC Standard 101-09, which was revised May 2009, is the institute's solar collector certification. It supersedes FSEC Standard 102-05. Website: http://www.fsec.ucf.edu/en/industry/testing/index.htm
    c. California Energy Commission (CEC), Senate Bill 1. This is the principle solar PV guideline for the state of California solar energy incentive program. The Senate Bill 1's charter is to ensure high quality systems are consistently installed in order to qualify for incentives. Systems and

products approved under this guideline are of uniformly high quality and reliability. Website: http://www.energy.ca.gov/2008publications/CEC-300-2008-007/CEC-300-2008-007-CMF.PDF. A listing of CEC approved solar PV system products is available at: http://www.gosolarcalifornia.org/equipment/index.html

4. **Contract Language**

***Please reference the appropriate Appendix for specific contract language***

a. Solar PV Specification **Appendix F,** page 19.
b. MCA Projects
    i. MT RFP Chapter 5
        1. 5.9.4. Solar PV electrical requirements through solar heating methodologies, unless the results of a Life Cycle Cost Analysis (LCCA) developed utilizing the Building Life Cycle Cost Program (BLCC) or the Life Cycle Cost in Design (LCCID) Program which demonstrates that the solar hot water system is not life cycle cost effective in comparison with other hot water heating systems. The type of system will be established during the contract or task order competition and award phase, including
        submission of an LCCA for government evaluation to justify non-selection of solar hot water heating. The LCCA uses a study period of 25 years and the Appendix K utility cost information. The LCCA shall include life cycle cost comparisons to a baseline system to provide domestic hot water without solar components, analyzing at least three different methodologies for providing solar hot water to compare against the baseline system.
    ii. MT RFP Chapter 6 **Appendix G**, page 43: Provides guidance for Fort Bragg.
c. SRM Projects
    i. New construction and/or renovation/retrofit projects that will include major HVAC changes/upgrades should use the Solar PV specifications located in the Installation Design Guide (IDG) located in Appendix G, page 43 .
d. Solar PV Installation Scope of Work: **Appendix D** , page 15

5. **Warranty Process**
    a. Following final acceptance of the installation, Government will take responsibility for operation and maintenance of the new system. Should a warranty claim arise, Government agrees to troubleshoot the system to identify the failure, if the failure is deemed to be a warranty issue, a warranty Service Order will be created for the installation vendor to respond.

6. **Subject Matter Expert (SME) Assistance**
    a. The SME will help your team make Solar PV systems a successful alternative energy solution at Fort Bragg. To make this happen the SME should be involved in the total process of these projects.
    b. Provide information for existing buildings and like facilities for buildings equipped with Solar PV.
    c. DD1391 development to include solar technologies
    d. RFP and Design review; The SME should be added to your email list for distribution of review material and meeting schedules.
        i. The SME will make comments directly into Dr. Checks.
        ii. The project timeline is a concern to the SME as it is to the Project Managers. All reviews and comments will be made in a timely matter.
    e. During construction, the SME is available to provide assistance with any questions, issues, or concerns including submittal review.
    f. The SME should be invited to any Pre-Final inspection meetings
    g. Commissioning, the SME should be involved with the Performance Verification Test to track and record any problems found during the test.
    h. Submittal / Turnover procedure
        i. The SME shall receive, at a minimum, 1 copy of the submittal documentation. The information should include the items listed in the SOW located in **Appendix D,** page 15**.**
        ii. The SME should be invited to turnover meetings
        iii. The SME can assist in tracking warranty dates for the solar PV system
        iv. SME will ensure Operations and Maintenance Department (OMD) receives information needed to service the solar PV system

## Appendix 12.2: Solar PV Guidelines

### 1 General:

- Fixed solar array.
- Flat plate or thin film collectors, See guide specification for more detail.
- High efficiency inverters.
- Utility (revenue) grade metering.

### 1.2 Application:

The solar Photovoltaic system is intended for production of electricity. The electrical energy produced by the PV system may be consumed by the building or structure it is mounted on, or if the system produces more power than is needed, the excess power may be injected back into the electrical grid.

Buildings or structures considered for Solar PV should have large un-shaded, south-facing (or nearly south-facing) surface on or near the building. Buildings with large flat, light colored (reflective) roofs, that are newer than 10 years old offer the best application. In addition, the ideal building candidate should have high electrical loads during the daytime:

- Highly-occupied buildings, such as
  - Hospitals
  - Schools
  - Child Development Centers (CDC) , Youth Centers
  - Company Operation Facility (COF)
  - Fire and police stations
  - Administration
  - Clinics, including for animals
  - PX, BX
  - AAFES
  - Some MWR facilities (bowling alley, etc.)
  - Fitness centers
  - Dining facilities and clubs
  - Laundry facilities
  - Central heating plants
  - Pumping stations
  - Hotels

### 1.3 Integration with existing electrical distribution system:

The Solar PV system generates electrical power which will be injected into an existing building distribution system at the panelboard level or at the building electrical service. In general, the solar arrays will be roof mounted with the inverter located on the ground or ideally on the roof in close proximity to the solar array. The inverters can be very large and heavy, so ground mount installations will likely be the most practical. Power output at the inverter shall be metered with a utility (revenue) grade meter to monitor power production and to diagnose trouble with the system.

**1.4 Sizing criteria:**

- Goal: Solar PV system to provide a minimum of 3% of building electrical load. Where the opportunity exists, systems larger than 30KW offer the best $/KW value.

**1.5 Remote Monitoring/controls:**

- All new Solar PV systems shall be remotely monitored by the base Utility Monitoring & Control System (UMCS). The intent of monitoring the SOLAR PV is to collect operational data to track the energy contributed by the Solar PV system, and to monitor the health of the system. Using the UMCS for monitoring the Solar PV system allows Ft Bragg to:
    - Increase consistency across many different installations.
    - Provide a robust centrally managed vehicle to collect trend data, monitor alarms, and dispatch service personnel.
    - Maximize effectiveness of service personnel by using familiar hardware and software.

With this goal, each new Solar PV installation shall be provided with the following minimum monitored points. See Appendix X for Point Schedules:

Solar PV operation:

- Solar array string DC Volts at input to inverter (provide for each string if a combiner box is not provided. Provide for output of each combiner box if a combiner box is used.)
- Solar array string DC AMPS at input to inverter (provide for each string if a combiner box is not provided. Provide for output of each combiner box if a combiner box is used.)
- Inverter AC Volts at output (each phase)
- Inverter AC Amps at output (each phase)
- Inverter AC frequency
- PV array temperature
- Inverter enable/disable
- Solar irradiance

The solar controller provided with the system shall be Lonworks compatible either directly or via an approved Lonworks gateway. The solar inverter shall have a local display panel (LDP) capable of showing the status of the inverter as well as the input and output voltages and currents by phase. Provide each point as outlined by **Appendix XXX** (not yet defined) Point Schedules.

Solar PV Systems shall be graphically represented at the UMCS. All integration shall be performed by Fort Bragg's System Integration Contractor as per the Fort Bragg

Integration SOW. Contact UMCS Manager for details. Coby Jones, joseph.c.jones4@us.army.mil 910-396-1868.

**1.6 Energy monitoring:**
The intent of the energy metering is to document the amount of energy captured from the solar system. For systems installed on buildings where the solar energy production exceeds consumption, the net energy delivered back into the grid is metered for utility credit. All meters shall be monitored by the UMCS.

**1.7 Trend data:**
Standard trend data collection:

- Days: 7 days per week, 365 days per year.
- Totalize KWH per day, month, year at the output of the inverter.

**1.8 Roofing:**
- The solar collector panels may be mounted to a frame which is in turn mounted to the building structure (roof or walls). Where the collector array is mounted to the roof, the intent is to minimize the number of roof penetrations. Roof penetrations may be required for the frame supports and conduit.
- Wherever possible the roofing company that installed the roof should be engaged to perform this work to preserve any remaining roof warranty. The Government shall furnish the contact information for the original roofer to the contractor.

**1.9 Solar array roof orientation:**
- Fixed solar array.
- Solar array ideally tilted at 36 degrees from horizontal (tilt angle acceptable range is 0 to 51 degrees) for c-Si applications. Solar collector design varies significantly, some products do not yield a significant increase in power production when tilted at the ideal angle.
- Solar array aligned with due south +/- 10 degrees. Solar array/panel designs vary significantly, some products do not yield a significant change in power production when aligned with due south.
- Locate to prevent or minimize shading. Use the Solar Pathfinder or Sun Eye tool to select optimum location for the solar array. Submit Solar shading report with design submittal.
- Ensure location of rack will not block, or otherwise interfere with any existing roof elements including, but not limited to, roof drains, maintenance access to roof mounted equipment, HVAC intake and exhaust flows, plumbing vents, flues, or chimneys, antennas, fire fighter access, etc.
- Array shall be located and positioned to enable cooling airflow to all sides of the collector.

**1.10 Solar panel array rack frame:**

- Where a solar array rack is required to mount the solar panels, rack shall be constructed of a non-corrosive metal. Aluminum is preferred. Connections may be shop welded or bolted. If bolts are used, they shall be stainless steel.
- Design for the rack and collector assembly shall be stamped by a registered professional engineer in the state of North Carolina. Where the mounting methodology is integrated with the solar panel, the engineer shall review the proposed product and issue a letter to the Contracting Officer or COR for the record stating the panel may be installed according to manufacturer's instructions without violating good engineering practice and all applicable codes.
- Rack design shall account for all applicable static, wind, snow, and seismic loads.

**1.14 Sequence of Operation**

Proposed solar PV sequences of operation:

- **System run command:**
  Solar PV system is normally enabled to run 24x7x365. Where the solar PV system is disabled remotely, the start command will enable the system remotely.
- **System stop command (emergency/maintenance)**
  Solar PV system may be remotely commanded to shutdown.
- **System stop command (anti-island protection):**
  If solar PV system is generating power and utility voltage is lost, inverter shall shut down. Upon restoration of utility voltage to the inverter, inverter shall restart automatically. Note this function is typically included in the standard sequences of the inverter logic.

## Appendix 12.3: Fort Bragg Specification Overview for PV

**Part 1**

**1.1 References**-CEC, FSEC, IEEE, IEC, NEC, UL, NABCEP

**1.2 Related Requirements** –list of other specification sections that may have content related to the installation of solar PV systems. Division 01 – General requirements, Division 05 – Metals, Division 07-PV and Moisture protection, Division 09-Finishes, Division 13-Special Construction (Seismic), Division 23 – HVAC (DDC systems), Division 26 - Electrical

**1.3 Submittals**-Shop Drawings, Product Data, Test Reports, Certificates, Manufacturer's instructions, O&M manuals, Closeout Submittals.

**1.4 Quality Assurance** – Install system in conformance with IEEE, and manufacturer's recommendations. Provide troubleshooting guide and maintenance schedule.

**1.5 Solar Collector Warranty** – One year parts and labor. After warranty period expires, all remaining warranties transfer to the Government. Minimum 5 year parts warranty on solar collectors.

**1.6 Posted Operating Instructions-**Provide with closeout submittals.

**Part 2**

**2.1 Solar Energy Systems** - Provide necessary materials to fabricate solar energy systems in accordance with this section. At the Contractor's option, provide factory-prefabricated solar equipment packages which include heat exchanger, compression and storage tanks, pumps and controls and which meet the requirements of this section. In general, the system shall have the following attributes:

- Fixed solar array.
- C-Si or GICS solar collectors
- Inverter with isolation transformer and anti-islanding protection
- Revenue grade meter on inverter output.

**2.2 Solar Collectors** – IEC 61215, IEC 61730, IEC 61646 and UL 1703 listed; Monocrystalline, and polycrystalline (IEC 61215, IEC 61730) or Copper Indium Gallium Diselenide (CIGS) (IEC 61730, IEC 61646) photovoltaic solar collectors. Collectors shall be certified by the FSEC and/or the CEC.

C-Si or CIGS

**2.2.1 Collector Performance Data** - Minimum of 8 peak rated watts (At STC) per square foot of gross collector area.

**2.2.2 Minimum Performance Parameters** –

Provide collector efficiency as follows:
Minimum measured at standard collector efficiency test conditions (STC) irradiance of 1000 W/m$^2$, air mass 1.5, and cell temperature of 25C.

Monocrystalline: Minimum efficiency, 17%
Polycrystalline: Minimum efficiency, 13%
CIGS: Minimum efficiency, 10%

For mono or polycrystalline solar panels:
1/8 in. tempered glass front, junction box with bypass diodes, non-corrosive metal or fiber reinforced frame, designed for snow and hail loads.
For CIGS panels:
Glass hermetically sealed enclosure, junction box with bypass diodes as necessary, non-corrosive metal or fiber reinforced frame, designed for snow and hail loads.

**2.2.3 Solar Collector Mounting Structure** - design stamped by a professional engineer. Fabricate from metal, aluminum preferred. Shop welded or bolted connections. Roof penetrations to be performed by original roofer where possible.

**2.2.4 DC Disconnect and Combiner Box**- NEMA 3R enclosure with DC string fusing and disconnects.

**2.2.5 Solar Power Inverter** – UL 1741, minimum CEC weighted efficiency of 93%, NEMA 3R enclosure.

**2.3 Monitoring System**-the following points are recommended as the minimum:

- Solar array string DC Volts at input to inverter (provide for each string if a combiner box is not provided. Provide for output of combiner box if a combiner box is used.)
- Solar array string DC AMPS at input to inverter (provide for each string if a combiner box is not provided. Provide for output of each combiner box if a combiner box is used.)
- Inverter AC Volts at output (each phase)
- Inverter AC Amps at output (each phase)
- Inverter AC frequency
- PV array temperature
- Inverter enable/disable
- Solar irradiance

The solar controller provided with the system shall be Lonworks compatible either directly or via an approved Lonworks gateway. If the points described cannot be delivered within the functionality of the inverter, provide a separate control interface as required.

**<u>Part 3</u>**
**3.1 Installation**-Install per approved submittals and in accordance with manufacturer's instructions. Use NABCEP certified installers. If NABCEP certified installers are not

available, installers shall have a minimum of 2 years experience installing solar PV systems. Provide references on at least 5 similar installations within the last 2 years of similar size and scope. Protect collectors from sunlight until system is ready for operation.

**3.2 Field quality control** - Provide training to at least four Government personnel. Training shall use approved closeout submittals as the basis for the training.

**Appendix 12.4: PV Installation SOW**

1.0 SYNOPSIS: The Contractor shall provide the materials and labor required to design and install a Solar Photovoltaic System (SOLAR PV) in the Fort Bragg building identified below.

2.0 PRICE PROPOSAL: The Contractor shall provide a firm fixed price proposal for installation of a SOLAR PV specified below for the building identified.

3.0 SPECIFIC WORK TO BE ACCOMPLISHED: The Contractor shall provide materials and labor required to design, and install a new SOLAR PV specified below for the building specified. All work shall be in accordance with the Fort Bragg Installation Design Guide, Fort Bragg Installation Design Guide (IDG) **http://www.bragg.army.mil/dpw/idg/index.htm,** Unified Facilities Guide Specification (UFGS) 48 14 13 "Solar Energy Collectors" http://wbdg.org/ and this Statement of Work (SOW).

3.1 The contractor shall provide SOLAR PV for the following building(s):

3.1.1 Buildings **< Number>**

3.2 For each system the contractor shall perform all tasks required to fully integrate the Solar PV system into the building electrical distribution system or grid, including but not limited to:

3.2.1 Pre-Design

3.2.1.1 System sizing – Use F-chart or NREL tool to select solar PV system size that best fits the application.

3.2.1.2 Array optimal location – Use the Solar Pathfinder or Sun Eye tool to select best array location. Submit photos and report with design.

3.2.2 Design

3.2.2.1 Collector array configuration and rack/support design.

3.2.2.2 Structural analysis of collector frame (static load, seismic, wind, and snow loading).

3.2.2.3 Roof penetration design.

3.2.2.4 Electrical room / roof / site equipment layout.

3.2.2.9 Controls/instrumentation/sequence of operation.

3.2.2.10 Electrical Power One line/riser diagram.

3.2.3 Submittals

3.2.3.1 Product data (FSEC or CEC certified solar equipment).

3.2.3.2 Shop drawings (wiring diagram, electrical plans, structural plans, roof support and penetration details, sequence of operation.).

3.2.3.3 Engineering calculations (stamped structural calcs, stamped electrical design).

3.2.3.4 Training.

3.2.3.5 O&M manual.
3.2.3.6 As-builts.

3.2.4 Installation
3.2.4.1 NABCEP certified installers.

3.2.5 Contractors Field Test (CFT)
3.2.5.1 QC checklist completed.

3.2.6 Performance Verification Test (PVT)
3.2.6.1 QC checklist completed.
3.2.6.2 Punch list signed off.
3.2.6.3 Operational test-trend system operation for a week then analyze results, manually demonstrate sequences for Government.

3.2.7 Training
3.2.7.1 Four hour training for system installation for a group of 4 people.
3.2.7.2 Use approved as-builts and O&M manuals for the training program.

3.2.8 Warranty
3.2.8.1 One year parts and labor. The warranty period starts upon Final Acceptance.

3.3 Contractor shall demonstrate completed installation to the Government during the PVT. This demonstration shall show all work performed and shall be sufficient to familiarize the Government with the installed system.

3.4 Prior to contract award, contractor must meet the following requirements:
3.4.1 The solar contractor shall be NABCEP certified.
3.4.2 The solar contractor shall have successfully completed at least five similar systems within the last 2 years.

4.0 GOVERNMENT FURNISHED INFORMATION:

4.1 Building type and occupancy.
4.2 Building drawings * to the extent available (architectural, structural, electrical, DDC controls).
4.3 Roof type and original installer if information is available.

* Note: If none or part of the above items cannot be furnished by the Government, the Contractor will provide pricing to the Government to reproduce, re-create or duplicate such information and/or provide alternate solutions.

5.0 DELIVERABLES:

5.1 Submittals per the SOW.

6.0 SCHEDULE: The performance period shall be as mutually agreed. Notice of demonstration of completed system shall be given to [point of contact] no less than one week before demonstration. Schedule impacts, for any cause, will be brought to the attention of the COR and the Contracting Officer immediately. The contractor shall provide a proposed resolution and basis for delay.

7.0 Warranty: The Solar PV contractor will warrant the system including parts and labor for one year. Warranties for system components extending beyond the warranty period shall be transferred to the Government. The warranty shall cover the following items:

- 7.1 Solar PV components including solar collectors, combiner boxes, inverters, instrumentation and metering systems. (exceptions; Damage by others, communication issues not controlled by contractor)
- 7.2 Roof integrity related to solar PV installation.

**Table 1: QC Checklist**

| Instructions: Initial each item, sign and date verifying that the requirements have been met. | | |
|---|---|---|
| # | Description | Initials |
| | | |
| 1 | All solar PV monitoring points and all energy monitoring devices are installed. All sensors and devices are calibrated and communicating on the UMCS system and the information is shown correctly both locally and at the UMCS monitoring head end. | |
| 2 | All electrical connections are complete and checked for correct torque. | |
| 3 | All sequences are performed using the solar controller. System functions according to the sequences. | |
| 4 | All software and associated licenses have been submitted to the Government. | |
| 5 | Final As-built Drawings accurately representing the final installed system submitted and approved. | |
| 6 | O&M manuals have been submitted and approved. | |
| 7 | All warranty certificates submitted to the Government. | |
| 8 | All punch list items have been completed. | |
| 9 | Training for Government personnel complete. | |
| 10 | Final Completion notice received. | |

By signing below I verify that all requirements of the contract, including but not limited to the above, been met. Signature:_____ Date:_____

## Appendix 13: Requirements for Thermal Comfort and Ventilation Rates

The simplest, most cost-effective, and easiest way to save energy in a building is to turn off all the lights, all the heating and cooling systems, and unplug all the appliance and equipment. This building would use no energy whatsoever, but it would be uncomfortably cold and hot, inadequately ventilated, dimly lit by whatever light comes in the windows, and a very unpleasant place to work. Freezing in the dark is not the object of energy conservation.

The object of energy conservation is to use the minimal amount of energy necessary to perform the required work in a building in a safe and efficient manner. The amount of energy a building uses depends upon its size (small Vs. large), the location (hot climate like Miami, FL; moderate climate like Washington, DC; or cold climate like Anchorage AK), and the type of building (barrack, office, warehouse, laboratory). For any given building, factors like ventilation rates, thermostat set points, and lighting levels have a significant impact on the energy consumption. All other things being equal, a building with higher ventilation rates will usually use more energy than a building with lower ventilation rates. A building with lower light levels will use less energy than a building with higher light levels. And a building with higher heating set points and lower cooling set points will use more energy than a building with lower heating set points and higher cooling set points.

It is important that engineers and O&M personnel design for and use appropriate rates and set points to maintain occupant comfort, health, and productivity AND minimize energy usage. Setting these rates and set points can be as much an art as a science, but there are a number of standard references that are used to help in the operation of the building. The following references provide guidance on the suggested values.

**Appendix 13.1: Thermal Comfort Requirements**

Thermal requirements include criteria for thermal comfort and health, process needs, and criteria preventing mold mildew and other damage to the building materials or furnishings.

**13.1.1**. Thermal comfort and health criteria primarily involve the temperature and humidity conditions in the building. Too high a temperature means that occupants are uncomfortably hot. Too low a temperature means that occupants are uncomfortably cold. The wrong humidity means that occupants feel damp or sweaty or too dry. Thermal comfort is defined by ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy. The latest version of Standard 55 was published in 2004 and is available from ASHRAE.

The following Dry Bulb room air temperatures are within the ASHRAE Standard 55 range and shall not be exceeded [IDG Benelux]:

***Cooling Period:*** The DBT in occupied spaces shall not be set below 70oF (21oC) with the RH maintained below 50%. When the space is unoccupied during the short period of time, room thermostat shall be reset to 85oF (29oC) with the relative humidity maintained below 50%. In space unoccupied for an extended period of time, temperature shall not be controlled but the building air RH shall be maintained below 50%.

***Heating period:*** Relative humidity of ALL building air shall be maintained below 50% and above 30% at all times (unless required differently for health reasons at the hospitals, day care facilities or by processes). The DBT in occupied spaces shall not exceed the following:

(1) Barracks and other living quarters: 70oF (21oC) Monday through Friday from 0500-2200 and 65ºF (18oC) from 2200-0500. Temperature settings for barracks Saturday and Sunday 70º (21oC) from 0600-2200 and 65ºF (18oC) from 2200-0600.

(2)Offices, warehouses, etc. where personnel work seated or in standing position involving little or no exercise: 70oF (21oC) during working hours and not more than 55oF (12.80C) during non-working hours.

(3) Child Care facilities: 72oF (22.2oC) during working hours.

(4) Issue and similar rooms: 60 oF/15.5oC.

(5) Special process rooms, such as paint shops and drying rooms: 80oF (26.6oC) allowed, or the one required by the process.

(6) Shops, hangars and other buildings where employees work in a standing position or exercise moderately, such as sorting, or light packing or crating: 60 oF/15.5oC during the day; 40oF (4.4oC) during night time.

(7)Shops, warehouses and the like, where employees do work involving considerable

exercise, such as foundries, heavy packing, crating, and stacking, or where heat is required to protect material or installed equipment from freezing: 40oF (4.4oC). EXCEPTION: Localized heat, not to exceed 55oF (13oC) may be furnished in areas where the work requires medium or light personnel activity.

(8) Heat will not be permitted in warehouse areas that do not contain material or equipment requiring protection from freezing or condensation, and warehousing of stored goods is the only operation. Heat for the prevention of condensation on stored machinery and material will be supplied after a thorough survey of all conditions and the approval of the major Army or operating agency (DeCA, AAFES, etc.) manager.

(9) Buildings other than those specified above will not be heated to temperatures higher than 65ºF (18oC) without approval (in writing) from the subordinate garrison or garrison DPW.

When the space is unoccupied during the short period of time, room thermostat shall be set back to 55oF (13oC) with the relative humidity maintained below 50%. In space unoccupied for an extended period of time, temperature shall be controlled at 40oF (5oC) to prevent freezing with the building air RH maintained under 50%.

**13.1.2.** Process related criteria include temperature and humidity needed to perform the process housed in the building (e.g., painting, printing) or to operate process equipment such as electronics. While new design guidance for computer systems indicates a much higher tolerance for high temperatures than previously thought, there are specialized electronic and laboratory equipment that have fairly tight temperature and humidity requirements. An archival storage of important documents also involves relatively tight tolerances for temperature and humidity.

**13.1.3.** Building materials and furnishings requirements

The environmental conditions (temperature and humidity) maintained in indoor spaces determines not only the comfort of the occupants of those spaces but also the long-term “health” of the building itself. Historically, only the dry-bulb temperature of indoor spaces was controlled to achieve comfortable indoor conditions for the occupants. Little attention was given to control of moisture/humidity in the spaces. As a result, many existing Army buildings have significant mold/mildew problems.

Eliminating mold/mildew from Army buildings requires year-round control of both the dry-bulb temperature and the dew point temperature (or air relative humidity) in the indoor spaces. Control of indoor humidity will also significantly improve the comfort of Army building occupants.

Building materials and furnishing damage occurs when humid air meets a cold surface. Mold/mildew grows on a surface in a building when that surface’s relative humidity is above 85% for extended periods. This condition easily occurs in buildings even with low

average air relative humidity when cold spots exist on poorly insulated supply air ducts and chilled water pipes, supply air diffusers and poorly insulated and not air tight building envelope elements and the areas with thermal bridges, etc. Careful design and operation of the building envelope and the HVAC, ventilation, and exhaust systems is required to eliminate the potential for mold growth in Army buildings. By controlling ALL the air inside the building above the dew point will reduce potential moisture related problems. According to the ASHRAE Humidity Control Design Guide, the suggested dew point limits which meet both health and mold problems requirements are < 57oF in summer and > 35oF in winter.

It is important, that designers and O&M personnel design and maintain the building and HVAC systems, to satisfy all three categories of requirements. In most of cases, thermal comfort requirements satisfy the process. Preventing moisture related problems require special attention to the design and building operation. Energy conservation shall not be achieved at expense of health, occupant's wellbeing and building sustainability. Certain strategies and technologies can minimize or eliminate premium energy use.

**13.1.4.** Thermal requirements to unoccupied spaces.

Requirements for temperatures and relative humidity discussed above are developed for occupied spaces (Table 2-1). Many DOD and other government buildings are not occupied at night or on weekends. Some DOD facilities including barracks, administrative and dining facilities may be unoccupied for an extended period of time due to training and deployment. So, one of energy conservation strategies may be to set back temperatures for heating or set up for cooling. One source of guidance on set back or set up temperatures is ANSI/ASHRAE/IESNA Standard 90.1-2004 *Energy Standard for Buildings Except Low-Rise Residential Buildings*. Standard 90.1-2007 does not regulate thermostat set backs or set ups, but it does regulate the capabilities of thermostats installed in buildings. Section 6.4.3.3.2 of Standard 90.1-2004 Setback Controls – requires that heating systems in all parts of the US outside of Miami FL and the tropical islands (zones 2-8) must have a capability to be set back to 55°F. Heating systems in zone 1 are assumed to have minimal usage and therefore no need of setbacks. Cooling systems in hot dry areas (zones 1b, 2b, and 3b) must have the capability to be set up to 90°F. However, cooling systems in hot and humid climates (zones 1a, 2a, and 3a) are not required to have cooling setbacks due to potential for moisture problems. It is wasteful to cool DOD facilities left unoccupied for an extended period of time, which are located in hot and humid climates. Significant energy savings can be achieved without damage to building materials and furnishing if a combination of measures (discussed in Appendix 14) related to the building envelope and HVAC maintain the requirements for ALL the air inside the building.

Table 0-1. Requirements to dry bulb temperature and relative humidity for occupied and unoccupied facilities to reduce the risk of moisture related problems.

| Occupancy/Use | Humidity not to exceed | Maximum Dry Bulb Temp | Minimum Dry Bulb Temp |
|---|---|---|---|
| Occupied | 50% | 75 °F | 70 °F |
| Unoccupied (Short term) | 50% | 85 °F | 55 °F |
| Unoccupied (long term) | 50% | No Max | 40 °F |
| Critical Equipment | 50% or equip requirement if less | Equip max allowed | Equip min allowed |

## Appendix 13.2: Ventilation rates

The key design considerations for maintaining adequate indoor air quality (IAQ) include providing adequate outdoor air rates which satisfy three major requirements: contaminant control, make-up air needs and building pressurization.

**13.2.1.** ASHRAE Standard 62-2007 specifies minimum outside air ventilation rates for residential, commercial, institutional, and industrial spaces. These rates for representative buildings at Army Installations are presented in Table 2-2.

**13.2.2.** Industrial buildings (i.e., motor pools, paint booths, plating tanks, etc.) require make-up air to replace the large volumes of air exhausted by process enclosures and open hoods. Make-up air rates depend upon the type and number of equipment requiring exhaust ventilation and efficiency of local exhausts. Minimum exhaust rates (and respective make-up air rates) are listed in Table 2-3, which is based on the ASHRAE Standard 62.1-2007 Table 6-4. and ASHRAE HVAC Applications Handbook (ASHRAE 2007), Kitchen Ventilation chapter.

Table 0-2. Minimum exhaust rates

| Equipment /facility Category | Exhaust Rate, cfm/unit (L/s $m^2$) | Remarks |
|---|---|---|
| Educational Science Laboratory | 1.00 cfm/ft2 | ASHRAE Std 62.1-2007, Table 6-4 |
| Janitor Closets, trash rooms | 1.00 cfm/ft2 | ASHRAE Std 62.1-2007, Table 6-4 |
| Kitchenettes | 0.3 cfm/ft2 | ASHRAE Std 62.1-2007, Table 6-4 |
| Kitchens – commercial | See Table 6 | ASHRAE Standard 154 |
| Motor Pools | 1.5cfm/ft2 | General exhaust ASHRAE Std 62.1-2007, Table 6-4 |
| Motor Pools (vehicle exhaust | See Table | |
| Showers | 60 cfm/unit | EN 15251, Table B5 |
| | 25/50 cfm/unit | ASHRAE Std 62.1-2007, Table 6-4 |
| Toilets – private | 25/50 cfm/unit | ASHRAE Std 62.1-2007, Table 6-4 |
| Toilets –public | 50/70 cfm/unit | ASHRAE Std 62.1-2007, Table 6-4 |
| Laboratory hoods | ASHRAE Std 110 Method of Testing Performance of Laboratory Fume Hoods | ASHRAE HVAC Applications Handbook (ASHRAE 2007), Kitchen Laboratories Chapter, Table 2 |

Table 0-3. Exhaust flow rates by unlisted and listed cooking hood type.

| Type of Hood | | Minimum Exhaust Flow Rate (cfm per linear foot of hood) | | | |
|---|---|---|---|---|---|
| | | Light Duty Equipment | Medium Duty Equipment | Heavy Duty Equipment | Extra Heavy Duty Equipment |
| Wall-mounted canopy, | unlisted | 200 | 300 | 400 | 550 |
| | listed | 150 - 200 | 200 - 300 | 200 - 400 | 350+ |
| Single island canopy, | unlisted | 400 | 500 | 600 | 700 |
| | listed | 250 - 300 | 300 - 400 | 300 - 600 | 550+ |
| Double island canopy, | unlisted | 250 | 300 | 400 | |

| | | | | |
|---|---|---|---|---|
| listed | 150 - 200 | 200 - 300 | 250 - 400 | 500+ |
| Eyebrow, unlisted | 250 | 250 | Not allowed | Not allowed |
| listed | 150 - 250 | 150 - 250 | — | — |
| Backshelf/proximity, unlisted | 300 | 300 | 400 | Not allowed |
| listed | 100 - 200 | 200 - 300 | 300 - 400 | Not recommended |
| Source: ASHRAE Standard 154 | | | | |

Mechanical codes recognize exceptions for hoods that have been tested against a recognized standard, such as Underwriters Laboratories (UL) Standard 710. Part of the UL standard is a “cooking smoke and flair up” test. This test is essentially a cooking effluent capture and containment (C&C) test where “no evidence of smoke or flame escaping outside the exhaust hood” must be observed. Hoods bearing a recognized laboratory mark are called *listed* hoods, while those constructed to the prescriptive requirements of the building code are called *unlisted* hoods.

As reflected by the range in exhaust rates in the table, a *listed* hood can be operated at a lower exhaust rate than an *unlisted* hood of comparable style and size over the same cook line. Lower exhaust rates may be proven by laboratory testing with specific hood(s) and appliance lineup using the test protocol described in ASTM Standard F-1704, *Test Method for Performance of Commercial Kitchen Ventilation Systems*. This process is sometimes referred to as “custom-engineering” a hood and is the foundation of this ECM. Within the specification to maximize hood performance and minimize exhaust rate are construction or installation details that include the addition of partial side panels, minimizing the gap between the appliances and the back wall and, in the case of canopy hoods, increasing the amount of overhang (e.g., from 6 to 18 in). These detailed specifications can permit a listed hood to operate satisfactorily at the lower end of the cfm range show (e.g., 200 cfm vs. 300 cfm) for a 30% or more saving over the Code values and or standard design practice).

ASHRAE Standard 154 categorizes cooking appliances as light-, medium-, heavy-, and extra heavy-duty, depending on the strength of the thermal plume and the quantity of grease, smoke, heat, water vapor, and combustion products produced. The strength of the thermal plume is a major factor in determining the exhaust rate. By their nature, these thermal plumes rise by natural convection, but they are turbulent and different cooking processes have different “surge” characteristics.

Appliance Duty Classifications from ASHRAE Standard 154

*Light Duty*

- Gas and electric ovens (including standard, bake, roasting, revolving, retherm, convection, combination convection/steamer, conveyor, deck or deck-style pizza, and pas-try)
- Electric and gas steam-jacketed kettles
- Electric and gas compartment steamers (both pressure and atmospheric)
- Electric and gas cheesemelters
- Electric and gas rethermalizers

*Medium Duty*

- Electric discrete element ranges (with or without oven)
- Electric and gas hot-top ranges
- Electric and gas griddles
- Electric and gas double-sided griddles
- Electric and gas fryers (including open deep-fat fryers, donut fryers, kettle fryers, and pressure fryers)
- Electric and gas pasta cookers
- Electric and gas conveyor (pizza) ovens
- Electric and gas tilting skillets /braising pans
- Electric and gas rotisseries

*Heavy Duty*

- Electric and gas underfired broilers
- Electric and gas chain (conveyor) broilers
- Gas open-burner ranges (with or without oven)
- Electric and gas wok ranges
- Electric and gas overfired (upright) broilers
- Salamanders

*Extra Heavy Duty*

Appliances using solid fuel such as wood, charcoal, briquettes, and mesquite provide all or part of the heat source for cooking.

Local exhausts and make-up air systems are significant energy consumers, required for heating and cooling the outside air and for transportation of supply and exhaust air. To extend it is feasible, change processes or use equipment with reduced contaminant and heat release into the space. To minimize hood exhaust airflow

- Use enclosed vs. open hoods when possible (e.g., over plating tanks, vehicle exhaust hoods, etc.). Otherwise, use high efficiency proximity hoods.
- Select location or co-location of process equipment (e.g., kitchen equipment) to increase local exhaust capture efficiency (Figure 2-2):
  - Position equipment (i.e., cooking appliances) close to the walls, avoid island installations when possible
  - Enclose appliances with the walls
- Use demand based exhaust ventilation systems (e.g., welding exhaust systems, kitchen hoods, see Figure 2-3)
- Use efficient hood configurations to to reduce exhaust flow (Figure 2-4)
- Avoid cross-drafts (i.e., in kitchen space, welding shops, laboratories, etc.)

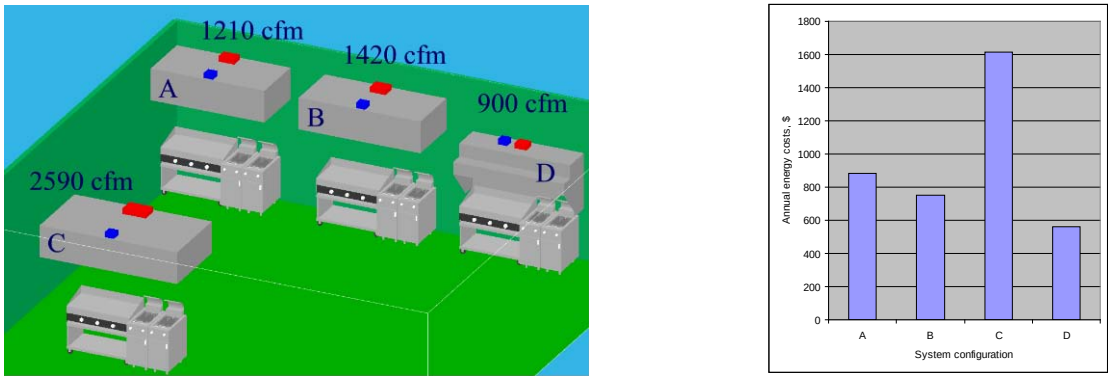



Figure 0-1. Effect of appliance position on the energy cost: A – appliances in the corner with canopy wall hood; B – appliances at the wall with canopy wall hood; C – appliances in the middle of the space with canopy island hood; D – appliances at the wall with close proximity back-shelf hood (Livchak Workshop 2007).

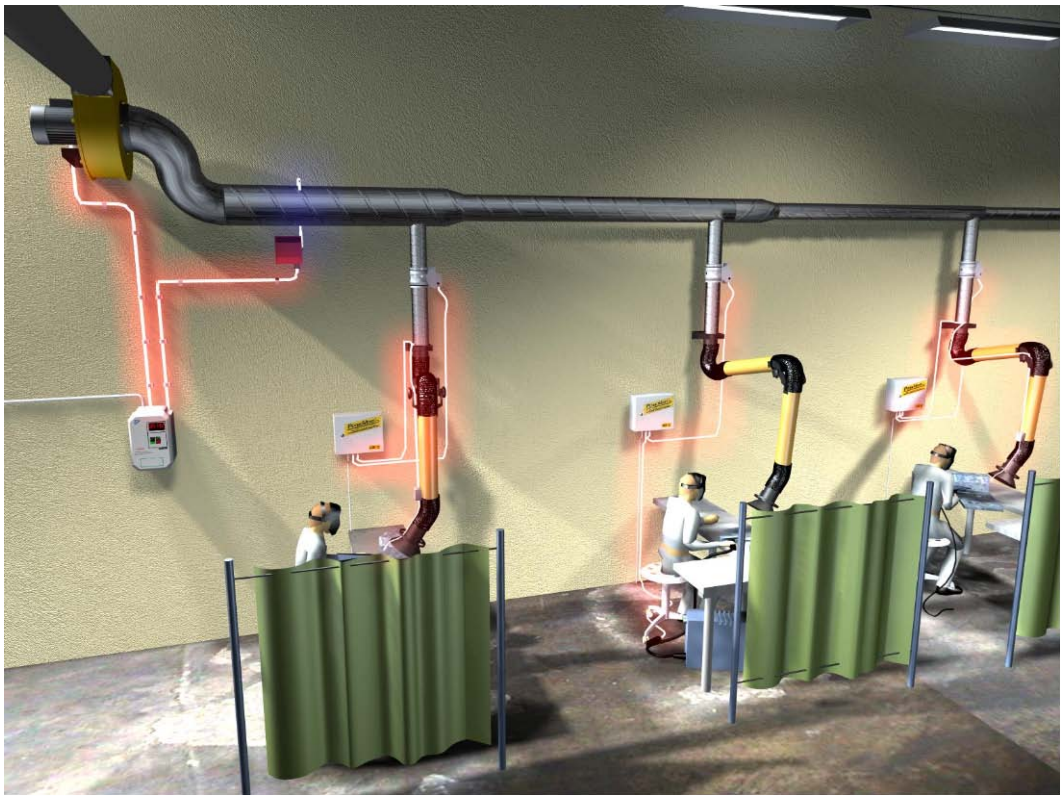


Figure 0-2. Schematic of the demand based exhaust ventilation system in welding shop (Annex 46 Fact Sheet).

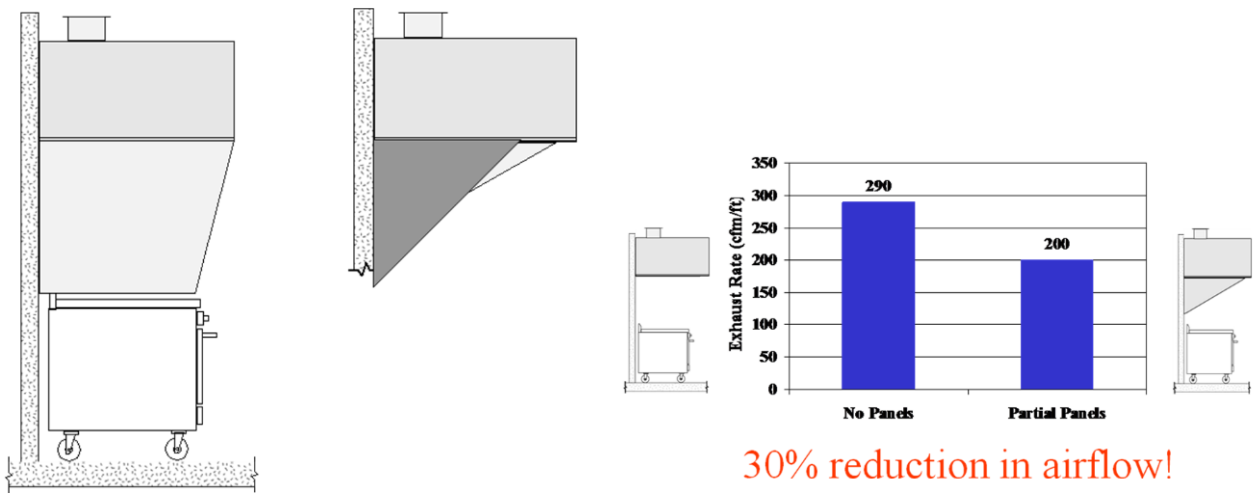



Figure 0-3. Incorporating partial side panels or end walls in different configuration of kitchen hoods allows exhaust flow reduction (www.Fishnick.org)

**13.2.3.** Outside airflow rate required for building pressurization depends upon the building air tightness. The tighter the building envelope, the smaller airflow rate is required to prevent infiltration of cold/warm air into the building, which reduces the sensible and latent heat load on HVAC systems. ASHRAE is considering implementing in standard 90.1 an overall building air leakage maximum requirement that is that building air leakage is not to exceed 0.4cfm/ft2 at a pressure difference of 75 Pa. The Army has implemented a more stringent requirement for total building air leakage not to exceed 0.25cfm/ft2 at a pressure difference of 75Pa.

In existing buildings air leakage can be determined using the “Blower door” technique in accordance with NFRC 400 and be calculated using the *power law flow* function of the form ($Q = C(\Delta P)^n$ . During a blower door test, the two parameters that quantitatively describe the building air leakage, the flow coefficient ,C (CFM/Pa), and the dimensionless flow exponent ,n, can be determined experimentally for a specific building.

The same power law function can be used to estimate the total air flow from infiltration which needs to be overcome to pressurize the building. To accomplish this, the total infiltration rate ($Q_{75}$) in CFM at 0.3 in w.g. (75Pa) is calculated based on the total wall, floor, and roof area of the building and the assumed overall maximum allowed air leakage rate of .25 CFM/ft2. Assuming that the building is pressurized to 0.02 in w.g. by the building ventilation system, the Power Law flow function can be used to determine the total air leakage rate ($Q_5$) in CFM at 0.02 in w.g. (5 Pa) assuming a flow coefficient of 0.65:

$$Q_5 = Q_{75} * (5/75)^{.65}$$
$$Q_5 = Q_{75} * .17$$

The mechanical ventilation system has to provide outside air to the building equal to the building exhaust plus $Q_5$, the air leakage rate at 0.02 in w.g. The infiltration leakage rate is about 10% higher than the outdoor ventilation rates required by ASHRAE Standard 62.1-2004.

**Appendix 13.3: Thermal Comfort and Ventilation Rate Contract Language**

- MTRFP Chapter 4
  - ISO 6781:1983, Qualitative detection of thermal irregularities in building envelopes – infrared method
  - (Should also be added to Chapter 4)
    - ASHRAE Standard 62.1-2004
- MTRFP Chapter 5
  - 5.5. THERMAL PERFORMANCE
  - 5.5.1. STANDARDS AND CODES: Building construction and thermal insulation for mechanical systems shall conform to APPLICABLE CRITERIA.
  - 5.5.2. BUILDING ENVELOPE SEALING PERFORMANCE REQUIREMENT. Design and construct the building envelope for office buildings, office portions of mixed office and open space (e.g., company operations facilities), dining, barracks and instructional/training facilities with a continuous air barrier to control air leakage into, or out of, the conditioned space. Clearly identify all air barrier components of each envelope assembly on construction documents and detail the joints, interconnections and penetrations of the air barrier components. Clearly identify the boundary limits of the building air barriers, and of the zone or zones to be tested for building air tightness on the drawings.
  - 5.5.2.1. Trace a continuous plane of air-tightness throughout the building envelope and make flexible and seal all moving joints.
  - 5.5.2.2. The air barrier material(s) must have an air permeance not to exceed 0.004 cfm / sf at 0.3” wg [0.02 L/s.m2 @ 75 Pa] when tested in accordance with ASTM E 2178
  - 5.5.2.3. Join and seal the air barrier material of each assembly in a flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of these assemblies and components.
  - 5.5.2.4. Support the air barrier so as to withstand the maximum positive and negative air pressure to be placed on the building without displacement, or damage, and transfer the load to the structure.
  - 5.5.2.5. Seal all penetrations of the air barrier. If any unavoidable penetrations of the air barrier by electrical boxes, plumbing fixture boxes, and other assemblies are not airtight, make them airtight by sealing the assembly and the interface between the assembly and the air barrier or by extending the air barrier over the assembly.
  - 5.5.2.6. The air barrier must be durable to last the anticipated service life of the assembly.
  - 5.5.2.7. Do not install lighting fixtures with ventilation holes through the air barrier
  - 5.5.2.8. Provide a motorized damper in the closed position and connected to the fire alarm system to open on call and fail in the open position for any fixed open louvers such as at elevator shafts.

- 5.5.2.9. Damper and control to close all ventilation or make-up air intakes and exhausts, atrium smoke exhausts and intakes, etc when leakage can occur during inactive periods.
- 5.5.2.10. Compartmentalize garages under buildings by providing air-tight vestibules at building access points.
- 5.5.2.11. Compartmentalize spaces under negative pressure such as boiler rooms and provide make-up air for combustion.
- 5.5.2.12. Performance Criteria and Substantiation: Submit the qualifications and experience of the testing entity for approval. Demonstrate performance of the continuous air barrier for the opaque building envelope by the following tests: (a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25cfm/ft2 at a pressure differential of 0.3" w.g.(75 Pa) in accordance with ASTM's E 779 (2003) or E- 1827-96 (2002). Accomplish tests using either pressurization or depressurization or both. Divide the volume of air leakage in cfm @ 0.3" w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to produce the air leakage rate in cfm/ft2 @ 0.3" w.g. (L/s.m2 @ 75 Pa). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner. (b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997). Determine air leakage pathways using ASTM E 1186-03 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems, and perform corrective work as necessary to achieve the whole building air leakage rate specified in (a) above. (c) Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.
- 5.9.1. The building including the building envelope, HVAC systems, service water heating, power, and lighting systems shall meet the Mandatory Provisions and the Prescriptive Path requirements of ASHRAE 90.1-2004. Substantiation requirements are defined in Section 01 33 16, Design After Award.
- 5.9.2. Design all building systems and elements to meet the minimum requirements of ANSI/ASHRAE/IESNA 90.1-2004. Design the buildings, including the building envelope, HVAC systems, service water heating, power, and lighting systems to achieve an energy consumption that is at least 30% below the consumption of a baseline building meeting the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004. Energy calculation methodologies and substantiation requirements are defined in Section 01 33 16, Design After Award.

- ASHRAE 55-2004 EO 13423, sec 2(f) /OAA 09, sec 748
- LEED
    - Credit EQ6.2, Controllability of Systems: Thermal Comfort
    - Credit EQ7.1, Thermal Comfort Design
    - Credit EQ7.2, Thermal Comfort Verification

## Appendix 14: Building Envelope

### Appendix 14.1: Insulation – Walls, Roofs, Slabs, Basement

The building envelope performs various tasks, which includes weather protection from wind, rain, irradiation, heat and cold, visibility and glare protection, fire protection, noise protection and protection against burglary. At the same time, the building envelope must fulfill internal space requirements, which include thermal conditions, acoustic, and visual comfort along with requirements for humidity conditions for both comfort and mold and mildew growth prevention.

Thermal performance of the building envelope influences the energy demand of a building in two ways. It effects annual energy consumption and thus, operating costs for building heating, cooling and humidity control. It also influences peak loads which consequently determine the size of heating, cooling and energy generation equipment and in this way has an impact on investment costs. In addition to energy saving and investment cost reduction, a better insulated building provides other significant advantages. Higher thermal comfort because of warmer surface temperatures on the interior surfaces in winter and lower temperatures in summer. This also results in a lower risk of mold growth on internal surfaces.

ASHRAE Standard 90.1-2007 prescriptive requirements for building envelope as a function of assembly type, climate zone, and building type are listed in Section 5.5 and Tables 5.5-1 to 5.5-8.

Requirements for building envelopes of small office buildings, small retail buildings, K-12 school buildings and Small Warehouses and Self-Storage Buildings, which allow in combination with other energy conservation measures to achieve 30% energy savings over ANSI/ASHRAE/IESNA Standard 90.1-1999 are listed in respective Advanced Energy Design Guides, which can be obtained from the ASHRAE or downloaded from the following website: http://www.ashrae.org/technology/page/938

Studies conducted by USACE in collaboration with DOE and ASHRAE [B, T, O, DF,CDC] resulted in prescriptive thermal properties (Tables 3-1 to 3-5) of the building envelop components which shall be followed to meet the EPAct 2005 requirement for 30% over the ASHRAE Standard 90.1-2004 building energy performance. These requirements shall be met with all new construction and major renovation projects.

Table 0-1. Barracks – UEPH

| Item | Component | Climate Zones | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Roof | Attic R ($ft^2hF/Btu$) | 40 | 40 | 40 | 50 | 50 | 60 | 60 | 60 |
| | Surface reflectance | .27 | .27 | .27 | .27 | .27 | .27 | .27 | ,.27 |
| Walls | Light Weight Construction R ($ft^2hF/Btu$) | 20 | 20 | 20 | 25 | 25 | 30 | 30 | 30 |
| Exposed Floors | Mass R ($ft^2hF/Btu$) | 5 | 10 | 10 | 20 | 20 | 30 | 30 | 30 |
| Slabs | Unheated R ($ft^2hF/Btu$) | NR | NR | NR | NR | NR | NR | NR | 10 |
| Doors | Swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| | Non-swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| Vertical Glazing | Window to Wall Area Ratio (%) | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% |

Table 0-2. Training barracks

| Item | Component | Climate Zones | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Roof | Attic R ($ft^2hF/Btu$) | 40 | 40 | 40 | 50 | 50 | 60 | 60 | 60 |
| | Surface reflectance | .27 | .27 | .27 | .27 | .27 | .27 | .27 | ,.27 |
| Walls | Light Weight Construction R ($ft^2hF/Btu$) | 20 | 20 | 20 | 25 | 25 | 30 | 30 | 30 |
| Exposed Floors | Mass R ($ft^2hF/Btu$) | 5 | 10 | 10 | 20 | 20 | 30 | 30 | 30 |
| Slabs | Unheated R ($ft^2hF/Btu$) | NR | NR | NR | NR | NR | NR | NR | 10 |
| Doors | Swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| | Non-swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| Vertical Glazing | Window to Wall Ratio (%) | 20% | 20% | 20% | 20% | 20% | 20% | 20% | 20% |

Table 0-3. Admin buildings

| Item | Component | Climate Zones | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Roof | Attic R ($ft^2hF/Btu$) | 30 | 38 | 38 | 38 | 44 | 44 | 60 | 60 |
| | Surface reflectance | .27 | .27 | .27 | .27 | .27 | .27 | .27 | ,.27 |
| Walls | Light Weight Construction R ($ft^2hF/Btu$) | 13 | 13 | 13 | 13+7.5 | 13+7.5 | 13+7.5 | 13+15 | 13+20 |
| Exposed Floors | Mass R ($ft^2hF/Btu$) | NR | NR | NR | NR | NR | NR | NR | NR |
| Slabs | Unheated R ($ft^2hF/Btu$) | NR | NR | NR | NR | NR | 10 | 15 | 20 |
| Doors | Swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| | Non-swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| Vertical Glazing | Window to Wall Ratio (%) | 40-ns 20-ew | 40-ns 20-ew | 40-ns 20-ew | 40-ns 20-ew | 40-ns 20-ew | 40-ns 20-ew | 40-ns 20-ew | 40-ns 20-ew |

Table 0-4. Tactical equipment maintenance facilities

| Item | Component | Climate Zones | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Roof | Attic R ($ft^2hF/Btu$) | 19 | 19 | 13+13 | 13+19 | 13+19 | 13+19 | 13+19 | 19+13 |
| | Surface reflectance | .27 | .27 | .27 | .27 | .27 | .08 | .09 | .08 |
| Walls | Light Weight Construction R ($ft^2hF/Btu$) | 13 | 13 | 13 | 13 | 13+13 | 13+13 | 13+13 | 13+16 |
| Exposed Floors | Mass R ($ft^2hF/Btu$) | NR | NR | NR | NR | NR | NR | NR | NR |
| Slabs | Unheated R ($ft^2hF/Btu$) | NR | NR | NR | NR | NR | NR | NR | 20 |
| Doors | Swinging U ($Btu/ft^2hF$) | U-.70 | U-.70 | U-.70 | U-.70 | U-.70 | U-.70 | U-.70 | U-.70 |
| | Non-swinging U ($Btu/ft^2hF$) | U-.25 | U-.25 | U-.25 | U-.25 | U-.25 | U-.25 | U-.25 | U-.25 |
| Vertical Glazing | Window to Wall Ratio (%) | <10% | <10% | <10% | <10% | <10% | <10% | <10% | <10% |

Table 0-5. Dining facilities

| Item | Component | Climate Zones | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Roof | Roof R ($ft^2hF/Btu$) | 15 | 15 | 20 | 20 | 20 | 20 | 20 | 30 |
| | Surface reflectance | .65 | .65 | .65 | .3 | .3 | .3 | .3 | .3 |
| Walls | Light Weight Construction R ($ft^2hF/Btu$) | 13 | 13 | 13+3.8 | 13+7.5 | 13+7.5 | 13+7.5 | 13+7.5 | 13+22 |
| Exposed Floors | Mass | NR | NR | NR | NR | NR | NR | NR | NR |
| Slabs | Unheated R ($ft^2hF/Btu$) | NR | NR | NR | NR | NR | NR | 15 | 20 |
| Doors | Swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| | Non-swinging | NR | NR | NR | NR | NR | NR | NR | NR |
| Vertical Glazing | Window to Wall Ratio | NR | NR | NR | NR | NR | NR | NR | NR |

In building retrofit projects, buildings can be insulated from inside or outside. Technically, the best way to insulate a building component is on the outside as this reduces problems with thermal bridges and does not reduce the usable floor area. With the sufficient exterior insulation, the dew point temperature will not fall within the wall cavity - reducing the risk of condensation. With current insulation technologies external insulation offers different color and texture options and improves the look of the façade (Figure 3-1).

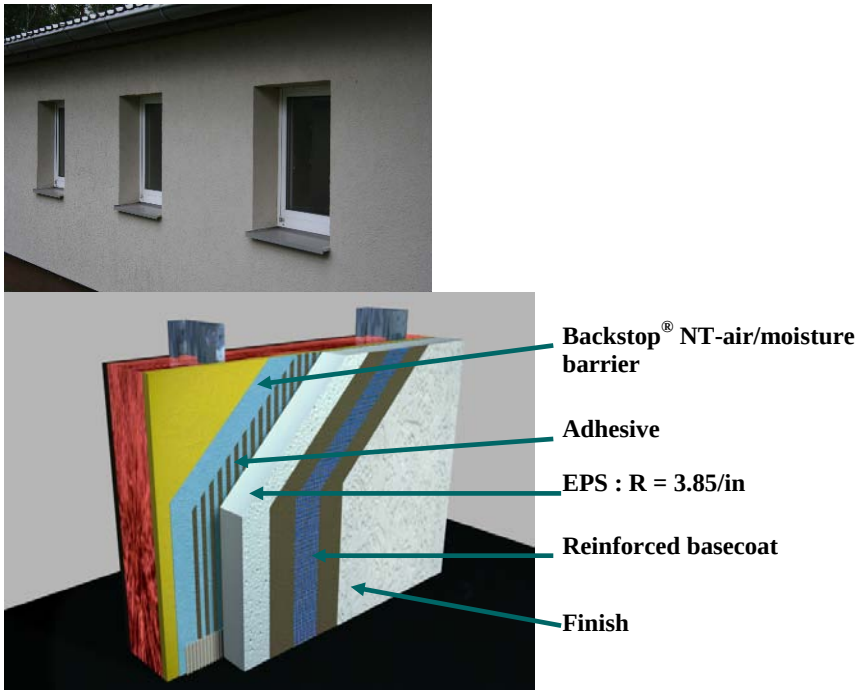



Figure 14-1. Reinsulated Army barrack and schematic of exterior insulation and finish systems

However, with some buildings (e.g., historic buildings) external insulation may not be approved and, therefore internal insulation shall be used. Internal insulation reduces usable floor area, may have a poorer aesthetics and requires interruption of the space usage (Figure 14-2).

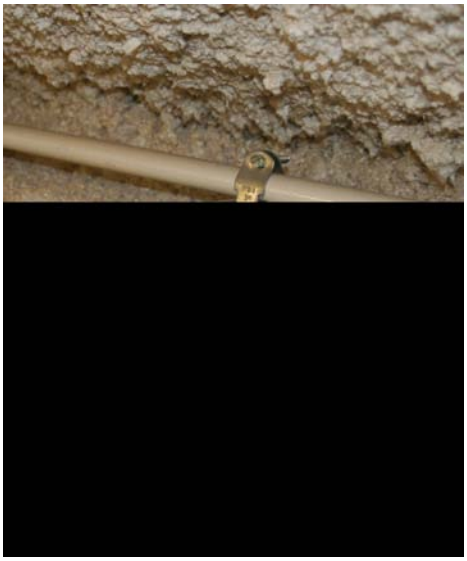


Figure 14-2. Internal insulation of the administrative building at the Rock Island Arsenal.

## Appendix 14.2: Windows, Skylights and Window Film

For new designs and major retrofits selecting windows will be selected to improve visual and thermal comfort and provide an opportunity for energy savings. While window replacement for energy conservation reason only is typically not cost efficient, energy efficient windows for new construction and major retrofit projects which include window replacement requirement is cost efficient and shall be specified. The selection of windows for cold climates shall be based on a window's ability to retain heat inside the building and reduce infiltration, whereas in warm climates – on the capacity to block heat gain from the sun and reduced infiltration. The main energy related parameters of a window are its insulation value, transparency to solar radiation, and air tightness.

The **U-factor** expresses a window's insulation value, its resistance to heat flow when there is a difference between inside and outside temperature. The U-factor is measured in Btu/hr-sq ft-°F (W/sq m-°C). The lower the U-factor, the greater a window's resistance to heat flow.

A window's transparency to the heat carried by solar radiation is expressed in the **solar heat gain coefficient (SHGC).** The SHGC is the fraction of solar heat admitted by the window on a range of 0 to 1. A window's transparency to visible light is expressed as its **visible transmittance (VT)** on a range of 0 to 1 (cf. Figure 3-3)**.**

The **air-leakage (AL)** rating of a window indicates its air tightness. It expresses the rate of air-leakage around a window at a specific pressure difference in units of cubic feet per minute per square foot of frame area (cfm/sq ft) or cubic meters per minute per square meter of frame area.(cmm/sq m).

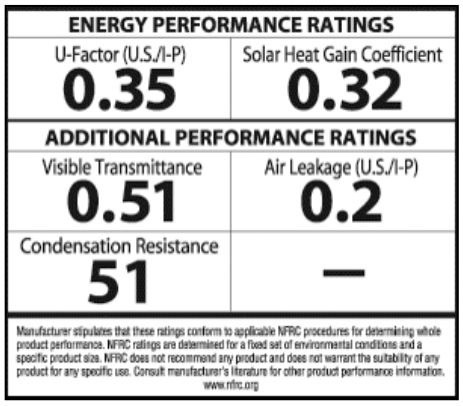



Figure 0-3. Example of the label verifying that the energy properties of windows are rated according to nationally accepted standards and certified by the National Fenestration Rating Council (NFRC).

Table 3-6 shows a range of energy efficient window options (A through F) to be used in barracks located in different climates.

Table 0-6. Window options with default values for barracks buildings

| Window Options with Default Performance Values | | | | | | |
|---|---|---|---|---|---|---|
| **#** | **Glazing type** | **Frame type** | **U-factor (imp./metric)** | **SHGC** | **VT** | **AL (imp./metric)** |
| **A** | 2-pane, low-solar-gain low-E | Aluminum, thermal break | 0.47 / 2.7 | 0.33 | 0.55 | 0.2 / 0.06 |
| **B** | 2-pane, low-solar-gain low-E | Non-metal | 0.34 / 1.9 | 0.30 | 0.51 | 0.2 / 0.06 |
| **C** | 2-pane, high-solar-gain low-E | Non-metal | 0.36 / 2.0 | 0.49 | 0.54 | 0.2 / 0.06 |
| **D** | 3-pane, low-solar-gain low-E | Non-metal | 0.26 / 1.4 | 0.25 | 0.40 | 0.1 / 0.03 |
| **E** | 3-pane, high-solar-gain low-E | Non-metal | 0.27 / 1.5 | 0.38 | 0.47 | 0.1 / 0.03 |
| **F** | 3-pane, high-solar-gain low-E | Non-metal, insulated | 0.18 / 1.0 | 0.40 | 0.50 | 0.1 / 0.03 |

Table 3-7 lists window options for barracks that shall be considered in different climates. Efficient window options are recommended based on the climate-specific considerations —a low SHGC for warm climates and a low U-factor for cold climates. Aluminum-framed window A is among the recommended options for regions where hurricane considerations might require the sturdiness of aluminum (1A, 2A, 2B, 3A).

Table 0-7. Window options recommended for barracks located in different US climates

| Zone | Climate | Efficient window options |
|---|---|---|
| 1A | Very hot | A, B |
| 2A,B | Hot | A, B, |
| 3A,B,C | Warm | A, B |
| 4A,B,C | Mixed | B, C |
| 5A,B | Cool | B, C, D, E |
| 6A,B | Cold | C, D, E |
| 7 | Very cold | C, E, F |
| 8 | Subarctic | E, F |

Operable windows provide building occupants with a connection to the outdoors and can serve to provide additional natural ventilation (under appropriate outdoor conditions) if the mechanical systems are shut down because of problems or servicing. Operable window shall not be used in hot and humid climates (Zones 1a, 2a, and 3a) to prevent mold problems.

The ventilation characteristics of a window that provides a modest connection to the outdoors are different from a window that can provide a portion of the cooling requirements for the interior space. The ventilation function of an operable sash must be incorporated into the total fenestration design. It may not be feasible or necessary to

make all windows operable in office or commercial buildings. A small awning or sliding window below a fixed window can provide the desired effect. All operable windows must have appropriate switches to disarm air-conditioning systems controlling sensible load (DOAS controlling latent load shall be operated all the time).

Table 3-8 shows a range of window options (A through D) and their energy related characteristics for administrative buildings which provide energy-efficiency benefits in different climates.

Table 0-8. Window options with default values for administrative buildings

| Window Options with Default Performance Values | | | | | | |
|---|---|---|---|---|---|---|
| **#** | **Glazing type** | **Frame type** | **U-factor (imp./metric)** | **SHGC** | **VT** | **Incremental cost ($ per ft$^2$)** |
| **A** | 2-pane, reflective coating | Aluminum, thermal break | 0.54 / 3.1 | 0.17 | 0.10 | $1.25 |
| **B** | 2-pane, low-E, tinted | Aluminum, thermal break | 0.46 / 2.6 | 0.27 | 0.43 | $1.75 |
| **C** | 2-pane, low-E | Aluminum, thermal break | 0.46 / 2.6 | 0.34 | 0.57 | $1.50 |
| **D** | 3-pane, low-E | Insulated | 0.20 / 1.1 | 0.22 | 0.37 | $8.00 |

Table 3-9 lists window options for administrative buildings that shall be considered in different climates. Efficient window options are recommended based on the climate-specific considerations —a low SHGC for warm climates and a low U-factor for cold climates. Aluminum-framed window A is among the recommended options for regions where hurricane considerations might require the sturdiness of aluminum (1A, 2A, 2B, 3A).

Table 0-9. Window options recommended for administrative buildings located in different U.S. climates

| Zone | Climate | Efficient window options |
|---|---|---|
| 1A | Very hot – humid | A, B |
| 2A,B | Hot | A, B |
| 3A | Warm -humid | B |
| 3B,C | Warm (dry, marine) | B, C |
| 4A,B,C | Mixed | B, C |
| 5A,B | Cool | B, C |
| 6A,B | Cold | B, C, D |
| 7 | Very cold | C, D |
| 8 | Subarctic | C, D |

**Appendix 14.3: Doors**

Exterior doors shall have infiltration rates not exceeding 0.3 cubic feet per minute per square foot (cfm/ft$^2$) of window area, 0.3 cfm/ft$^2$ of door area for residential doors, 0.3 cfm/ft$^2$ of door area for nonresidential single doors (swinging and sliding), and 1.0 cfm/ft$^2$ for nonresidential double door (swinging) when tested according to NFRC-400 or ASTM E 283 at a pressure differential of 75 Pascals or 1.57 pounds per square foot.

For a solid wood exterior door, the required U-factor is less than or equal to 0.40 Btu/hr-ft$^2$-F. Weather-stripping along the top, jambs, and bottom sweeps is required to minimize air infiltration around exterior doors. All glass in exterior doors shall have a U-factor or energy efficiency rating less than or equal to 0.65 Btu/hr-ft$^2$-F.

**Appendix 14.3.1: Overhead and High Speed Doors**

**SCOPE OF WORK**
**Replace/Install High-Speed and Standard Overhead Doors**
**Building**

1. The work to be performed consists of furnishing all labor, materials, and equipment to install new high-speed doors at Doors [ ] at Building [ ]. Work shall be performed in strict accordance with the requirements of OSHA, NFPA, NEC, Fort Bragg IDG and product manufacturers' specifications.

2. Work to be under this scope of work includes the following items:

a. Replace/Install High-Speed Doors: Install [ ] new high-speed doors at [existing] [new] door openings designated as Doors .

(1) Perform all preparatory work as required to install the new high-speed doors. Modify any existing features as required to accomplish the required installation.

(2) Install new high-speed doors and tracks. Door openings shall match the existing overhead door opening in size. Doors and associated electrical work shall meet the following requirements:

(a) Door shall be high-speed roll-up door. Door panels shall be minimum 0.125-inch PVC. Door guides shall be steel. Door shall include electrically-operated bottom safety bar, weatherstripping, cowling, door operator, and three-position (up-down-stop) push-button control station inside the door opening. Motors shall be housed in enclosures rated for the environment specified. Door shall have blue factory finish on opaque panels.

(b) Door operator shall be 208-volt. Door shall have a safety strip on the bottom edge that will stop the downward motion of the door when it contacts any object. This safety device is not to reverse the direction of door travel. Push button station shall have an up, down and stop position. The up button shall be a momentary contact, the down button shall require continuous pressure to operate the door, and the stop button will interrupt travel in either direction. Door shall be equipped with motion sensors to activate inside and outside the door and shall open on detection of motion.

(c) Provide a separate lockable safety switch for the high-speed door. Provide all necessary connections for provision of electric service to door operator/control station. All electrical wiring shall be encased in rigid steel conduit; and all electrical devices and construction methods shall be suitable for the environment specified.

b. Replace/Install Standard (Non High Speed) Overhead Door:

(1) Remove existing door and track and other existing features as required to accomplish the required door replacement. Install a new door header and enclose the former door opening to the header.

(2) Install one new insulated steel roll-up door and track. Door shall match the existing door in size and operational characteristics. Door and associated electrical work shall meet the following requirements:

(a) Door shall be 20-gauge steel insulated overhead roll-up type complete with electrically-operated bottom safety bar, weatherstripping, cowling, door operator, and three-position (up-down-stop) push-button control station inside and outside the door opening. Motors shall be housed in enclosures rated for the environment specified. Cowling shall include baffles for weather-tightness. A closer bar between the door header and door curtain shall also be provided. Door shall have gray factory finish.

(b) Door operator shall be 208-volt. Door shall have a safety strip on the bottom edge that will stop the downward motion of the door when it contacts any object. This safety device is not to reverse the direction of door travel. Push button station shall have an up, down and stop position. The up button shall be a momentary contact, the down button shall require continuous pressure to operate the door, and the stop button will interrupt travel in either direction.

(c) Provide all necessary connections for provision of electric service to door operator/control station using the existing lockable safety switch. All electrical wiring shall be encased in rigid steel conduit; and all electrical devices and construction methods shall be suitable for the environment specified.

c. Install new 6-inch pipe bollards to protect the exterior rails on the high-speed doors.

d. Provide as-built drawings for completed project. As-built drawings shall be provided on both CD (Micro-station and PDF) and reproducible media.

3. In addition to the drawings, the following technical clarifications shall be incorporated into the work:

a. The work will need to be scheduled to minimize interference with operations in the affected areas of the building. Therefore, the existing doors shall not be removed until all materials for the new installation are on site and ready for installation.

b. All disconnect switches and panels shall be labeled using self-adhesive rigid plastic labels. Labels shall be black plastic with white engraved lettering (minimum 1/4-

inch in height). Labels shall state the voltage, where the panel or disconnect switch is fed from and what it feeds.

c. A separate ground wire shall be installed for all equipment.

d. The panelboard schedule indicating equipment or fixtures fed from each circuit shall be modified to include the new door, if required.

e. The scope of work shall include any ancillary materials to include clamps, bolts, anchors, connectors, fittings, supports, hardware, etc.

f. The contractor shall provide any temporary bracing, supports, dust control, weather enclosures, or other features necessary to complete the work.

4. Submittals shall be provided for Government approval for the items listed below. Four copies of catalog cuts, pamphlets, manufacturer's information, or other data shall be provided for Government review and approval.

a. Operations and maintenance manuals for doors
b. Overhead door and high-speed overhead door
c. Switches and fuses
d. Overhead door operators and control stations
e. Motion sensors and activation devices

**Appendix 14.4: Roofs**

Roofs are vulnerable to solar gain in summer and heat loss in winter. Dark, non-reflective roofing surfaces create heat island effects by absorbing energy from the sun and radiating it as heat. High-reflectance and high emissivity, roofs (often referred to as “cool roofs”) that can reflect heat instead of absorbing it, thereby reducing the building’s interior temperature and the running time of the air conditioning system. In winter “cool” roofs might have a negative effect on the building energy consumption by increasing load on the heating system compared to standard roofs. Studies conducted under the IEA ECBCS Annex 46 showed that “cool roofs” are cost effective over air-conditioned spaces only for buildings located in climate zones 1-5. In these locations, a minimum of 75% of the entire roof surface not used for roof penetrations, renewable energy power systems (e.g. photovoltaics or solar thermal collectors), harvesting systems for rainwater to be used on-site, buildings shall be covered with roofing products that comply with one or more of the following:

(a) Have a minimum initial *SRI* of 0.78 for a low-sloped roof (a slope less than or equal to 2:12) and a minimum initial *SRI* of 0.29 for a steep-sloped roof (a slope of more than 2:12).

(b) Comply with the criteria for the USEPA’s Energy Star Program Requirements for Roof Products – Eligibility Criteria.

In the case of industrial ventilated and heated, but not air-conditioned buildings, “cool roofs” reduce indoor air temperature during the hot part of the year and therefore improves worker’s comfort and productivity and is cost effective in all climates.

The *solar reflective index (SRI)* shall be calculated in accordance with ASTM E1980 for medium-speed wind conditions. The SRI shall be based upon solar reflectance as measured in accordance with ASTM E1918 or ASTM C1549, and the thermal emittance as measured in accordance with ASTM E408 or ASTM C1371. For roofing products, the values for solar reflectance and thermal emittance shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the Cool Roof Rating Council CRRC-1 Product Rating Program, and shall be labeled and certified by the manufacturer.

Solar reflectance is the fraction of solar energy that a roof reflects. Thermal emittance is a measure of the roof’s ability to radiate any heat absorbed back into the air, rather than the building below. Both properties are measured on a scale of zero to one; the higher the values, the cooler the roof.

Cool roof options exist for many traditional roofing materials. Each cool roof product offers a different level of reflectance and emissivity, as well as different costs. For flat-roofed industrial buildings membranes are feasible options since based on the NAVFAC Technology evaluation program study there is no difference in first cost between the cool roof and the regular roof options. For sloped residential and non-residential roofs metal roofs, reflective tiles and architectural shingles are feasible.

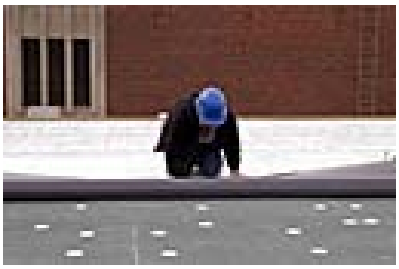
Metal Roofs: Several metal roof products have earned the ENERGY STAR® label, thanks to the development of pigments that make metal roofs highly reflective. The cost of "cool" and standard painted metal roofing materials is practically the same.
Membranes (single-ply): These flexible or semi-flexible pre-fabricated sheets consist of EPDM (ethylene-propylene-dieneterpolymer), PVC (polyvinyl chloride) or TPO (thermoplastic polyolefin). They can be applied over existing low-slope roofs using heat-sealed seams or caulk. Some are self-cleaning and mold resistant.

Coatings: There elastomeric, polyurethane or acrylic liquids are the consistency of thick paint. They can be applied over existing low-slope roofs with a roller or power sprayer and last from 10 to 20 years.

Reflective Tiles: Clay or concrete tiles can incorporate special pigments that reflect solar energy while mimicking traditional colors, including green, brown and terra cotta. These tiles are extremely durable and especially suitable for new homes or for construction projects where a white roof might be aesthetically unacceptable.

Architectural shingles: These products resemble traditional roofing shingles but have the reflective properties characteristic of other cool roof materials (Figures 3-4 and 3-5). The shingles are available in a variety of colors, and the difference in cost between architectural shingles and conventional asphalt shingles is minimal.

(a)



(b)

Figure 0-4. Reflective roof coating (a), and reflective roof membrane (b).

(a)

(b)

©

Figure 0-5. White metal roof (a), roof tile coatings (b), and architectural shingles (c) (http://www.elkcorp.com).

Reflective "cool roofs" which reduce the building cooling load, are available in many colors besides white, though roof color, has an impact on energy usage. Table 3-10

shows the reflectance and emittance values by roof type and color for new and aged roofing materials (ORNL).

Table 0-10. Reflectance and emittance values by roof type and color for new and aged roofing materials

| Roofing Type | Color | New Solar Reflectance | Aged Solar Reflectance | New Thermal Emittance |
|---|---|---|---|---|
| Roof Coatings | White | 0.70 – 0.85 | 0.50 –0.65 | 0.85 |
| Roof Coatings | Grey or Tan | 0.70 | 0.50 | 0.85 |
| Roof Coatings | Terra Cotta or Brown | 0.40 | 0.30 | 0.85 |
| Roof Coatings | Aluminized | 0.50 | 0.40 | 0.50 |
| Metal Paint | Red | 0.25 | 0.25 | 0.83 |
| Metal Paint | Terra Cotta | 0.35 | 0.35 | 0.83 |
| Metal Paint | Bright Red | 0.35 | 0.35 | 0.83 |
| Metal Paint | Beige/Off White | 0.55 | 0.55 | 0.83 |
| Metal Paint | Tan | 0.45 | 0.45 | 0.83 |
| Metal Paint | Dark Blue | 0.25 | 0.25 | 0.83 |
| Metal Paint | Medium to Light Blue | 0.32 | 0.32 | 0.83 |
| Metal Paint | Dark Brown | 0.25 | 0.25 | 0.83 |
| Metal Paint | Medium to Light Brown | 0.32 | 0.32 | 0.83 |
| Metal Paint | Dark Green | 0.25 | 0.25 | 0.83 |
| Metal Paint | Medium to Light Green | 0.32 | 0.32 | 0.83 |
| Metal Paint | White | 0.65 | 0.65 | 0.83 |
| Metal Paint | Bright White | 0.70 | 0.70 | 0.83 |
| Metal Paint | Black | 0.25 | 0.25 | 0.83 |
| Metal Paint | Dark Grey | 0.25 | 0.25 | 0.83 |
| Metal Paint | Medium to Light Grey | 0.35 | 0.35 | 0.83 |
| Metal Paint | Pearlescent Colors | 0.35 | 0.35 | 0.75 |
| Galvalume | Unpainted | 0.65 | 0.55 | 0.05 |
| Copper Metal | Unpainted | 0.85 | 0.18 | 0.03 |
| Galvanized Steel | Unpainted | 0.40 | 0.20 | 0.50 |
| EPDM Membrane | Black | 0.05 | 0.10 | 0.85 |
| TPO Membrane | White | 0.80 | 0.60 | 0.85 |
| TPO Membrane | Grey | 0.50 | 0.40 | 0.85 |
| PVC Membrane | White | 0.80 | 0.60 | 0.85 |
| PVC Membrane | Grey | 0.50 | 0.40 | 0.85 |
| Asphalt Shingle | Dark Color | 0.10 | 0.10 | 0.85 |
| Asphalt Shingle | Light Color | 0.25 | 0.25 | 0.85 |
| Modified Bitumen Cap Sheet | Dark Color | 0.10 | 0.10 | 0.85 |
| Modified Bitumen Cap Sheet | Light Color | 0.25 | 0.25 | 0.85 |
| Modified Bitumen Cap Sheet | White | 0.50-0.60 | 0.40 – 0.45 | 0.85 |

## *Appendix 14.5: Air Tightness and Moisture Control*

The air tightness of the building enclosure or envelope becomes an increasingly significant factor in the overall energy consumption of buildings. The energy required to heat, cool and maintain humidity control in buildings is increased significantly due to uncontrolled air transfer through the enclosure, as well as by convection. Investigations of building enclosure problems have led many building science consultants, investigators and researchers to conclude that air leakage is the leading cause of moisture problems in exterior building enclosures. These problems include mold and durability problems in exterior walls and other cavities connected to the exterior, excessive rain penetration into wall cavities, poor indoor temperature and humidity control, high heating and air conditioning costs and compromised Noise, fire and smoke control measures. In colder climates the problems of air leakage include icicles on exterior facades, spalling of masonry, premature corrosion of metal parts in exterior walls, high wood moisture contents and rot, excessive rain penetration and indoor temperature and humidity control problems (Figure 3-6). In hot humid climates infiltrating air can cause mold due to condensation on cold air conditioned surfaces.

Figure 0-6. Cold climate exfiltration problems (left) and hot humid air infiltration problems (right)

Where are the leaks? When the building does not have assemblies with a designated layer selected as the airtight layer “an air barrier,” and when the airtight layer of adjacent assemblies are not joined together, air leakage is the result. The most common problems show up in between adjacent assemblies, in particular, the wall-to-roof juncture, canopies and soffits, wall to foundation connection and window-to-wall air barrier; these kinds of problems cause “orifice” and “channel” air flow (Figures 3-7 and 3-8). Occasionally building materials are selected that are not tight enough by air barrier standards, causing “diffuse” air flow through them (Figure 3-9). In existing buildings, operable windows and doors generally are a target for either replacement or re-gasketing and weather stripping (Figure 3-10).

Figure 0-7. Examples and unsealed chases between floors and the attic

Figure 0-8. Examples of unsealed pipe penetrations through walls and floors

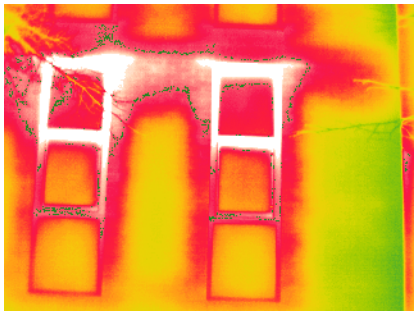


Figure 0-9. Blow-door tests complemented by thermography identify problems with building air tightness and areas with poor insulation where leakage occurs (red and white areas in photos to the right).

Figure 0-10. Penetration through the walls designed to accommodate outdoor air supply to individual room's fan-coil units.

Application of air barrier theory in a building design requires the selection of a component or layer in an assembly to serve as the airtight layer.

Design and construct the building envelopes of office buildings, office portions of mixed office and open space (e.g., company operations facilities), dining, barracks and instructional/training facilities with a continuous air barrier to control air leakage into, or out of, the conditioned space. Clearly identify all air barrier components of each envelope assembly on construction documents and detail the joints, interconnections and penetrations of the air barrier components. Clearly identify the boundary limits of the building air barriers, and of the zone or zones to be tested for building air tightness on the drawings.

Trace a continuous plane of air-tightness throughout the building envelope and make flexible and seal all moving joints. The air barrier material(s) must have an air permeance not to exceed 0.004 cfm / sf at 0.3” wg [0.02 L/s.m2 @ 75 Pa] when tested in accordance with ASTM E 2178. Join and seal the air barrier material of each assembly in a flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of these assemblies and components.

Support the air barrier so as to withstand the maximum positive and negative air pressure to be placed on the building without displacement, or damage, and transfer the load to the structure. Seal all penetrations of the air barrier. If any unavoidable penetrations of the air barrier by electrical boxes, plumbing fixture boxes, and other assemblies are not airtight, make them airtight by sealing the assembly and the interface between the assembly and the air barrier or by extending the air barrier over the assembly. The air barrier must be durable to last the anticipated service life of the assembly. Do not install lighting fixtures with ventilation holes through the air barrier

Provide a motorized damper in the closed position and connected to the fire alarm system to open on call and fail in the open position for any fixed open louvers such as at elevator shafts. Damper and control to close all ventilation or make-up air intakes and exhausts, atrium smoke exhausts and intakes, etc when leakage can occur during inactive periods. Compartmentalize garages under buildings by providing air-tight vestibules at building access points. Provide air-tight vestibules at building entrances with high traffic (Figures 3-11, 3-12, and 3-13.)

Figure 0-11. Unprotected building entrances with a high traffic.

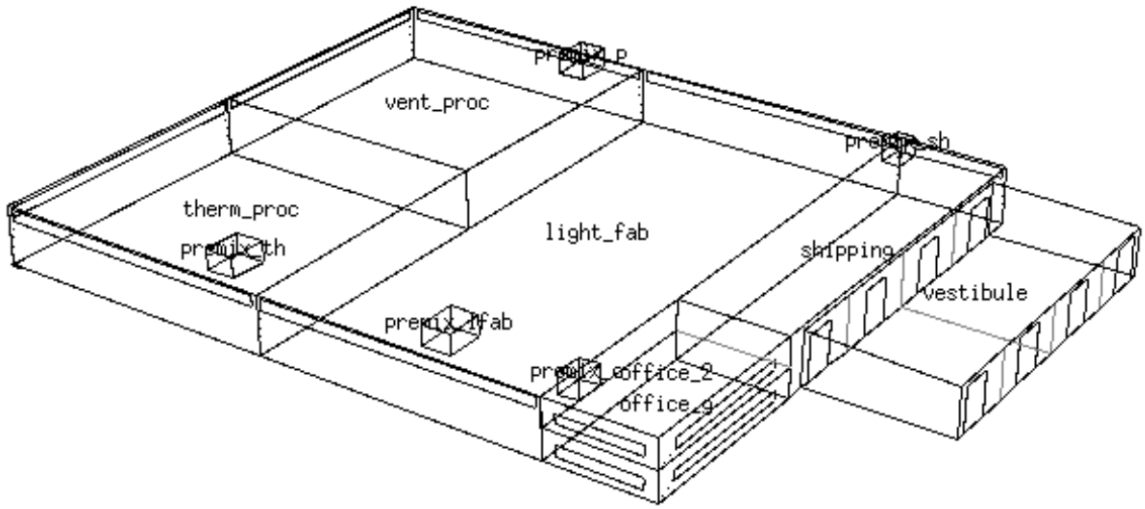



Figure 0-12. Schematic of external vestibule for an industrial building shipping entrance

Figure 0-13. Examples of vestibules at the high traffic doors of admin buildings (a,b) and the dining facility (c)

Compartmentalize spaces under negative pressure such as boiler rooms and provide make-up air for combustion.

Performance Criteria and Substantiation: Submit the qualifications and experience of the testing entity for approval. Demonstrate performance of the continuous air barrier for the opaque building envelope by the following tests:

(a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25cfm/ft2 at a pressure differential of 0.3” w.g.(75 Pa) in accordance with ASTM’s E 779 (2003) or E-1827-96 (2002). Accomplish tests using either pressurization or depressurization or both. Divide the volume of air leakage in cfm @ 0.3” w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to produce the air leakage rate in cfm/ft2 @ 0.3”

w.g. (L/s.m2 @ 75 Pa). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner.

(b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997). Determine air leakage pathways using ASTM E 1186-03 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems, and perform corrective work as necessary to achieve the whole building air leakage rate specified in (a) above. (c) Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.

Figure 3-14 illustrates some visualization techniques which can be used to identify location or leaks

Figure 0-14. Identification of leakage pathways using smoke pencil (left), theatrical fog and infra-red thermography (right)

Existing buildings undergoing major renovations especially the ones located in cold or hot and humid climates shall be sealed to the same standard as newly constructed ones.

The need for and reasonableness of destructive analysis of the state of exiting air barrier shall be evaluated based on the type of renovation considering related cost issues. This can be challenging due to difficulty in accessing gaps through hard or expensive finishes. Removable ceiling tiles allow easy access to problem areas; walls require destructive access through finishes to expose gaps such as around windows; occasionally if a gap is discovered it may be possible to blind-seal with spray polyurethane foam injected through holes drilled in the drywall. For large holes, bulkheads can be built out of studs and drywall sealed with spray polyurethane foam (SPF); smaller gaps up to 50 mm (2”) can be sealed with one part SPF; larger gaps can be sealed with two-component SPF. Note that stuffing glass-fiber insulation in cracks is not useful, because glass-fiber merely acts as a dust filter and allows air under a pressure differential to pass through it. Air leaks shall be sealed in the following order of priority:

1. Top of building
   - Attics
   - Roof/wall intersections and plenum spaces
   - Mechanical penthouse doors and walls
   - HVAC equipment
   - Other roof penetrations
2. Bottom of Building
   - Soffits and ground floor access doors
   - Underground parking access doors
   - Exhaust and air intake vents
   - Pipe, duct, cable and other service penetrations into core of building
   - Sprinkler hangar penetrations, inspection hatches and other holes
   - Seal core wall to floor slab
   - Crawl spaces
3. Vertical shafts
   - Gasket stairwell fire doors
   - Fire hose cabinets or toilet room recessed accessories connected to shafts
   - Plumbing, electrical, cable and other penetrations within service rooms
   - Elevator rooms, electric rooms- reduce size of cable holes, firestop and seal bus bar openings
4. Exterior Walls
   - Weather-strip windows, doors, including balcony/patio doors and seal window trim
   - Exhaust fans and ducting
   - All service penetrations
   - Baseboard heaters
   - Electrical receptacles
   - Baseboards
5. Compartmentalize
   - Garages
   - Vented mechanical rooms
   - Garbage compactor rooms
   - Emergency generator rooms
   - High voltage rooms
   - Shipping docks
   - Elevator rooms
   - Workshops

Potential energy conservation due to reduced energy used for building heating, cooling and dehumidification is demonstrated by the graph shown in Figure 3-15. The data based on the study of computer simulation of the typical barrack building located in different US climate zones show that air leakage reduction from 1cfm/ft2 at a pressure differential of 0.3” w.g. (75 Pa) to 0.25cfm/ft2 results in the total building energy conservation between 5% and 45% depending on climate zone. In addition,

to energy conservation tighter building envelop results in decreased O&M costs for mold problems remediation.

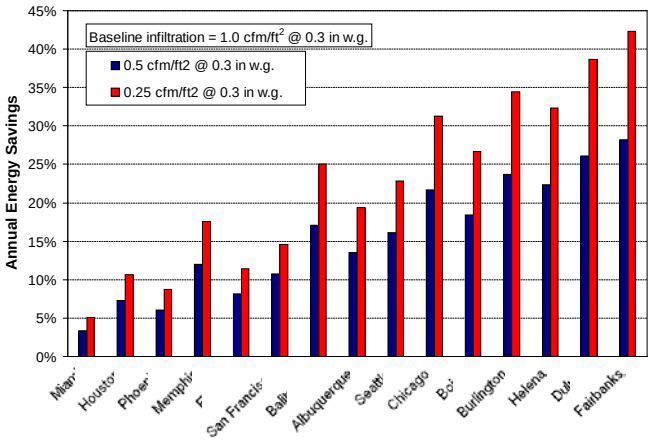



Figure 0-15. Annual energy savings calculated for a typical barrack building for different US climate zones.

A list of air barrier contractors and manufacturers can be found on the Air Barrier Association's website http://www.airbarrier.org

## *Appendix 14.6: Building Envelope Contract Language*

- MTRFP Chapter 4
    - ASTM C1060-90(1997). Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings
    - ISO 6781:1983, Qualitative detection of thermal irregularities in building envelopes- infrared method.
- MTRFP Chapter 5
    - 5.5. THERMAL PERFORMANCE
    - 5.5.1. STANDARDS AND CODES: Building construction and thermal insulation for mechanical systems shall conform to APPLICABLE CRITERIA.
    - 5.5.2. BUILDING ENVELOPE SEALING PERFORMANCE REQUIREMENT. Design and construct the building envelope for office buildings, office portions of mixed office and open space (e.g., company operations facilities), dining, barracks and instructional/training facilities with a continuous air barrier to control air leakage into, or out of, the conditioned space. Clearly identify all air barrier components of each envelope assembly on construction documents and detail the joints, interconnections and penetrations of the air barrier components. Clearly identify the boundary limits of the building air barriers, and of the zone or zones to be tested for building air tightness on the drawings.
    - 5.5.2.1. Trace a continuous plane of air-tightness throughout the building envelope and make flexible and seal all moving joints.
    - 5.5.2.2. The air barrier material(s) must have an air permeance not to exceed 0.004 cfm / sf at 0.3” wg [0.02 L/s.m2 @ 75 Pa] when tested in accordance with ASTM E 2178
    - 5.5.2.3. Join and seal the air barrier material of each assembly in a flexible manner to the air barrier material of adjacent assemblies, allowing for the relative movement of these assemblies and components.
    - 5.5.2.4. Support the air barrier so as to withstand the maximum positive and negative air pressure to be placed on the building without displacement, or damage, and transfer the load to the structure.
    - 5.5.2.5. Seal all penetrations of the air barrier. If any unavoidable penetrations of the air barrier by electrical boxes, plumbing fixture boxes, and other assemblies are not airtight, make them airtight by sealing the assembly and the interface between the assembly and the air barrier or by extending the air barrier over the assembly.
    - 5.5.2.6. The air barrier must be durable to last the anticipated service life of the assembly.
    - 5.5.2.7. Do not install lighting fixtures with ventilation holes through the air barrier
    - 5.5.2.8. Provide a motorized damper in the closed position and connected to the fire alarm system to open on call and fail in the open position for any fixed open louvers such as at elevator shafts.

- 5.5.2.9. Damper and control to close all ventilation or make-up air intakes and exhausts, atrium smoke exhausts and intakes, etc when leakage can occur during inactive periods.
- 5.5.2.10. Compartmentalize garages under buildings by providing air-tight vestibules at building access points.
- 5.5.2.11. Compartmentalize spaces under negative pressure such as boiler rooms and provide make-up air for combustion.
- 5.5.2.12. Performance Criteria and Substantiation: Submit the qualifications and experience of the testing entity for approval. Demonstrate performance of the continuous air barrier for the opaque building envelope by the following tests: (a) Test the completed building and demonstrate that the air leakage rate of the building envelope does not exceed 0.25cfm/ft2 at a pressure differential of 0.3" w.g.(75 Pa) in accordance with ASTM's E 779 (2003) or E- 1827-96 (2002). Accomplish tests using either pressurization or depressurization or both. Divide the volume of air leakage in cfm @ 0.3" w.g. (L/s @ 75 Pa) by the area of the pressure boundary of the building, including roof or ceiling, walls and floor to produce the air leakage rate in cfm/ft2 @ 0.3" w.g. (L/s.m2 @ 75 Pa). Do not test the building until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions so that repairs to the continuous air barrier, if needed to comply with the required air leakage rate, can be done in a timely manner. (b) Test the completed building using Infrared Thermography testing. Use infrared cameras with a resolution of 0.1deg C or better. Perform testing on the building envelope in accordance with ISO 6781:1983 and ASTM C1060-90(1997). Determine air leakage pathways using ASTM E 1186-03 Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems, and perform corrective work as necessary to achieve the whole building air leakage rate specified in (a) above. (c) Notify the Government at least three working days prior to the tests to provide the Government the opportunity to witness the tests. Provide the Government written test results confirming the results of all tests.
- 5.9.1. The building including the building envelope, HVAC systems, service water heating, power, and lighting systems shall meet the Mandatory Provisions and the Prescriptive Path requirements of ASHRAE 90.1-2004. Substantiation requirements are defined in Section 01 33 16, Design After Award.
- 5.9.2. Design all building systems and elements to meet the minimum requirements of ANSI/ASHRAE/IESNA 90.1-2004. Design the buildings, including the building envelope, HVAC systems, service water heating, power, and lighting systems to achieve an energy consumption that is at least 30% below the consumption of a baseline building meeting the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004. Energy calculation methodologies and substantiation requirements are defined in Section 01 33 16, Design After Award.

- EO 13423, sec 2(f) (i), HPSB MOU (2006)

## Appendix 15: Lighting

### Appendix 15.1: General Lighting Requirements

1. General Requirements

a. Fort Bragg shall be equipped with the most efficient lighting systems practicable, and shall have the proper controls to enable building occupants to operate buildings as efficiently as possible.
b. Lighting systems in all facilities shall be connected to a LONWorks lighting control panel and networked to the Building Automation System when LCCA. All spaces shall have appropriate automatic or manual controls to permit lights to be turned off when not in use. Zones shall be established in large areas so that groups of lights may be operated independently of other groups.
c. Incandescent light bulbs and mercury vapor lamps are prohibited in all facilities. Incandescent light bulbs shall be replaced by compact fluorescent lamps in table and floor lamps, floodlights, fire alarm boxes, and all other fixtures.
d. Natural light will be considered whenever feasible and cost-effective. Reflector tubes, which pass sunlight into interior spaces, may be considered where cost-effective.
e. Janitorial work shall be done during regular working hours to eliminate excessive lighting of facilities at night. Where cleaning crews must work at night, they shall be instructed to light only the immediate area in which they are working, turning off lights as they leave.
f. Supplementary task lighting shall be used to provide more light where it is needed rather than adding more general lighting. Task lighting shall be compact fluorescent type/LED lights of equal efficiency.

2. Lighting intensity

Lighting systems are designed based on lighting intensity in buildings recommended to meet OSHA can be found in the IESNA Handbook (IESNA stands for the Illuminating Engineering Society of North America). There are many types of spaces that are overlit for various reasons.

Office spaces are often over-lit as a result of having been installed prior to 1985, when overhead lighting was the only light source and light levels were designed for paper-based reading tasks, using 750-1000 lux as the lighting criteria due to the poor reprographics available at that time; now office lighting designs are based on computer tasks and higher quality printed tasks, so overhead lighting can be reduced to between 300 and 500 lux.

Recent findings show that when the spectral properties of the peripheral lighting are shifted to include more blue, our eyes respond the same as if the lighting levels were increased – the pupils of our eyes get smaller, spaces seem brighter, and we see things more clearly. Thus, additional energy savings can be obtainable through the use of spectrally enhanced lighting and extra-efficient electronic ballasts.

One of the easiest and most cost effective methods for saving energy is to design lighting systems to the correct light level for the tasks being performed, and not over-lighting spaces.

Another parameter used in the lighting systems design is Lighting Power Density which is limited by Section 9 of ASHRAE/IESNA Standard 90.1 2007 with the modifications and additions required by CHAPTER 7 of BSR/ASHRAE/USGBC/IESNA Standard 189.1P ASHRAE Standard 90.1 limits lighting power consumption by defining limits for Lighting Power Densities (LPD) in Watts per sq. Fort The Standard does this by using IESNA lighting recommendations for light levels and calculating the wattage that would be consumed by energy-efficient lighting systems in specific building types. The LPD's in Standard 90.1 are based on standard lamps and ballasts, and do not include the latest in ballast technologies or any spectral contributions.

Table 2-4 provides current requirements for Lighting intensities a for typical Army facilities.

Table 0-11. Examples of design illumination levels for some Army buildings and spaces from EN 12464.

| Type of building | Space | Maintained luminance, Ê m, at working areas, lx | UGR | Ra | Remarks |
|---|---|---|---|---|---|
| Barracks/Dormitories | | | | | |
| Educational Buildings | Play room, nursery, classroom | 300 | 19 | 80 | |
| | Lecture hall | 500 | 19 | 80 | |
| | Computer practice rooms (menu driven) | 300 | 19 | 80 | |
| Office buildings | Single offices | 500 | 19 | 80 | at 0,8 m |
| | Open plan offices | 500 | 19 | 80 | at 0,8 m |
| | Conference rooms | 500 | 19 | 80 | at 0,8 m |
| Educational buildings | Classrooms | 300 | 19 | 80 | at 0,8 m |
| | Classrooms for adult education | 500 | 19 | 80 | at 0,8 m |
| | Lecture hall | 500 | 19 | 80 | at 0,8 m |
| Hospitals | General ward lighting | 100 | 19 | 80 | at 0,8 m |
| | Simple examination | 300 | 19 | 80 | at 0,8 m |
| | Examination and treatment | 1000 | 19 | 90 | at 0,8 m |
| Hotels and restaurants | Self-service restaurant, dining room | 200 | 22 | 80 | at 0,8 m |
| | Kitchen | 500 | 22 | 80 | |

| Type of building | Space | Maintained luminance, Ê m, at working areas, lx | UGR | Ra | Remarks |
|---|---|---|---|---|---|
| | Buffet | 300 | 22 | 80 | |
| Sport facilities | Sports halls | 300 | 22 | 80 | at 0,1 m |
| Wholesale and retail premises | Sales area | 300 | 22 | 80 | at 0,8 m |
| | Till area | 500 | 19 | 80 | at 0,8 m |
| Circulation areas | Corridor | 100 | 28 | 40 | at 0,1 m |
| | Stairs | 150 | 25 | 40 | at 0,1 m |
| | Restrooms | 100 | 22 | 80 | |
| | Cloakrooms, washrooms, bathrooms, toilets | 200 | 25 | 80 | |
| Industrial | Metal working/ welding | 300 | 25 | 60 | |
| | Assembly | | | | |
| | Rough | 200 | 25 | 80 | |
| | Medium | 300 | 25 | 80 | |
| | Fine | 500 | 22 | 80 | |
| | precision | 750 | 19 | 80 | |
| Central Plant | Boiler house | 100 | 28 | 40 | |
| | Machine Halls | 200 | 25 | 80 | |
| | Side rooms, e.g. pump rooms, condenser rooms etc. | 200 | 25 | 60 | |
| | Control rooms | 500 | 16 | 80 | |
| Vehicle Construction/ Maintenance | Body work and assembly | 500 | 22 | 80 | |
| | Painting, spraying and polishing | 750 | 22 | 80 | |
| | Painting, touch-up, inspection | 1000 | 19 | 90 | |
| Wood working and processing | Saw frame | 300 | 25 | 60 | |
| | Work at joiner's bench, gluing, assembly | 300 | 25 | 80 | |
| | Polishing, painting, fancy joinery | 750 | 22 | 80 | |
| | Work on wood working machines e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking | 500 | 19 | 80 | |

1. EN 12464-1 Light and lighting – Lighting of work places – Part 1: Indoor work places. Approved by CEN on 16 October 2002.
2. http://www.voltimum.it/news/4666//Illumination-levels-for-inside--zones---tasks-and-activity-according-to-EN-12464-1.html

**Appendix 15.2: Interior Lighting Retrofit**

1. Use 2-lamp fluorescent fixtures, wherever possible (or retrofit existing fixtures to 2-lamp) (no need for 4-L fixtures and 3-L usually provide too much light at normal mounting centers – 6’ x 8’ or 8’ x 8’)
2. Use 32-w High-Performance T8 lamps (a.k.a “Super” T8) 4100K or 5000K and 85 CRI and 2-lamp, NEMA Premium Instant-Start electronic ballasts, NPB (normal power) (BF=0.88) with the 4100K lamps or LPB (low-power ballast) (BF=0.71) with the 5000K lamps (cut-sheets supplied)
3. Retrofit 2x2 lensed fixtures with a retrofit kit consisting of a reflector & new end bars to accept 2, 17-w (2-ft) T8 lamps and change ballast to 2-lamp, NEMA Premium Instant-Start electronic ballast, NPB (normal power) (BF=0.88) with the 4100K lamps or LPB (low-power ballast) (BF=0.71) with the 5000K lamps (cut-sheets supplied for fixture retrofit kit)
4. Retrofit deep-cell parabolic fixtures with Lightonia ES-8R that converts the existing body to two lamp fixture with a new louver with larger cells (both 2x2 and 2x4 kits available) (cut sheets supplied)
5. Ensure that all retrofits or new fixtures have a “luminaire disconnect” installed in the power line feeding the fixture (this is for safety of electricians servicing fixtures) (info attached)
6. When retrofitting existing fixtures, specify cleaning the light reflecting and transmitting materials (inside & out) (cleaning info attached)
7. Retrofit or replace incandescent 6-in recessed cans with the Cree LR-6 LED 12-w module or the Lightolier 20-w or Halo 20-w LED downlights (cut-sheets supplied)
8. Replace Stairwell lighting with fluorescent wall-mounted bi-level “smart” fixtures e/w built-in ultrasonic occupancy sensors, such as those described in the Lamar Lighting cut-sheets supplied. Designed so that the low level will provide the required minimum light level of 1 FC. When occupants enter stairwell the light level is increased for best visibility.
9. Exit signs shall be solid-state, LED type, with battery backup. Exit signs with incandescent or compact fluorescent lamps shall be upgraded to LED type. Self-illuminating radio luminous (radioactive) signs are prohibited except under unique circumstances, and only as authorized by the AC/S FAC (FMO).

**Appendix 15.3: New Construction Lighting (TBD)**

**Appendix 15.4: Open Bay Lighting**

1. Floors in hangars, warehouses, and industrial facilities, shall be highly reflective epoxy or painted white to provide reflected light in the area. When painting office areas, non-glossy, light, reflective colors should be used to improve illumination of area. (Glossy paint can cause glare).
2. HID lights should be replaced with spectrally-enhanced lighting using T5HO amalgam lamps. Also consider installing hangar lighting control, consisting of photo-sensors and lighting controllers that turn off selected fixtures when sufficient daylight is present from open hangar doors.

**Appendix 15.5: Exterior Lighting**

1. Install photocells control on all outside of buildings and street lighting.
2. Decorative lighting is prohibited in facilities except as specifically authorized by the DPW Energy Manger. Decorative lighting includes exterior floodlights, down lights, up lights, and other architectural lighting.
3. Holiday lighting displays must be approved by the DPW Energy Manager. Where allowed, lights shall be low wattage light emitting diode (LED) lights.
4. Replace HID parking lot area lights with LED units, such as BetaLED units.
5. Ball fields and other outside sporting areas may use metal halide lighting. Such lighting shall be photocell controlled to preclude being turned on during daylight hours, and timer controlled to assure turn off after use at night. Fixture and reflector design shall be such as to minimize glare, sky glow, and light trespass.
6. Soda and juice vending machines shall be de-lamped except where light is provided by LED lamps.
7. Gas-fired decorative lighting, such as torchieres, is not authorized

**Appendix 15.6: Day Lighting**

1. Envelope Shape
    a. Increase perimeter (atria, courtyards, etc.)
    b. Orient building East/West (use North/South for fenestration)
2. Fenestration placement/orientation
    a. Sidelighting (windows, clerestories)
    b. Toplighting (skylights, roof monitors, sawtooth monitors)
3. Enhance available daylighting
    a. Use highly reflective finishes to allow deeper daylight penetration into the space
    b. Consider light shelves on southern windows to increase sidelight penetration
4. Benefits of Daylighting:
    a. Improved life-cycle cost analysis
    b. Increased user productivity
    c. Reduced emissions
    d. Reduced operating costs

Figure 16.1 Skylight

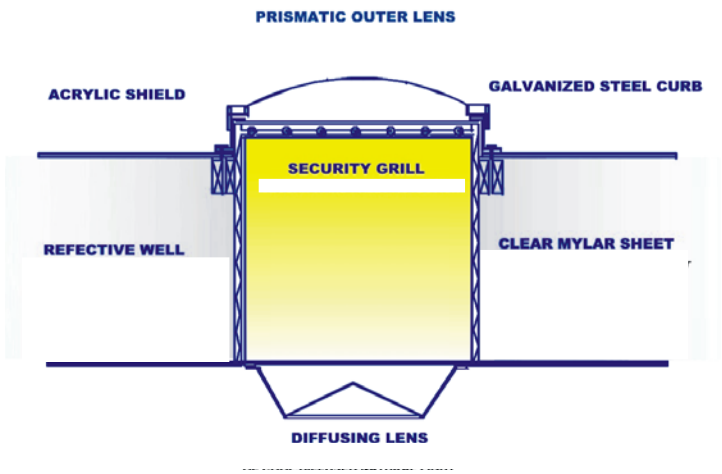


Figure 16.2 Warehouse application without (left) and with (right) skylights

**Appendix 15.7: Lighting Contract Language**

- MTRFP Chapter 4 Reference
  - IESNA RP-1, Office Lighting
  - IESNA RP-8, Roadway Lighting
  - IESNA Lighting Handbook, Reference and Application
- MTRFP Chapter 5
  - 5.5.2.7. Do not install lighting fixtures with ventilation holed through the air barrier
  - 5.7.5. Lighting shall comply with the recommendations of the Illumination Engineering Society of North America (IESNA).
  - 5.7.5.1. Interior Lighting: Interior lighting shall utilize electronic ballast and energy efficient fluorescent lamps with a Correlated Color Temperature of 4100K. Compact fluorescent fixtures shall have a Color Rendering Index of (CRI) of 82 or higher. Linear fluorescent fixtures shall have a CRI of 85 or higher. Fluorescent lamps shall be the low mercury type qualifying as non-hazardous waste upon disposal. Surface mounted fixtures shall not be used on acoustical tile ceilings. An un-switched fixture with emergency ballast shall be provided at each entrance to the building.
  - 5.9.1. The building including the building envelope, HVAC systems, service water heating, power, and lighting systems shall meet the Mandatory Provisions and the Prescriptive Path requirements of ASHRAE 90.1-2004. Substantiation requirements are defined in Section 01 33 16, Design After Award.
  - 5.9.2. Design all building systems and elements to meet the minimum requirements of ANSI/ASHRAE/IESNA 90.1-2004. Design the buildings, including the building envelope, HVAC systems, service water heating, power, and lighting systems to achieve an energy consumption that is at least 30% below the consumption of a baseline building meeting the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004. Energy calculation methodologies and substantiation requirements are defined in Section 01 33 16, Design After Award.\
- LEED Credit
  - EQ6.1 Controllability of Systems; Lighting
  - EQ8.1 Daylight & Views: Daylight 75% of Spaces
  - EQ8.2 Daylight & Views: Daylight 90% of Spaces
- EO 13423, sec 2(f) Day-lighting: Achieve a minimum daylight factor of 2% in 75% of all spaces occupied for critical visual tasks.
- Lighting: Natural lighting will be considered whenever possible; cost-effective lighting (ESIA 2007 Public Law 110-140 Title IV 121 Stat. 1597). General service incandescent lamps: compact fluorescent lamps and LED (ESIA 2007 Public Law 110-140 Title 3 Subtitle B 121 Stat. 1576)

**Appendix 16: Mechanical Systems**

**Appendix 16.1: Mechanical Systems Design Criteria**

1. Heating Ventilating and Air Conditioning

(a) Design Conditions:
Outdoor design weather conditions are based on engineering weather data from UFC 3-400-02 for Fort Bragg, NCl. Winter design condition is the 99% occurrence design value. Summer design condition is the 1% occurrence design value. Indoor design conditions are from UFC 3-410-01FA.

Heating Season:
Outdoor: 25 degrees F Dry Bulb.
Indoor (Storage Areas): 55 degrees F Dry Bulb;
Indoor (Maintenance Bays): 55 degrees F.
Indoor (Mechanical Room): 40 degrees F.
Indoor (Core Area): 68 degrees F.
Heating Degree Days (Base 65 F): 3107

Cooling Season:
Outdoor: 94 degrees F Dry Bulb
76 degrees F Wet Bulb.
Indoor (Core Area): 78 degrees F.
Cooling Degree Days(Base 50 F): 5007

(b) U-Values: Net
Wall = xx Btu/sf-F
Roof = xx Btu/sf-Fx

(c) Ventilation Rates (from ASHRAE 62.1):
Maintenance Bays: 1.5 cfm/sf.
Storage: 0.12 cfm/square foot, positive & 1 cfm/sf negative.
Toilets: 50 cfm/water closet/urinal, negative.
Mechanical rooms: 10/20 air changes per hour, negative.

(d) Lighting Loads (from ASHRAE 90.1):
High Bay Area: 1.7 watt/sf
Storage and Bathrooms Areas: 1.0 watts/sf

General: Outdoor and indoor design conditions shall be in accordance with UFC 3-410-01FA. The Administration Building occupied areas will be maintained at 75°F in summer with 50 percent relative humidity and 72 °F in winter. The communications and SiPRNT rooms will be maintained at 72 F/ 50% RH year round. The Readiness Buildings will be maintained at 82 F in the summer and 55 F in the winter. The communications and SiPRNT rooms will be maintained at 72 F and 50% relative humidity all year.

**Appendix 16.2: Ducts and Pipes (TBD)**

**Appendix 16.2.1: Ducts and Pipes Insulation and Seal Levels**

Duct and pipes convey heated or cooled fluids (air, water, or other fluids) from HVAC or service water heating equipment to the place where that fluid is used in the building. Section 109 of the Energy Policy Act of 2005 sets the absolute minimum duct and piping requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.

Standard 90.1-2007 provides one type of requirement for ducts and pipes – mandatory:

- Ducts, plenums, and piping must be insulated (Section 6.4.4.1.1).
- Duct should be sealed. (Section 6.4.4.2)
- Service hot water piping insulation should be insulated. (Section 7.4.3)

ASHRAE Advanced Energy Design Guides have developed a set of requirements, including ducts and pipes, for buildings that are considerably more stringent than Standard 90.1-2007, although not necessarily 30% better as required for Federal agencies.

For ducts, the Advanced Energy Design Guides impose four additional requirements on ducts that will all lead to increased energy savings:

1. Low friction rate for ducting (0.08 in. w.c./1000 feet) – this reduces the energy needed to move air through the ducts.
2. Duct seal class B for all ducts – this ensures that ducts deliver the air to where it is needed
3. Ducts located in interior spaces only – this ensures that any duct leakage that does occur takes place in conditioned spaces and not to the outside air. And it reduces the need for insulation.
4. Duct insulated to R-6 – this ensures that heat gain or loss to the air in the ducts is minimized

For piping, the Advanced Energy Design Guide recommends additional service water heating piping insulation beyond what is required for Standard 90.1-2004.

When the building is located in hot and humid climates (zones 1a, 2a, and 3a), in addition to energy conservation consideration, the level of chilled and cold water pipes and supply air ducts insulation shall be designed such, that the surface temperature of the insulated pipe or duct anywhere inside the interior space of the building (including duct and pipe chases) is above the dew point, to prevent condensation and mold problems

**Appendix 16.2.2: Duct Sealing Technology**

ASHRAE Standard 189 requires that the ducts shall be sealed to a Level A, which surpasses requirements of the ASHRAE Standard 90.1.

Supply and exhaust ducts which don't meet this criteria in the buildings undergoing major retrofits shall be sealed. When the leaky supply duct passes through unconditioned space, air leaks result in a waste of heating and cooling energy. If ductwork is behind barriers, such as within a plenum above suspended ceilings, heating and cooling are not delivered effectively to occupants. In either case, more fan power is required to move air to achieve desired ambient temperatures. Leaks in exhaust ducts result either in ineffective removal of contaminants from the ventilated spaces or in more fan power. Sealing leaks saves both the energy required to heat and cool air, and the energy required to move it to occupants. It may also alleviate occupant comfort problems, if inadequate conditioned air reaches certain locations due to ductwork leakage. Aerosol duct sealing technology seals leaks from the inside out, using a process that is somewhat similar to self-sealing automobile tires.

This technology seals leaks in ductwork from the inside by pressurizing the duct system with a fog of atomized sealant particles. By temporarily blocking all of the normal exits from the duct system (as well as any coils or fans), the fog is forced to the leaks. The acceleration of the air through the leaks causes the sealant particles to leave the air stream and deposit on the leak edges. The right choice of particle size ensures duct flow rate and duct pressure so that the particles remain suspended as they travel through the duct system; thus only a very small fraction of the particles deposit on the duct walls. The Figure 3-16 shows a duct sealing system applied to a small laboratory exhaust system.

The aerosol sealing technology allows leaks that had previously been inaccessible to be sealed. Aerosol sealing has been commercially available for single-family residences since 1999, and became commercially available for large buildings in 2003 with the introduction of a new atomization technology that significantly increases sealing rates, and allows sealant to be atomized inside the ductwork instead of externally.

The technology was developed at Lawrence Berkeley Laboratory (LBNL) by Carrie and Modera (Carrie and Modera 1993, Modera et al. 1996).

The energy savings resulting from implementation of the duct sealing technology can vary considerably depending on the location, length, and condition of the ducts. Tests performed by LBNL on 10 buildings indicated an average leakage of 23% of fan flow, and showed that aerosol sealant injection sealed 87% of that leakage.

The U. S. Navy Technology Validation (TechVal) program conducted evaluation and test installations of duct sealing, and provides the following rules of thumb to help decide whether duct sealing is appropriate for a given facility:

- Laboratory Supply and Laboratory Exhaust systems are worth sealing whenever it can be confirmed that they leak because of the large flow rates, the high fan power, and the heating/cooling loads associated with 100% outside air.

- Large Office Supply systems often benefit from sealing, particularly downstream of terminal boxes, as leakage in these duct sections is often not sealed very well at initial construction.
- Constant Volume Packaged Systems are usually worth sealing as long as the ducts are located above a ceiling, and there is insulation on the ceiling. A lack of additional insulation on the roof, or the existence of vents on the roof, makes these applications even more cost effective.
- Toilet/Shower Exhaust, Ventilation Supply or Exhaust systems are often not very well sealed at initial construction and are usually worth sealing, particularly if there are multiple vertical shafts to be sealed from the same roof or penthouse (Figure 4-1).

Figure 0-1. Duct sealing system.

Energy Savings calculated by assuming a duct leakage rate (20%) and a duct sealing rate (85%) showed, that in industrial buildings with ventilation and heating needs and no cooling in summer, 17% of fan power energy and gas can be saved. energy for the industrial building prototype. With the cost of sealing the entire system estimated at $0.45/sq ft floor area, a simple payback period varies between 2.5 and 8.0 years based on the climate (Figure 4-2). In air conditioned buildings, savings in compressor power are typically much greater than fan power use, and electrical savings in hot climates are considerably higher, resulting in a shorter payback (Figure 4-2).

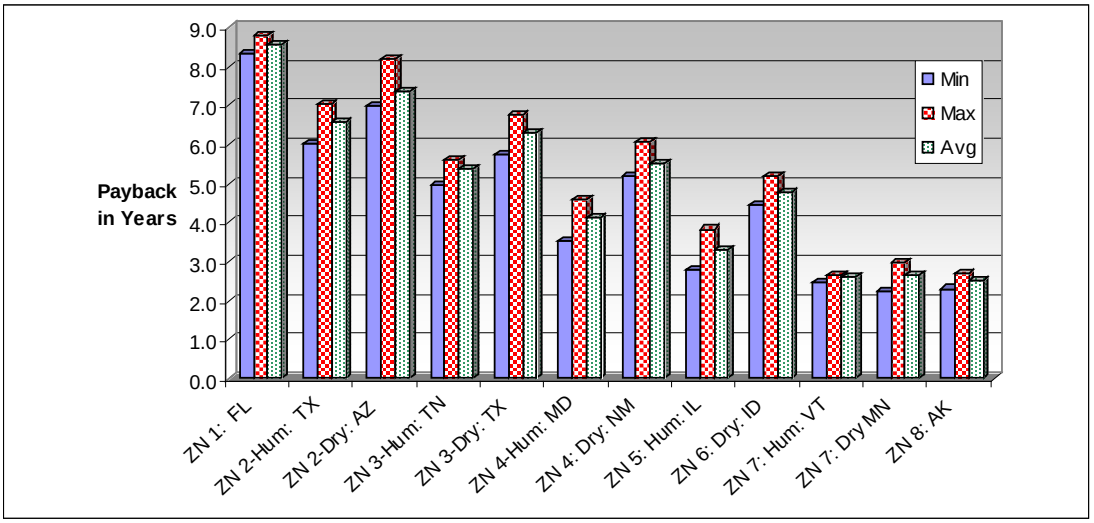



Figure 0-2. Estimated payback due to duct sealing.

The technology was developed for residential application in 1993 and for commercial application in 2003. Duct sealing technology is suitable for all climates.

***Contacts and Major Manufacturers: Xetex, RenewAire, Fantech***

# Appendix 16.3: Heating Systems

## Appendix 16.3.1: Boilers

**Appendix 16.3.1.1 Water-Tube Boilers**

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes packaged, factory-fabricated and -assembled, gas-fired, finned water-tube boilers, trim, and accessories for generating hot water.

B. This Section includes packaged, factory-fabricated and -assembled, atmospheric-gas and forced-draft gas-fired, water-tube boilers, trim, and accessories for generating hot water.

1.2 SUBMITTALS

A. Product Data: Include performance data, operating characteristics, furnished specialties, and accessories.
   1. Wiring Diagrams: Power, signal, and control wiring.

B. Field quality-control test reports.

C. Operation and maintenance data.

PART 2 - PRODUCTS

2.1 FINNED WATER-TUBE BOILERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings or a comparable product by one of the following:
   1. Bryon Boilers
   2. Laars

B. Description: Factory-fabricated, -assembled, and -tested boiler with tubes sealed into headers pressure tight, and set on a steel base; including insulated jacket, flue-gas vent, combustion-air intake connections, water supply and return connections, and controls.

C. Heat Exchanger:
   1. Finned copper or steel or copper-nickel tubing with stainless-steel baffles.
   2. Cast-iron or Steel headers.
   3. Tubes shall be sealed in header with silicone O-ring gaskets by welding or by mechanically rolling tubes in header.

D. Combustion Chamber Internal Insulation: Interlocking panels of refractory insulation, high-temperature cements, mineral fiber, and ceramic refractory tile for service temperatures to 2000 deg F

E. Casing:
   1. Jacket: Sheet metal, with snap-in or interlocking closures.
   2. Control Compartment Enclosure: NEMA 250, Type 1A.
   3. Finish: Baked enamel over primer or Baked enamel over galvanizing or Powder coated.
   4. Insulation: Minimum 1-inch- thick, mineral-fiber insulation surrounding the heat exchanger.
   5. Draft Hood: Integral.

6. Combustion-Air Connection: Inlet duct collar and sheet metal closure over burner compartment.
7. Mounting base to secure boiler with accessory for mounting on combustible surface.

F. Burner:
1. Burner Tubes and Orifices: Stainless steel, for natural and or propane gas or fuel oil.
a. Sealed Combustion: Factory-mounted centrifugal fan to draw outside air into boiler and discharge into burner compartment.
b. Direct Vent: Factory-mounted centrifugal fan to draw flue gas out of boiler and discharge into boiler vent.
2. Vertical Burner:
a. High-temperature stainless steel or Ceramic to fire in a 360-degree pattern.
b. Fan shall be controlled to prepurge and postpurge the combustion chamber before firing.
3. Gas Train: Control devices and low-high-low control sequence shall comply with requirements in AGA. In addition to these requirements, include shutoff cock, pressure regulator, and control valve.
4. Gas Train: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
5. Pilot: Intermittent-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

G. Trim:
1. Aquastat Controllers: Operating and high limit.
2. Safety Relief Valve: ASME rated.
3. Pressure and Temperature Gage: Minimum 3-1/2-inch- diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
4. Boiler Air Vent
5. Drain Valve: Minimum NPS 3/4 hose-end gate valve.
6. Circulation Pump ( where on schedule) : Non-overloading, in-line pump with split-capacitor motor having thermal-overload protection and lubricated bearings; designed to operate at specified boiler pressures and temperatures.

H. Controls:
1. Refer to UFGS 23 09 23 "LONWorks DDC for HVAC and other Local Building Systems."
2. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
a. High Cutoff: Automatic reset stops burner if operating conditions rise above maximum boiler design temperature.
b. Water Flow Switch: Automatic-reset paddle-switch shall prevent burner operation on low water flow.
c. Blocked Vent Safety Switch: Manual-reset switch factory mounted on draft diverter.

d. Rollout Safety Switch: Factory mounted on boiler combustion chamber.
e. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.

3. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
   a. A communication interface with building automation system with open protocol LON Works shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

2.2 FLEXIBLE WATER-TUBE BOILERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

C. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings or a comparable product by one of the following:
   1. AESYS Technologies, LLC.
   2. Ajax Boiler Inc.
   3. Bryan Steam, LLC.
   4. Cleaver-Brooks; div. of Aqua-Chem, Inc.
   5. Parker Boiler Company.
   6. Rite Engineering & Manufacturing Corporation.
   7. Approved Equal

D. Description: Factory-fabricated and -assembled, water-tube boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, supply and return connections, and controls.

E. Heat-Exchanger Design: Straight steel tubes rolled into steel headers.
   1. Accessible head plates at both ends.
   2. Handholes or couplings in headers for water-side inspections.
   3. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
   4. Lifting lugs on top of boiler.
   5. Built-in air separator.

F. Heat-Exchanger Design: Bent steel tubes swaged or welded into steel headers.
   1. Accessible drain and blowdown tappings, both high and low, for surface and mud removal.
   2. Accessible inspection ports in drum, mud legs, and tube manifolds.
   3. Lifting lugs on top of boiler.
   4. Built-in air separator.

G. Combustion Chamber: Equipped with minimum 3-inch2700 deg F poured refractory on floor and minimum 2-inch lap-jointed cast refractory with fiber-

blanket joint seals on side walls. Combustion chamber shall have flame observation ports .

H. Draft Diverter: Galvanized-steel assembly with flue-gas thermometer.

I. Burner:

1. Burner and Orifices: Rated for natural gas or oil.
2. Gas Train: Control devices and full-modulation or low-high-low control sequence shall comply with requirements in ASME.
3. Gas Train: Combination gas valve with manual shutoff, pressure regulator, and pilot adjustment.
4. Pilot: Intermittent-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.

J. Trim:

1. Aquastat Controllers: Operating and high limit.
2. Safety Relief Valve: ASME rated.
3. Pressure and Temperature Gage: Minimum 3-1/2-inch- diameter, combination water-pressure and -temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
4. Boiler Air Vent: Automatic] or Manual.
5. Drain Valve: Minimum NPS 3/4 hose-end gate valve.

K. Controls:

1. Refer to UFGS 23 09 23 "LONWorks DDC for HVAC and other Local Building Systems."
2. Building Automation System Interface: Factory install hardware and software to enable building automation system using LON Works open protocol to monitor, control, and display boiler status and alarms.

## 2.3 ELECTRICAL POWER

A. Single-Point Field Power Connection: Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.

## 2.4 VENTING KITS

A. Vent Damper: Motorized, UL listed for use on atmospheric burner boiler equipped with draft hood; motor to open and close damper; stainless-steel vent coupling and damper blade; keyed wiring harness connector plug; and dual-position switches to permit burner operation.

# PART 3 - EXECUTION

## 3.1 BOILER INSTALLATION

A. Install boilers level on concrete base

B. Install gas-fired boilers according to manufacturer’s instructions.

C. Assemble and install boiler trim.

D. Install electrical devices furnished with boiler but not specified to be factory mounted.

E. Install control wiring to field-mounted electrical devices.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to boiler to allow service and maintenance.

C. Connect gas piping to boiler gas-train inlet with union. Piping shall be at least full size of gas train connection. Provide a reducer if required.

D. Connect hot-water piping to supply- and return-boiler tappings with shutoff valve and union or flange at each connection.

E. Install piping from safety relief valves to nearest floor drain.

F. Install piping from equipment drain connection to nearest floor drain. Piping shall be at least full size of connection. Provide an isolation valve if required.

G. Boiler Flue Venting:

1. Install venting kit and combustion-air intake.
2. Connect full size to boiler connections.

H. Connect breeching to full size of boiler outlet.

I. Connect wiring according to Division 26.

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. Perform installation and startup checks according to manufacturer's written instructions.
2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
   a. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and water temperature.
   b. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

C. Remove and replace malfunctioning units and retest as specified above.

3.4 DEMONSTRATION

A. Engage a factory-authorized service representative to train. Owner's maintenance personnel to adjust, operate, and maintain boilers.

## Appendix 16.3.2: Radiant Floor Heating

Low intensity hydronic radiant floor heating systems are commonly used in industrial facilities, hangars, warehouses, garages, gymnasiums, hospitals, kindergartens, apartments, and in different other types of buildings. Heat to the space is provided by hot water supplied through pipes embedded in floors. Thermal energy is exchanged by at least 50% by radiation between the room and people present in the space and the heated floor surface. Transfer from the hot water pipes to the surface of the floor is the important consideration. Figure 16-14 shows the installation of plastic piping for a radiant floor heating system, and Figure 16-15 shows a radiant floor heating system installed in a TEMF at Fort Lewis, WA.

The uniform temperature distribution from floor heating increases comfort and reduces room air temperature stratification especially in high ceiling buildings. Low intensity radiant heating provides greater comfort for mechanics working near or on the floor. Radiant energy transmitted to the cold (sometimes snow-covered) vehicles results in rapid conditioning of the vehicles for service, which improves workers' productivity and adds to their comfort.

Figure 0-3. Installation of plastic piping for the radiant floor heating system (Uponor, 2007)

Figure 0-4. Radiant floor heating system installed in a TEMF at Fort Lewis, WA.

Radiant floor systems are more energy efficient.

1. Compared to warm air heating systems traditionally used in TEMF, a radiant floor system provides the same comfort level in the working zone at a lower room air temperature during the heating season. This results in reduced ventilation and infiltration losses.
2. In hydronic radiant floor systems, energy is transported by water instead of air. Auxiliary energy for circulation pumps is less than for fans.
3. The system uses lower water temperature for heating, than the warm air heating systems. This allows for using return water for radiant floor system, which increases energy performance of boilers (condensing boilers) and heat pumps.
4. Reduced air temperature stratification along the room height results in heating energy saving, typically at least by 25 to 30 percent.

With the introduction of polybutelene tubing and new design techniques, as well as reduced energy losses due elimination of room air temperature stratification, the first cost of radiant floor system became comparable or even lower than the warm air system.

Application of radiant floor systems requires under the slab insulation with 2 in. of EPS insulation (R-10) for climate zones 1 to 7 and 3 in. (R-15) for climate zone 8 (Figure 16-16).

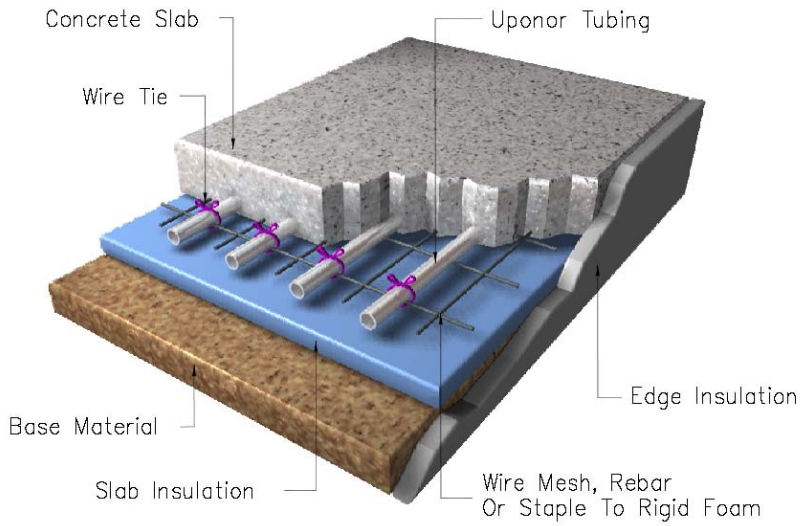



Figure 0-5. Concrete floor radiant heating system with edge and slab insulation (Uponor 2008).

**Appendix 16.4: Cooling Systems**

Cooling Systems. ASHRAE Standard 90.1-2007 provides mandatory efficiency requirements to cooling equipment (section 6.8). Equipment must meet or exceed the seasonal energy efficiency ratio (SEER) or energy efficiency ratio (EER) for the required capacity. The cooling equipment should also meet or exceed the integrated part-load value (IPLV) where applicable. However, requirements to use in Federal Buildings only Energy Star or FEMP designated products are considerably more stringent than Standard 90.1-2007.
(http://www1.eere.energy.gov/femp/procurement/eep_requirements.html)

For central refrigeration air-conditioning systems, provide freeze protection for all exposed piping and components for outdoor packaged chiller units.

Air handling units of the single zone building cooling systems in hot and humid climates (zones 1a, 2a, and 3a) shall be designed with a reheat coil to ensure that the supply air temperature is above the dew point. Variable temperature chilled water single zone units are also not acceptable without a reheat coil.

**Appendix 16.4.1: Chillers**

**Appendix 16.4.1.1: Centrifugal Water Chillers**

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

1.2 SUMMARY

A. Section Includes:
   1. Packaged, water-cooled, electric-motor-driven centrifugal chillers.

1.3 DEFINITIONS

A. BAS: Building automation system.
B. COP: Coefficient of performance. The ratio of the rate of heat removal to the rate of energy input using consistent units for any given set of rating conditions.
C. EER: Energy-efficiency ratio. The ratio of the cooling capacity given in terms of Btu/h to the total power input given in terms of watts at any given set of rating conditions.
D. IPLV: Integrated part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and referenced to ARI standard rating conditions.
E. kW/Ton: The ratio of total power input of the chiller in kilowatts to the net refrigerating capacity in tons at any given set of rating conditions.
F. NPLV: Nonstandard part-load value. A single-number part-load efficiency figure of merit calculated per the method defined by ARI 550/590 and intended for operating conditions other than the ARI standard rating conditions.

1.4 SUBMITTALS

A. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
   1. Performance at ARI standard conditions and at conditions indicated.
   2. Performance at ARI standard unloading conditions.
   3. Refrigerant capacity of chiller..
   4. Characteristics of safety relief valves.
   5. Minimum entering condenser-fluid temperature.
B. LEED Submittal:
   1. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
C. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.
   1. Detail equipment assemblies and indicate dimensions, weights, load

distribution, required clearances, method of field assembly, components, and location and size of each field connection.

2. Wiring Diagrams: For power, signal, and control wiring.

D. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Structural supports.
2. Piping roughing-in requirements.
3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

E. Operation and Maintenance Data: For each chiller to include in emergency, operation, and maintenance manuals.

1.5 QUALITY ASSURANCE

A. ARI Rating: Rate chiller performance according to requirements in ARI 550/590.

B. ASHRAE Compliance:

1. ASHRAE 15 for safety code for mechanical refrigeration.
2. ASHRAE 147 for refrigerant leaks, recovery, and handling and storage requirements.

C. Comply with requirements of UL and UL Canada, and include label by a qualified testing agency showing compliance.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Ship each chiller with a full charge of refrigerant. Charge each chiller with nitrogen if refrigerant is shipped in containers separate from chiller.

B. Ship each oil-lubricated chiller with a full charge of oil.

1.7 COORDINATION

A. Coordinate sizes and locations of concrete bases with actual equipment provided.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Manufacturers:

1. Trane; a division of American Standard.

2.2 MANUFACTURED UNIT

A. Description: Factory-assembled and -tested chiller complete with compressor, compressor motor, compressor motor controller, evaporator, condenser, controls, interconnecting unit piping and wiring, and indicated accessories.

2.3 COMPRESSOR-DRIVE ASSEMBLY

A. Description: Single-stage or multistage, variable-displacement, centrifugal-type compressor driven by an electric motor.

B. Compressor:
1. Casing: Cast iron, precision ground.
2. Impeller: High-strength cast aluminum or cast-aluminum alloy on carbon- or alloy-steel shaft.

C. Compressor Motor:
1. Continuous-duty, squirrel-cage, induction-type, two-pole motor with energy efficiency required to suit chiller energy efficiency indicated.
2. Factory mounted, aligned, and balanced as part of compressor assembly before shipping.
3. Motor shall be of sufficient capacity to drive compressor throughout entire operating range without overload and with sufficient capacity to start and accelerate compressor without damage.

D. Vibration Balance: Balance chiller compressor and drive assembly to provide a precision balance that is free of noticeable vibration over the entire operating range.
1. Overspeed Test: 25 percent above design operating speed.

E. Service: Easily accessible for inspection and service.
1. Compressor's internal components shall be accessible without having to remove compressor-drive assembly from chiller.
2. Provide lifting lugs or eyebolts attached to casing.

F. Capacity Control: Modulating, variable-inlet, guide-vane assembly to achieve performance indicated.
1. Chillers with variable frequency controllers shall modulate compressor speed with variable-inlet, guide-vane control to achieve optimum energy efficiency.

## 2.4 REFRIGERATION

A. Refrigerant:
1. Type: R-123 or R-134a
2. Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.

B. Refrigerant Flow Control: Manufacturer's standard refrigerant flow-control device satisfying performance requirements indicated.

C. Pressure Relief Device:
1. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
2. For Chillers Using R-123: Rupture disc constructed of frangible carbon.
3. For Chillers Using R-134a: ASME-rated, spring-loaded, pressure relief valve; single- or multiple-reseating type. Pressure relief valve(s) shall be provided for each heat exchanger. Condenser shall have dual valves with one being redundant and configured to allow either valve to be replaced without loss of refrigerant.

D. Purge System:
1. For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic purge system for collection and return of refrigerant and lubricating oil and for removal of noncondensables including, but not limited to, water, water vapor, and noncondensable gases.
2. System shall be a thermal purge design, refrigerant or air cooled, equipped with a carbon filter that includes an automatic regeneration cycle.
3. Factory wire to chiller's main power supply and system complete with controls, piping, and refrigerant valves to isolate the purge system from the chiller.
4. Construct components of noncorrodible materials.
5. Controls shall interface with chiller control panel to indicate modes of operation, set points, data reports, diagnostics, and alarms.
6. Efficiency of not more than 0.02 lb of refrigerant per pound of air when rated according to ARI 580.
7. Operation independent of chiller per ASHRAE 147.

E. Positive-Pressure System:
1. For chillers operating at subatmospheric pressures (using R-123 refrigerant), factory install an automatic positive-pressure system.
2. During nonoperational periods, positive-pressure system shall automatically maintain a positive pressure for atmosphere in the refrigerant pressure vessel of not less than 0.5 psig (adjustable) up to a pressure that remains within the vessel design pressure limits.
3. System shall be factory wired and include controller, electric heat, pressure transmitter, or switch.

2.5 EVAPORATOR

A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from condenser.

B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.

C. Designed to prevent liquid refrigerant carryover from entering compressor.

D. Provide evaporator with sight glass or other form of positive visual verification of liquid-refrigerant level.

E. Tubes:
1. Individually replaceable from either end and without damage to tube sheets and other tubes.
2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.

F. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.

G. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting

in abrasion and wear.

H. Water Box:
1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standardtype for water box with piping connections. Standard type for water box without piping connections.
3. Provide water boxes with lifting lugs or eyebolts.
4. Nozzle Pipe Connections: Grooved for mechanical-joint coupling.
5. Thermistor or RTD temperature sensor factory installed in each nozzle.

2.6 CONDENSER

A. Description: Shell-and-tube design with water in tubes and refrigerant surrounding tubes within shell. Shell is separate from evaporator.
B. Shell Material: Carbon-steel rolled plates with continuously welded seams or seamless pipe.
C. Designed to prevent direct impingement of high-velocity hot gas from compressor discharge on tubes.
D. Provide condenser with sight glass or other form of positive visual verification of refrigerant charge and condition.
E. Tubes:
1. Individually replaceable from either end and without damage to tube sheets and other tubes.
2. Mechanically expanded into end sheets and physically attached to intermediate tube sheets.
F. End Tube Sheets: Continuously welded to each end of shell; drilled and reamed to accommodate tubes with positive seal between fluid in tubes and refrigerant in shell.
G. Intermediate Tube Sheets: Installed in shell and spaced along length of tube at intervals required to eliminate vibration and to avoid contact of tubes resulting in abrasion and wear.
H. Water Box:
1. Cast-iron or carbon-steel construction; arranged to provide visual inspection and cleaning of tubes from either end without disturbing refrigerant in shell.
2. Standard] type for water box with piping connections. Standard type for water box without piping connections.
3. Provide water boxes with lifting lugs or eyebolts.
4. Nozzle Pipe Connections: Grooved for mechanical-joint coupling.
5. Thermistor or RTD temperature sensor factory installed in each nozzle.

2.7 INSULATION

A. Closed-cell, flexible elastomeric thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
1. Thickness: 3/4 inch.
B. Adhesive: As recommended by insulation manufacturer.

C. Factory-applied insulation over all cold surfaces of chiller capable of forming condensation. Components shall include, but not be limited to, evaporator shell and end tube sheets, evaporator water boxes including nozzles, refrigerant suction pipe from evaporator to compressor, cold surfaces of compressor, refrigerant-cooled motor, and auxiliary piping.
   1. Apply adhesive to 100 percent of insulation contact surface.
   2. Before insulating steel surfaces, prepare surfaces for paint, and prime and paint as indicated for other painted components. Do not insulate unpainted steel surfaces.
   3. Seal seams and joints to provide a vapor barrier.

2.8 VARIABLE FREQUENCY CONTROLLER

A. Motor controller shall be factory mounted and wired on the chiller to provide a single-point, field-power termination to the chiller and its auxiliaries.
B. Description: NEMA ICS 2; listed and labeled as a complete unit and arranged to provide variable speed by adjusting output voltage and frequency.
C. Enclosure: Unit mounted, NEMA 250, Type 1, with hinged full-front access door with lock and key.
D. Integral Disconnecting Means: Door-interlocked, NEMA AB 1, instantaneous-trip circuit breaker with lockable handle.
E. Motor Protection: Controller shall protect motor against overvoltage and undervoltage, phase loss, reverse phase, overcurrent, overtemperature, and ground fault.
F. Automatic Reset and Restart: Capable of three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Controller shall be capable of automatic restart on phase-loss and overvoltage and undervoltage trips.
G. Operator Interface: At controller or chiller control panel; with start-stop and auto-manual selector with manual-speed-control potentiometer.

2.9 CONTROLS

A. Control: Standalone and microprocessor based, with all memory stored in nonvolatile memory so that reprogramming is not required on loss of electrical power.
B. Enclosure: Unit mounted, NEMA 250, Type 1 , hinged or lockable; factory wired with a single-point, field-power connection and a separate control circuit.
C. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units selectable through the interface, display the following information:
   1. Date and time.
   2. Operating or alarm status.
   3. Fault history with not less than last 10 faults displayed.
   4. Set points of controllable parameters.

5. Trend data.
6. Operating hours.
7. Number of chiller starts.
8. Entering- and leaving-fluid temperatures of evaporator and condenser.
9. Difference in fluid temperatures of evaporator and condenser.
10. Refrigerant pressures in evaporator and condenser.
11. Refrigerant saturation temperature in evaporator and condenser shell.
12. Compressor refrigerant suction and discharge temperature.
13. Compressor bearing temperature.
14. Motor bearing temperature.
15. Motor winding temperature.
16. Oil temperature.
17. Oil discharge pressure.
18. Phase current.
19. Percent of motor rated load amperage.
20. Phase voltage.
21. Demand power (kilowatts).
22. Energy use (kilowatt-hours).
23. Power factor.
24. For chillers equipped with variable frequency controllers and harmonic filters, include the following:
    a. Output voltage and frequency.
    b. Voltage total harmonic distortion for each phase.
    c. Supply current total demand distortion for each phase.
    d. Inlet vane position.
    e. Controller internal ambient temperature.
    f. Heatsink temperature.
25. Purge suction temperature if purge system is provided.
26. Purge elapsed time if purge system is provided.

D. Control Functions:
1. Manual or automatic startup and shutdown time schedule.
2. Entering and leaving chilled-water temperatures, control set points, and motor load limits.
3. Current limit and demand limit.
4. Condenser-fluid temperature.
5. External chiller emergency stop.

E. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:
1. Low evaporator fluid temperature.
2. Low evaporator pressure or temperature; high condenser pressure.
3. Low oil differential pressure.
4. High or low oil pressure.
5. High oil temperature.
6. High compressor-discharge temperature.

7. Loss of condenser-fluid flow.
8. Loss of evaporator fluid flow.
9. Motor overcurrent.
10. Motor overvoltage.
11. Motor undervoltage.
12. Motor phase reversal.
13. Motor phase failure.
14. Sensor- or detection-circuit fault.
15. Processor communication loss. Motor controller fault.
16. Extended compressor surge.
17. Excessive air-leakage detection for chillers using R-123 refrigerant.

F. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
G. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
H. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
I. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.

2.10 FINISH

A. Paint chiller, using manufacturer's standard procedures.

2.11 ACCESSORIES

A. Flow Switches:
1. Chiller manufacturer shall furnish a switch for each condenser .
2. Paddle Flow Switches:
a. Vane operated to actuate a double-pole, double-throw switch with one pole field wired to the chiller control panel and the other pole field wired to the BAS.
b. Contacts: Platinum alloy, silver alloy, or gold-plated switch contacts with a rating of 10 A at 120-V ac.
c. Pressure rating equal to pressure rating of heat exchanger.
d. Construct body and wetted parts of Type 316 stainless steel.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Examine chillers before installation.
B. Examine roughing-in for equipment support, anchor-bolt sizes and locations, piping, and electrical connections to verify actual locations, sizes, and other conditions affecting chiller performance, maintenance, and operations before equipment installation.
1. Final chiller locations indicated on Drawings are approximate. Determine

exact locations before roughing-in for piping and electrical connections.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 CHILLER INSTALLATION

A. Equipment Mounting: Install chiller on concrete bases.
B. Maintain manufacturer's recommended clearances for service and maintenance.
C. Charge chiller with refrigerant and fill with oil if not factory installed.
D. Install separate devices furnished by manufacturer and not factory installed.

3.3 CONNECTIONS

A. Comply with requirements for piping specified in Division 23 Section "Hydronic Piping". Drawings indicate general arrangement of piping, fittings, and specialties.
B. Install piping adjacent to chiller to allow service and maintenance.
C. Refrigerant Pressure Relief Device Connections: For chillers installed indoors, extend vent pipingto the outdoors without valves or restrictions. . Connect to chiller pressure relief device with flexible connector and dirt leg per manufacturer’s instructions..

3.4 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.
   1. Complete installation and startup checks according to manufacturer's written instructions.
   2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
   3. Verify that pumps are installed and functional.
   4. Verify that thermometers and gages are installed.
   5. Operate chiller for run-in period.
   6. Check bearing lubrication and oil levels.
   7. Verify that refrigerant pressure relief device is vented outside.
   8. Verify proper motor rotation.
   9. Verify static deflection of vibration isolators, including deflection during chiller startup and shutdown.
   10. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser.
   11. Verify and record performance of chiller protection devices.
   12. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.
B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.
C. Prepare test and inspection startup reports.
D. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain chillers.

**Appendix 16.4.1.2: Scroll Water Chillers**

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes: Packaged, air-cooled, electric-motor-driven, scroll water chillers.

1.2 SUBMITTALS

A. Product Data: Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.
B. LEED Submittal: Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.
C. Startup service reports.
D. Operation and maintenance data.

1.3 QUALITY ASSURANCE

A. ARI Certification: Certify chiller according to ARI 590 certification program.
B. ARI Rating: Rate water chiller performance according to requirements in ARI 550/590, "Water Chilling Packages Using the Vapor Compression Cycle."
C. ASHRAE Compliance: ASHRAE 15 for safety code for mechanical refrigeration.
D. Comply with NFPA 70.

PART 2 - PRODUCTS

2.1 PACKAGED AIR-COOLED WATER CHILLERS

A. Basis-of-Design Product:
   1. Trane.
B. Description: Factory-assembled and run-tested water chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.
C. Fabricate base, frame, and attachment to water chiller components strong enough to resist movement during a seismic event when water chiller base is anchored to field support structure.
D. Cabinet:
   1. Base: Galvanized-steel base extending the perimeter of water chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
   2. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported from base.
   3. Casing: Galvanized steel.
   4. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500 hour salt-spray test according to ASTM B 117.

E. Compressors:
   1. Description: Positive-displacement direct drive with hermetically sealed casing.
   2. Each compressor provided with suction and discharge service valves, crankcase oil heater, and suction strainer.
   3. Operating Speed: Nominal 3600 rpm for 60-Hz applications.
   4. Capacity Control: On-off compressor cycling.
   5. Oil Lubrication System: Automatic pump with strainer, sight glass, filling connection, filter with magnetic plug, and initial oil charge.
   6. Vibration Isolation: Mount individual compressors on vibration isolators.
F. Compressor Motors:
   1. Hermetically sealed and cooled by refrigerant suction gas.
   2. High-torque, two-pole induction type with inherent thermal-overload protection on each phase.

G. Compressor Motor Controllers:
   1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing.
H. Refrigeration:
   A. Refrigerant R-410a.
   B. Refrigerant Compatibility: Parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   C. Refrigerant Circuit: Each circuit shall include a thermal-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor suction and discharge shutoff valves, a liquid-line shutoff valve, a replaceable-core filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
   D. Refrigerant Isolation: Factory install positive shutoff isolation valves in the compressor discharge line and the refrigerant liquid-line to allow the isolation and storage of the refrigerant charge in the chiller condenser.
I. Evaporator:
   1. Brazed-plate or shell-and-tube design, as indicated.
   2. Shell and Tube:
      a. Description: Direct-expansion, shell-and-tube design with fluid flowing through the shell and refrigerant flowing through the tubes within the shell.
      b. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
      c. Shell Material: Carbon steel.
      d. Shell Heads: Removable carbon-steel heads with multipass baffles designed to ensure positive oil return and located at each end of the tube bundle.
      e. Shell Nozzles: Fluid nozzles located along the side of the shell and terminated with mechanical-coupling end connections for connection to field piping.
      f. Tube Construction: Individually replaceable copper tubes with

enhanced fin design, expanded into tube sheets.

3. Brazed Plate:
   a. Direct-expansion, single-pass, brazed-plate design.
   b. Type 316 stainless-steel construction.
   c. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code.
   d. Fluid Nozzles: Terminate with mechanical-coupling end connections for connection to field piping.
4. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to minus 20 deg F
5. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.

J. Air-Cooled Condenser:
1. Plate-fin coil with integral subcooling on each circuit, rated at 450 psig
   a. Construct coils of copper tubes mechanically bonded to aluminum fins.
   b. Coat coils with a baked epoxy corrosion-resistant coating after fabrication.
   c. Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.

2. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
3. Fan Motors: Totally enclosed nonventilating (TENV) or totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings, and having built-in overcurrent- and thermal-overload protection.
4. Fan Guards: Steel safety guards with corrosion-resistant coating.

K. Electrical Power:
1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to water chiller.
2. House in a unit-mounted, NEMA 250, enclosure with hinged access door with lock and key or padlock and key.
3. Wiring shall be numbered and color-coded to match wiring diagram.
4. Install factory wiring outside of an enclosure in a raceway.
5. Field power interface shall be to nonfused disconnect switch.
6. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
   a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
   b. NEMA KS 1, heavy-duty, nonfusible switch.
   c. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit trip coordinated with motor locked-rotor amperes.
7. Provide each motor with overcurrent protection.
8. Overload relay sized according to UL 1995, or an integral component of

water chiller control microprocessor.

9. Phase-Failure and Undervoltage: Solid-state sensing with adjustable settings.
10. Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
    a. Power unit-mounted controls where indicated.
    b. Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.
11. Control Relays: Auxiliary and adjustable time-delay relays.
12. Indicate the following for water chiller electrical power supply:
    a. Current, phase to phase, for all three phases.
    b. Voltage, phase to phase and phase to neutral for all three phases.
    c. Three-phase real power (kilowatts).
    d. Three-phase reactive power (kilovolt amperes reactive).
    e. Power factor.
    f. Running log of total power versus time (kilowatt hours).
    g. Fault log, with time and date of each.

L. Controls:
1. Stand-alone, microprocessor based.
2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure of matching construction.
3. Operator Interface: Keypad or pressure-sensitive touch screen. Multiple-character, backlit, liquid-crystal display or light-emitting diodes
4. Control Functions:
    a. Manual or automatic startup and shutdown time schedule.
    b. Entering and leaving chilled-water temperatures, control set points, and motor load limit. .
    c. Current limit and demand limit.
    d. External water chiller emergency stop.
    e. Antirecycling timer.
    f. Automatic lead-lag switching.
5. Manual-Reset Safety Controls: The following conditions shall shut down water chiller and require manual reset:
    a. Low evaporator pressure or high condenser pressure.
    b. Low chilled-water temperature.
    c. Refrigerant high pressure.
    d. High or low oil pressure.
    e. High oil temperature.
    f. Loss of chilled-water flow.
    g. Control device failure.

M. Insulation:
1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I, for tubular materials and Type II, for sheet materials.
2. Thickness: 3/4 inch
3. Factory-applied insulation over cold surfaces of water chiller components.
    a. Adhesive: As recommended by insulation manufacturer and applied to

100 percent of insulation contact surface. Seal seams and joints.

4. Apply protective coating to exposed surfaces of insulation.

N. Accessories:

1. Factory-furnished, chilled water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigeration circuit.
3. Factory-furnished neoprene isolators for field installation.

PART 3 - EXECUTION

3.1 WATER CHILLER INSTALLATION

A. Install water chillers on support structure indicated.
B. Equipment Mounting: Install water chiller on concrete bases .
   A. Install dowel rods to connect concrete base to concrete floor.
   B. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
   C. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   D. Install anchor bolts to elevations required for proper attachment to supported equipment.
C. Equipment Mounting: Install water chiller on concrete bases.
D. Maintain manufacturer's recommended clearances for service and maintenance.
E. Charge water chiller with refrigerant if not factory charged and fill with oil if not factory installed.
F. Install separate devices furnished by manufacturer and not factory installed.

3.2 CONNECTIONS

A. Comply with requirements in Division 23 Section "Hydronic Piping" Drawings indicate general arrangement of piping, fittings, and specialties.
B. Install piping adjacent to chiller to allow service and maintenance.
C. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve. Connect to evaporator outlet with shutoff valve, balancing valve and drain connection with valve. Provide a shutoff valve at each connection if required.

3.3 STARTUP SERVICE

A. Perform startup service.
B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
C. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
   1. Verify that refrigerant charge is sufficient and water chiller has been leak tested.
   2. Verify that pumps are installed and functional.
   3. Verify that thermometers and gages are installed.
   4. Operate water chiller for run-in period.
   5. Check bearing lubrication and oil levels.

6. Verify proper motor rotation.
7. Verify static deflection of vibration isolators, including deflection during water chiller startup and shutdown.
8. Verify and record performance of chilled-water flow and low-temperature interlocks.
9. Verify and record performance of water chiller protection devices.
10. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

D. Prepare a written startup report that records results of tests and inspections.

**Appendix 16.4.1.3: Rotary-Screw Water Chillers**

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:

1. Packaged, air-cooled chillers.

1.2 PERFORMANCE REQUIREMENTS

A. Seismic Performance: Chillers shall withstand the effects of earthquake motions determined according to IBC 2006

B. Site Altitude: Chiller shall be suitable for altitude in which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude.

1.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.

B. LEED Submittal:

1. Product Data for Credit EA 4: Documentation required by Credit EA 4 indicating that equipment and refrigerants comply.

C. Startup service reports.

D. Operation and maintenance data.

1.4 QUALITY ASSURANCE

A. ARI Certification: Certify chiller according to [ARI 550] [and] [ARI 590] certification program(s).

B. ARI Rating: Rate chiller performance according to requirements in ARI 550/590.

C. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1-2004

D. ASME Compliance: Fabricate and label chiller to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1, and include an ASME U-stamp and nameplate certifying compliance.

E. Comply with NFPA 70.

F. Comply with requirements of UL and UL Canada and include label by a qualified testing agency showing compliance.

PART 2 - PRODUCTS

2.1 PACKAGED, AIR-COOLED CHILLERS

A. Basis-of-Design Product:

1. Trane; a division of American Standard.

B. Description: Factory-assembled and run-tested chiller complete with base and frame, condenser casing, compressors, compressor motors and motor controllers, evaporator, condenser coils, condenser fans and motors, electrical power, controls, and accessories.

C. Fabricate base, frame, and attachment to chiller components strong enough to

resist chiller movement during a seismic event when chiller base is anchored to field support structure.

D. Cabinet:
    1. Base: Galvanized-steel base extending the perimeter of chiller. Secure frame, compressors, and evaporator to base to provide a single-piece unit.
    2. Frame: Rigid galvanized-steel frame secured to base and designed to support cabinet, condenser, control panel, and other chiller components not directly supported by base.
    3. Casing: Galvanized steel.
    4. Finish: Coat base, frame, and casing with a corrosion-resistant coating capable of withstanding a 500 hour salt-spray test according to ASTM B 117.

E. Compressors:
    1. Description: Positive displacement, hermetically sealed.
    2. Casing: Cast iron, precision machined for minimum clearance about periphery of rotors.
    3. Rotors: Manufacturer's standard one- or two-rotor design.
    4. Each compressor provided with discharge shutoff valves, crankcase oil heater, and suction strainer.

F. Service: Easily accessible for inspection and service.

G. Capacity Control: On-off compressor cycling and modulating slide-valve assembly or port unloaders combined with hot-gas bypass, if necessary, to achieve performance indicated.
    1. Maintain stable operation throughout range of operation. Configure to achieve most energy-efficient operation possible.
    2. Operating Range: From 100 to 20 percent of design capacity.
    3. For units equipped with a variable frequency controller, capacity control shall be both "valveless" and "stepless," requiring no slide valve or capacity-control valve(s) to operate at reduced capacity.

H. Oil Lubrication System: Consisting of pump if required, filtration, heater, cooler, factory-wired power connection, and controls.
    1. Provide lubrication to bearings, gears, and other rotating surfaces at all operating, startup, shutdown, and standby conditions including power failure.
    2. Thermostatically controlled oil heater properly sized to remove refrigerant from oil.
    3. Factory-installed and pressure-tested piping with isolation valves and accessories.
    4. Oil compatible with refrigerant and chiller components.
    5. Positive visual indication of oil level.

I. Vibration Control:
    1. Vibration Balance: Balance chiller compressors and drive assemblies to provide a precision balance that is free of noticeable vibration over the entire operating range.
    2. Isolation: Mount individual compressors on vibration isolators.

J. Compressor Motors:
   1. Hermetically sealed and cooled by refrigerant suction gas.
   2. High-torque, induction type with inherent thermal-overload protection on each phase.
K. Compressor Motor Controllers:
   1. Across the Line: NEMA ICS 2, Class A, full voltage, nonreversing
   2. Star-Delta, Reduced-Voltage Controller: NEMA ICS 2, closed transition.
      a. Motor current at start shall not exceed the rated load amperes, providing no electrical inrush.
L. Refrigerant Circuits:
   1. Refrigerant: Type as indicated on Drawings.
   2. Refrigerant Type: R-134a.. Classified as Safety Group A1 according to ASHRAE 34.
   3. Refrigerant Compatibility: Chiller parts exposed to refrigerants shall be fully compatible with refrigerants, and pressure components shall be rated for refrigerant pressures.
   4. Refrigerant Circuit: Each shall include a thermal- or electronic-expansion valve, refrigerant charging connections, a hot-gas muffler, compressor and discharge shutoff valves, a liquid-line shutoff valve, a filter-dryer, a sight glass with moisture indicator, a liquid-line solenoid valve, and an insulated suction line.
   5. Pressure Relief Device:
      a. Comply with requirements in ASHRAE 15 and in applicable portions of ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
      b. ASME-rated, spring-loaded pressure relief valve; single- or multiple-reseating type.
M. Evaporator:
   1. Description: Shell-and-tube design.
      a. Direct-expansion (DX) type with fluid flowing through the shell, and refrigerant flowing through the tubes within the shell.
      b. Flooded type with fluid flowing through tubes and refrigerant flowing around tubes within the shell.
   2. Code Compliance: Tested and stamped according to ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
   3. Shell Material: Carbon steel.
   4. Shell Heads: Removable carbon-steel heads located at each end of the tube bundle.
   5. Fluid Nozzles: Terminated with mechanical-coupling end connections for connection to field piping.
   6. Tube Construction: Individually replaceable copper tubes with enhanced fin design, expanded into tube sheets.
   7. Heater: Factory-installed and -wired electric heater with integral controls designed to protect the evaporator to minus 20 deg F.
   8. Remote Mounting: Designed for remote field mounting where indicated. Provide kit for field installation.

N. Air-Cooled Condenser:
   1. Plate-fin coil with integral subcooling on each circuit, rated at 450 psig.
      a. Construct coil casing of galvanized.
      b. Construct coils of copper tubes mechanically bonded to aluminum fins.
      c. Coat coils with a baked-epoxy, corrosion-resistant coating after fabrication.
      d. Hail Protection: Provide condenser coils with louvers, baffles, or hoods to protect against hail damage.
   2. Fans: Direct-drive propeller type with statically and dynamically balanced fan blades, arranged for vertical air discharge.
   3. Fan Motors: Totally enclosed totally enclosed air over (TEAO) enclosure, with permanently lubricated bearings. Equip each motor with overload protection integral to either the motor or chiller controls.
   4. Fan Guards: Steel safety guards with corrosion-resistant coating.

O. Electrical Power:
   1. Factory-installed and -wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point, field-power connection to chiller.
   2. House in a unit-mounted, NEMA 250 enclosure with hinged access door.
   3. Wiring shall be numbered to match wiring diagram.
   4. Install factory wiring outside of an enclosure in a raceway.
      a. Disconnect means shall be interlocked with door operation.
      b. Minimum withstand rating shall be as required by electrical power distribution system.
   5. Provide branch power circuit to each motor and to controls with one of the following disconnecting means:
      a. NEMA KS 1, heavy-duty, fusible switch with rejection-type fuse clips rated for fuses. Select and size fuses to provide Type 2 protection according to IEC 60947-4-1.
      b. NEMA AB 1, motor-circuit protector (circuit breaker) with field-adjustable, short-circuit-trip set point.
   6. Provide each motor with overcurrent protection.
   7. Overload relay sized according to UL 1995 or an integral component of chiller control microprocessor.
   8. Phase-Failure and Undervoltage Relays: Solid-state sensing with adjustable settings.
   9. Provide power factor correction capacitors to correct power factor to 0.90 at full load.
   10. Control Transformer: Unit-mounted transformer with primary and secondary fuses and sized with enough capacity to operate electrical load plus spare capacity.
      a. Power unit-mounted controls where indicated.
      b. Power unit-mounted, ground fault interrupt (GFI) duplex receptacle.
   11. Control Relays: Auxiliary and adjustable time-delay relays.
   12. For chiller electrical power supply, indicate the following:

a. Current and phase to phase for all three phases.
b. Voltage, phase to phase, and phase to neutral for all three phases.
c. Three-phase real power (kilowatts).
d. Three-phase reactive power (kilovolt amperes reactive).
e. Power factor.
f. Running log of total power versus time (kilowatt-hours).
g. Fault log, with time and date of each.

P. Controls:

1. Standalone and microprocessor based.
2. Enclosure: Share enclosure with electrical power devices or provide a separate enclosure.
3. Operator Interface: Multiple-character digital or graphic display with dynamic update of information and with keypad or touch-sensitive display located on front of control enclosure. In either imperial or metric units, display the following information:

h. Date and time.
i. Operating or alarm status.
j. Operating hours.
k. Outdoor-air temperature if required for chilled-water reset.
l. Temperature and pressure of operating set points.
m. Entering and leaving temperatures of chilled water.
n. Refrigerant pressures in evaporator and condenser.
o. Saturation temperature in evaporator and condenser.
p. No cooling load condition.
q. Elapsed time meter (compressor run status).
r. Pump status.
s. Antirecycling timer status.
t. Percent of maximum motor amperage.
u. Current-limit set point.
v. Number of compressor starts.

4. Control Functions:

a. Manual or automatic startup and shutdown time schedule.
b. Entering and leaving chilled-water temperatures, control set points, and motor load limits.
c. Current limit and demand limit.
d. External chiller emergency stop.
e. Antirecycling timer.

5. Manually Reset Safety Controls: The following conditions shall shut down chiller and require manual reset:

a. Low evaporator pressure or high condenser pressure.
b. Low chilled-water temperature.
c. Refrigerant high pressure.

d. High or low oil pressure.
e. High oil temperature.
f. Loss of chilled-water flow.

6. Trending: Capability to trend analog data of up to five parameters simultaneously over an adjustable period and frequency of polling.
7. Security Access: Provide electronic security access to controls through identification and password with at least three levels of access: view only; view and operate; and view, operate, and service.
8. Control Authority: At least four conditions: Off, local manual control at chiller, local automatic control at chiller, and automatic control through a remote source.
9. BAS Interface: Factory-installed hardware and software to enable the BAS to monitor, control, and display chiller status and alarms.

a. Hardwired Points:
1) Monitoring: On-off status.
2) Control: On-off operation.

b. ASHRAE 135 LonTalk communication interface with the BAS shall enable the BAS operator to remotely control and monitor the chiller from an operator workstation. Control features and monitoring points displayed locally at chiller control panel shall be available through the BAS.

Q. Insulation:
1. Material: Closed-cell, flexible elastomeric, thermal insulation complying with ASTM C 534, Type I for tubular materials and Type II for sheet materials.
2. Thickness: 3/4 inch
3. Factory-applied insulation over cold surfaces of chiller components.
a. Adhesive: As recommended by insulation manufacturer and applied to 100 percent of insulation contact surface. Seal seams and joints.
4. Apply protective coating to exposed surfaces of insulation to protect insulation from weather.

R. Accessories:
1. Factory-furnished, chilled-water flow switches for field installation.
2. Individual compressor suction and discharge pressure gages with shutoff valves for each refrigerant circuit.
3. Factory-furnished neoprene isolators for field installation.

PART 3 – EXECUTION

3.1 CHILLER INSTALLATION
A. Install chillers on support structure indicated.
B. Equipment Mounting: Install chiller on concrete bases.
C. Maintain manufacturer's recommended clearances for service and maintenance.
D. Charge chiller with refrigerant and fill with oil if not factory installed.
E. Install separate devices furnished by manufacturer and not factory installed.

3.2 CONNECTIONS

a. Comply with requirements for piping specified in Division 23 Section "Hydronic Piping. Drawings indicate general arrangement of piping, fittings, and specialties.

b. Install piping adjacent to chiller to allow service and maintenance.

c. Evaporator Fluid Connections: Connect to evaporator inlet with shutoff valve . Connect to evaporator outlet with shutoff valve, balancing valve, flow switch, plugged tee with shutoff valve and drain connection with valve. Make connections to chiller with a flange or mechanical coupling.

3.3 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify that refrigerant charge is sufficient and chiller has been leak tested.
3. Verify that pumps are installed and functional.
4. Verify that thermometers and gages are installed.
5. Operate chiller for run-in period.
6. Check bearing lubrication and oil levels.
7. Verify proper motor rotation.
8. Verify and record performance of fluid flow and low-temperature interlocks for evaporator and condenser.
9. Verify and record performance of chiller protection devices.
10. Test and adjust controls and safeties. Replace damaged or malfunctioning controls and equipment.

B. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assembly, installation, and connection.

Prepare test and inspection startup reports.

**Appendix 16.4.2: Cooling Towers**

PART 1 - GENERAL

1.1 SUMMARY

A. Section Includes:
   1 Open-circuit, induced-draft, cross flow cooling towers.
   2 Condenser water solid separator

1.2 PERFORMANCE REQUIREMENTS

A. Structural Performance: Cooling tower support structure shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated according to IBC-2006,

B. Seismic Performance: Cooling towers shall withstand the effects of earthquake motions determined according to SEI/ASCE

1.3 SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, pressure drop, fan performance data, rating curves with selected points indicated, furnished specialties, and accessories.
B. Startup service reports.
C. Operation and maintenance data.
D. Warranty.

1.4 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
B. CTI Certification: Cooling tower thermal performance according to CTI STD 201, "Certification Standard for Commercial Water-Cooling Towers Thermal Performance."

PART 2 – PRODUCTS

2.1 OPEN-CIRCUIT, INDUCED-DRAFT, CROSSFLOW COOLING TOWERS

A. Products:
   1. Baltimore Aircoil Company; Series 3000.
B. Fabricate cooling tower mounting base with reinforcement strong enough to resist cooling tower movement during a seismic event when cooling tower is anchored to field support structure. Cooling tower designed to resist wind load of 30 lbf/sq. ft.Casing and Frame:
   1 Casing Material Galvanized steel, ASTM A 653/A 653M, G235 coating.
   2 Frame Material: Galvanized steel, ASTM A 653/A 653M, G235 coating. Fasteners: Galvanized or Stainless steel depending upon metal being fastened
   3 Joints and Seams: Sealed watertight.
   4 Welded Connections: Continuous and watertight.

C. Collection Basin:
   1 Material: Stainless steel.
   2 Removable stainless-steel strainer with openings sized smaller than nozzle orifices.
   3 Overflow and drain connections.
   4 Makeup water connection.
   5 Outlet Connection: ASME B16.5, Class 150 flange.
D. Mechanically Operated, Collection Basin Water-Level Control: Manufacturer's standard adjustable, mechanical float assembly and valve, one in each cold water basin.
E. Electric Basin Heater:
   1 Electric Immersion Heaters: Installed in a threaded coupling on the side of the collection basin.
   2 BAC to provide heater elements, sump thermostat and low water cut-out only. Control panel, magnetic contactors, disconnect switches, transformer, terminal blocks, circuit breakers, internal or external wiring are all provided by others. [Heater Control Panel: Mounted on the side of each cooling tower cell.
   3 Enclosure: NEMA 250, Type 3R
   4 Magnetic contactors controlled by a temperature sensor/controller to maintain collection basin water-temperature set point. Water-level probe shall monitor cooling tower water level and de-energize the heater when the water reaches low-level set point.
   5 Control-circuit transformer with primary and secondary side fuses.
   6 Terminal blocks with numbered and color-coded wiring to match wiring diagram.
   7 Field-power connection to a disconnect switch disconnect switch and heater branch circuiting complying with NFPA 70.
   8 Factory Wiring Method: Metal raceway for factory-installed wiring outside of enclosures, except make connections to each electric basin heater with liquidtight conduit.
F. Gravity Water Distribution Basin: Nonpressurized design with head of water level in basin adequate to overcome spray nozzle losses and designed to evenly distribute water over fill throughout the flow range indicated.
   1 Material [Galvanized steel, ASTM A 653/A 653M, G235 coating.
   2 Location: Over each bank of fill with easily replaceable plastic spray nozzles mounted in bottom of basin.
   3 Inlet Connection: ASME B16.5, Class 150 flange.
   4 Joints and Seams: Sealed watertight.
   5 Partitioning Dams: Same material as basin to distribute water over the fill to minimize icing while operating throughout the flow range indicated.
   6 Removable Panels: Same material as basin to completely cover top of basin. Secure panels to basin with removable corrosion-resistant hardware.
   7 Valves: Manufacturer's standard valve installed at each bottom inlet connection and arranged to balance flow to each gravity distribution basin.
   8 Single-Inlet, Field Pipe Connection: PVC pipe arranged to provide balancing of flow within cooling tower cell without the need for additional

balancing valves. Pipe each cooling tower cell internally to a single, field connection suitable for mating to a grooved coupling and located inside each cooling tower cell with access from the bottom] unless otherwise indicated.

G. Fill:
1 Materials: PVC, with maximum flame-spread index of [5] > according to ASTM E 84.
2 Minimum Thickness: 15 mils before forming.
3 Fabrication: Fill-type sheets, fabricated, formed, and bonded together after forming into removable assemblies that are factory installed by manufacturer.
4 Fill Material Operating Temperature: Suitable for entering-water temperatures up through 130 deg F

H. Drift Eliminator:
1 Material: PVC with maximum flame-spread index of [5] according to ASTM E 84.
2 UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3 Configuration: Multipass, designed and tested to reduce water carryover to achieve performance indicated.
4 Location: Integral to fill.

I. Air-Intake Louvers:
1 Material: Matching casing.
2 UV Treatment: Inhibitors to protect against damage caused by UV radiation.
3 Louver Blades: Arranged to uniformly direct air into cooling tower, to minimize air resistance, and to prevent water from splashing out of tower during all modes of operation including operation with fans off.
4 Location: Separate from fill.

J. Axial Fan: Balanced at the factory after assembly.
1 Blade Material: Aluminum.
2 Hub Material: Aluminum.
3 Blade Pitch: Field adjustable.
4 Fan Shaft Bearings: Self-aligning ball bearings with moisture-proof seals and premium, moisture-resistant grease . Bearings designed for an L-10 life of 40,000 hours.
5 Bearings Grease Fittings: Extended lubrication lines to an easily accessible location.

K. Belt Drive:
1 Service Factor: 1.0based on motor nameplate horsepower.
2 Sheaves: Fan and motor shafts shall have taper-lock sheaves fabricated from corrosion-resistant materials.
3 Belt: One-piece, multigrooved, solid-back belt.

L. Fan Motor:
1 General Requirements for Fan Motors: Comply with NEMA designation and temperature-rating requirements specified in Division 23 Section "Common Motor Requirements for HVAC Equipment" and not indicated below.
2 Motor Enclosure: Totally enclosed air over (TEAO) Energy Efficiency:

NEMA Premium Efficient.

3 Service Factor: 1.00 Insulation: Class F.

4 Variable-Speed Motors: Inverter-duty rated per NEMA MG-1, Section IV, "Performance Standard Applying to All Machines," Part 31, "Definite-Purpose, Inverter-Fed, Polyphase Motors."

5 Motor Base: Adjustable, or other suitable provision for adjusting belt tension.

6 Fan Discharge Cowl: Material shall match casing, Stack Termination: Wire-mesh, galvanized-steel screens; complying with OSHA regulations.

M. Vibration Switch: For each fan drive.

1 Enclosure: NEMA 250, Type 4

2 Vibration Detection: Mechanical switch with a field-adjustable set point in a range of .22.0 0 to 3600 cycles per minute. Cooling tower manufacturer shall recommend switch set point for proper operation and protection by making initial setting at start-up.

3 Provide switch with manual-reset button and hardwired connection to fan motor electrical circuit.

4 Switch shall, on sensing excessive vibration, signal an alarm through the BMS and shut down the fan.

N. Personnel Access Components:

1 Doors: Large enough for personnel to access cooling tower internal components from both cooling tower end walls. Doors shall be operable from both sides of the door.

2 External Ladders with Safety Cages: Aluminum fixed ladders with ladder extensions to access top of cooling tower from adjacent grade without the need for portable ladders. Comply with 29 CFR 1910.27.

3 Handrail: , galvanized steel, complete with knee rail and toe board, around top of cooling tower to safeguard personnel while accessing components located on top of cooling tower. Comply with 29 CFR 1910.23.

4 Internal Platforms: galvanized-steel bar grating.

a. Spanning the collection basin from one end of cooling tower to the other and positioned to form a path between the access doors. Platform shall be elevated so that all parts are above the high water level of the collection basin.

2.2 CONDENSER WATER SOLID SEPARATOR:

A. Products:

1. Puroflux PF64-050 or approved equal

B. Fabricate the solid separator with fusion bonded polyester coated vessel rated to 100PSI with manual bleed valve.

1 Pump: Close couples end suction centrifugal pump with TEFCmotor.g.

2 Skid: Fusion bonded polyester coated carbon steel.

3 Electrical Controls: Starter w/ overload/short circuit protection in NEMA- 4 X fiberglass enclosure.

4 Automatic purge: Electrically activated ball valve with adjustable pulse timer.

C. Interconnecting pipe: Schedule 80 PVC.

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install cooling towers on support structure indicated.
B. Equipment Mounting: Install cooling tower on concrete piers. Comply with requirements for concrete base in Division 03 Section.
C. Install anchor bolts to elevations required for proper attachment to supported equipment.
D. Maintain manufacturer's recommended clearances for service and maintenance.
E. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.

3.2 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
B. Install piping adjacent to cooling towers to allow service and maintenance.
C. Install flexible pipe connectors at pipe connections of cooling towers mounted on vibration isolators.
D. Provide drain piping with valve at cooling tower drain connections and at low points in piping.
E. Connect cooling tower overflows and drains, and piping drains to sanitary sewage system.
F. Domestic Water Piping: Comply with applicable requirements in Division 22 . Connect to water-level control with shutoff valve and union, flange, or mechanical coupling at each connection.
G. Supply and Return Piping: Comply with applicable requirements in Division 23 Section "Hydronic Piping." Connect to entering cooling tower connections with shutoff valve, plugged tee and drain connection with valve. Connect to leaving cooling tower connection with shutoff valve. Make connections to cooling tower with a union, flange, or mechanical coupling.

3.3 FIELD QUALITY CONTROL

A. Perform tests and inspections.

3.4 STARTUP SERVICE

A. Inspect field-assembled components, equipment installation, and piping and electrical connections for proper assemblies, installations, and connections.
B. Obtain performance data from manufacturer.
    1. Complete installation and startup checks according to manufacturer's written instructions and perform the following:
        a. Clean entire unit including basins.
        b. Verify that accessories are properly installed.
        c. Verify clearances for airflow and for cooling tower servicing.
        d. Lubricate bearings.

e. Verify fan rotation for correct direction and for vibration or binding and correct problems.
f. Adjust belts to proper alignment and tension.
g. Operate variable-speed fans through entire operating range and check for harmonic vibration imbalance. Set motor controller to skip speeds resulting in abnormal vibration.
h. Check vibration switch setting. Verify operation.
i. Verify water level in tower basin. Fill to proper startup level. Check makeup water-level control and valve.
j. Verify operation of basin heater and control.
k. Verify that cooling tower air discharge is not recirculating air into tower or HVAC air intakes. Recommend corrective action.
l. Replace defective and malfunctioning units.

C. Start cooling tower and associated water pumps. Follow manufacturer's written starting procedures.
D. Prepare a written startup report that records the results of tests and inspections.

3.5 ADJUSTING

A. Set and balance water flow to each tower inlet.
B. Adjust water-level control for proper operating level.

3.6 DEMONSTRATION

Train the Owner's maintenance personnel to adjust, operate, and maintain cooling towers.

**Appendix 16.4.3: HVAC Water Treatment**

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following HVAC water-treatment systems:
   1 Bypass chemical-feed equipment and controls.
   2 Biocide chemical-feed equipment and controls.
   3 Chemical treatment test equipment.
   4 HVAC water-treatment chemicals.

1.2 PERFORMANCE REQUIREMENTS

A. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or the environment.
B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
C. Closed hydronic systems, including hot-water heating and chilled water shall have the following water qualities:
   1. pH: Maintain a value within 9.0 to 10.5.
   2. "P" Alkalinity: Maintain a value within 100 to 500 ppm.
   3. Boron: Maintain a value within 100 to 200 ppm.
   4. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
   5. Soluble Copper: Maintain a maximum value of 0.20 ppm.
   6. TDS: Maintain a maximum value of 10 ppm.
   7. Ammonia: Maintain a maximum value of 20 ppm.
   8. Free Caustic Alkalinity: Maintain a maximum value of 20 ppm.
   9. Microbiological Limits:
      a. Total Aerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
      b. Total Anaerobic Plate Count: Maintain a maximum value of 100 organisms/ml.
      c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
      d. Sulfate Reducers: Maintain a maximum value of 0. organisms/ml.
      e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.
D. Open hydronic systems, including condenser water, shall have the following water qualities:

   1. pH: Maintain a value within 8.0 to 9.1.
   2. "P" Alkalinity: Maintain a maximum value of 100 ppm.
   3. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
   4. Soluble Copper: Maintain a maximum value of 0.20 ppm.

5. TDS: Maintain a maximum value of 10 ppm.
6. Ammonia: Maintain a maximum value of 20 ppm.
7. Free "OH" Alkalinity: Maintain a maximum value of 0 ppm.
8. Microbiological Limits:
   a. Total Aerobic Plate Count: Maintain a maximum value of 10,000 organisms/ml.
   b. Total Anaerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
   c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
   d. Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.
   e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.
9. Polymer Testable: Maintain a minimum value within 10 to 40.

E. Passivation for Galvanized Steel: For the first 60 days of operation.
   1 pH: Maintain a value within 7 to 8.
   2 Calcium Carbonate Hardness: Maintain a value within 100 to 300 ppm.
   3 Calcium Carbonate Alkalinity: Maintain a value within 100 to 300 ppm.

## 1.3 SUBMITTALS

A. Product Data: For each type of product indicated.

B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems. Include plans, elevations, sections, details, and attachments to other work.
   1. Wiring Diagrams: Power and control wiring.

C. Field quality-control test reports.

D. Other Informational Submittals:
   1 Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in the "Performance Requirements" Article above.
   2 Water Analysis: Illustrate water quality available at Project site.
   3 Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to Architect.

## 1.4 QUALITY ASSURANCE

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

## PART 2 - PRODUCTS

### 2.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    1. Ampion Corp.
    2. Anderson Chemical Co, Inc.
    3. Aqua-Chem, Inc.; Cleaver-Brooks Div.
    4. Barclay Chemical Co.; Water Management, Inc.
    5. Boland Trane Services.
    6. GE Betz.
    7. GE Osmonics.
    8. H-O-H Chemicals, Inc.
    9. Metro Group. Inc. (The); Metropolitan Refining Div.
    10. ONDEO Nalco Company.
    11. Watcon, Inc.
    12. Approved equal.

### 2.2 MANUAL CHEMICAL-FEED EQUIPMENT

A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.
    1 Capacity: 5 gal..
    2 Minimum Working Pressure: 125 psig

### 2.3 AUTOMATIC CHEMICAL-FEED EQUIPMENT

A. Water Meter:
    1 AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
    2 Body: Bronze.
    3 Maximum Pressure Loss at Design Flow: 3 psig
    4 Registration: Gallons
    5 Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.
B. Inhibitor Injection Timers:
    1. Microprocessor-based controller with LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface with the DDC system using LONWorks in Division 23 Section "Instrumentation and Control for HVAC."

2. Programmable timers with infinite adjustment over full range, and mounted in cabinet with hand-off-auto switches and status lights.
3. Test switch.
4. Hand-off-auto switch for chemical pump.
5. Illuminated legend to indicate feed when pump is activated.
6. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
7. LCD makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.

C. pH Controller:

1 Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface with the DDC system using LONWorks as described in Division 23 Section "Instrumentation and Control for HVAC."

2 Digital display and touch pad for input.

3 Sensor probe adaptable to sample stream manifold.

4 High, low, and normal pH indication.

5 High or low pH alarm light, trip points field adjustable; with silence switch.

6 Hand-off-auto switch for acid pump.

7 Internal adjustable hysteresis or deadband.

D. TDS Controller:

1 Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door Interface with the DDC system using LONWorks as described in Division 23 Section "Instrumentation and Control for HVAC."]

2 Digital display and touch pad for input.

3 Sensor probe adaptable to sample stream manifold.

4 High, low, and normal conductance indication.

5 High or low conductance alarm light, trip points field adjustable; with silence switch.

6 Hand-off-auto switch for solenoid bleed-off valve.

7 Bleed-off valve activated indication.

8 Internal adjustable hysteresis or deadband.

9. Bleed Valves:

a. Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.

E. Biocide Feeder Timer:

1. Microprocessor-based controller with digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door Interface with the DDC system using LONWorks as described in Division 23 Section "Instrumentation and Control for HVAC."
2. 24-hour timer with 14-day skip feature to permit activation any hour of day.
3. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide pump timer. Prebleed and bleed lockout timers.

4. Solid-state alternator to enable use of two different formulations.
5. 24-hour display of time of day.
6. 14-day display of day of week.
7. Battery backup so clock is not disturbed by power outages.
8. Hand-off-auto switches for biocide pumps.
9. Biocide A and Biocide B pump running indication.

F. Chemical Solution Tanks:
   1 Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
   2 Molded cover with recess for mounting pump.
   3 Capacity: 30 gal.

G. Chemical Solution Injection Pumps:
   1. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
   2. Adjustable flow rate.
   3. Metal and thermoplastic construction.
   4. Built-in relief valve.
   5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

H. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints.

I. Injection Assembly:
   1 Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
   2 Ball Valve: [Three] [Two]-piece, stainless steel; selected to fit quill.
   3 Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
   4 Assembly Pressure/Temperature Rating: Minimum 200 psig at 200 deg F

## 2.4 CHEMICAL TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TDS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers, and oxidizing biocide test for open cooling systems.

B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.
   1. Two station rack for closed-loop systems.
   2. Four station rack for open systems.

## 2.5 CHEMICALS

A. Chemicals shall be as recommended by water-treatment system manufacturer that are compatible with piping system components and connected equipment,

and that can attain water quality specified in Part 1 "Performance Requirements" Article.

B. Water Softener Chemicals:
   1 Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum 30,000 grains/cu. ft. of calcium carbonate of resin when regenerated with 15 lb of salt.
   2 Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are not acceptable.

PART 3 - EXECUTION

3.1 WATER ANALYSIS

Perform an analysis of supply water to determine quality of water available at Project site.

3.2 INSTALLATION

A. Install chemical application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
B. Install water testing equipment on wall near water chemical application equipment.
C. Install interconnecting control wiring for chemical treatment controls and sensors.
D. Mount sensors and injectors in piping circuits.
E. Bypass Feeders: Install in closed hydronic systems, including hot-water heating and chilled water , and equipped with the following:
   1 Install bypass feeder in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   2 Install water meter in makeup water supply.
   3 Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   4 Install a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
   5 Install a swing check on inlet after the isolation valve.
F. Install automatic chemical-feed equipment for condenser water and include the following:
   1. Install makeup water softener.
   2. Install water meter in makeup water supply.
   3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.

a. Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.

4. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
5. Install TDS controller with sensor and bleed valves.
   a. Bleed valves shall cycle to maintain maximum TDS concentration.
6. Install pH sensor and controller with injection pumps and solution tanks.
   a. Injector pumps shall operate to maintain required pH.
7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.

a. Injection pumps shall operate to feed biocide on an alternating basis.

## 3.3 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
B. Install piping adjacent to equipment to allow service and maintenance.
C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Division 23 Section "Hydronic Piping."
D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Division 23 Section "Hydronic Piping."

Refer to Division 22 Section "Plumbing" for backflow preventers required in makeup water connections to potable-water systems.

## 3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
B. Perform tests and inspections and prepare test reports.
   1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

C. Tests and Inspections:
   1 Inspect field-assembled components and equipment installation, including piping and electrical connections.
   2 Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational

before introducing chemicals for water-treatment system.

3 Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.

4 Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.

5 Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.

6 Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.

7 Repair leaks and defects with new materials and retest piping until no leaks exist.

D. Remove and replace malfunctioning units and retest as specified above.

E. Comply with ASTM D 3370 and with the following standards:

1 Silica: ASTM D 859.

2 Acidity and Alkalinity: ASTM D 1067.

3 Iron: ASTM D 1068.

4 Water Hardness: ASTM D 1126.DEMONSTRATION

F. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

**Appendix 16.5: Misc. Equipment**

**Appendix 16.5.1: Motors, Pumps, Air Compressors, etc.**

1. New and replacement electrical equipment and appliances shall be in the top 25% of the energy efficient products available, as recommended by the following products web site http://www.energystar.gov/index.c£m?c=home.index. This site also provides tools to help activities analyze product lifecycle costs. Less energy efficient products may be purchased only when their life-cycle costs are more than 15% less than the most efficient products. These requirements apply to anyone buying equipment including Government credit card holders.

2. Motor belt tension and alignment shall be checked immediately after installation, and periodically thereafter, to ensure efficient operation. Alignment between motor shaft, coupling, and the drive shaft of pumps shall also be checked. Personnel shall ensure that motor and/or shaft bearings are properly lubricated and that all V-belts on motors shall be notched. Replace individual multiple belts with ganged web belts.

3. The use of variable speed drives in HVAC is encouraged when determined to be applicable to the system design and cost effective through life cycle cost analysis.

4. Power factor controllers shall be installed in electrical circuits where advantageous.

5. New and replacement 400 HZ motor-generators shall be equipped with solid state frequency converters meeting required Military Standard (MIL-STD) specifications.

6. Rewinding of less energy efficient motors is prohibited.

7. All pumps and motors shall be operated in the Auto mode. Switching these systems to the Hand or Manual mode of operation is prohibited.

8. All pumps, motors and air compressors shall be connected to the Building Automation System for control, status and alarm monitoring.

**Appendix 16.6: Ground Source Heat Pumps (GSHP)**

- Ground Coupled Heat Pumps (GCHPs), Ground Source Heat Pumps (GSHPs), Geoexchange Heat Pumps (GxHPs) are common terms for geothermal (geo = ground, thermal = energy) systems that are employed for cooling and heating of facilities.
- These systems use the ground as a source of energy for heating (taking the heat of the ground and delivering it to the facility) and a sink of energy for cooling (taking the heat of the facility and delivering it to the ground).
- Across Fort Bragg at depths beyond approximately 15 feet below ground surface, the ground is at a fairly steady temperature of 65F (18C).
- Vertical closed loop systems are generally the best type to employ at Fort Bragg.
- These systems typically use 25% to 50% less electricity than conventional heating or cooling systems.

Fort Bragg Ground Source Heat Pump thermal conductivity test results. Test were conducted July 12 – July 20, 2004.
Five test bores were drilled and 1” u-bends were installed to depths of 130 – 200 feet:
200’
178’
158’
200’
130’

The line source method was utilized to determine the formation thermal conductivity at each bore. The formation thermal conductivity at each bore was determined to be:
1.37 Btu/h-ft-°F
1.46 Btu/h-ft-°F
1.49 Btu/h-ft-°F
1.38 Btu/h-ft-°F
1.20 Btu/h-ft-°F

In order to provide necessary information for the design calculations, an attempt was made to estimate the thermal diffusivity. The thermal diffusivity of the formation at each bore hole is estimated to be:
0.90 $ft^2$/day
0.93 $ft^2$/day
0.94 $ft^2$/day
0.90 $ft^2$/day
0.76 $ft^2$/day

The undisturbed soil temperature at each bore was determined from the loop water temperature at system start-up, and was observed to be:
67.0° F
66.5° F
66.8° F
64.2° F
67.3° F

**Appendix 16.6.1: Ground Source Heat Pump SOW**

Scope Overview

Building X-XXXX: Complete installation of 100% Geothermal HVAC system including demo of existing equipment.

The current system will be removed and replaced with a system that is 100% geothermal. The new system will consist of water-to-water heat pumps and a four-pipe fan coil system with factory mounted controls. It will also include a new ventilation system consisting of a VAV air handling unit with heating and cooling coils served by the water-to-water heat pump(s), VAV boxes, and ductwork. The building control system will be Open LonWorks that will be fully integrated into the base wide UMCS. New controls and modified electrical system will be installed as required to complete new work.

This building will remain occupied while we are working.

**General Requirements (All):**

***Scheduling***

Review construction schedule. Address any concerns that may cause delay immediately in writing. Coordinate with other trades to prevent conflicts, maintain quality and adhere to overall job schedule.

***Submittals***

Submittals are to be in binders with complete table of contents and tabbed sections. Where multiple parts or part variations are shown on the same page, item to be supplied must be clearly marked. Submittals are to be received by the Contracting Officer, within 15 days of contract issuance. Commencement of work prior to acceptance of submittals will be at the risk of the performing subcontractor. Items that are not accepted will change accordingly.

Six copies of submittals are required on the following:

- Valves
- Hydronic Specialties
- Pressure Gauges
- Thermometers
- Insulation
- Diffusers
- Starters
- Disconnects
- Service Panels
- Transformers
- Balancing Valves

***O&M Manuals***

Equipment manuals are to be in binders with complete table of contents and tabbed sections. Where multiple parts or part variations are shown on the same page, item to be supplied must be clearly marked. Manuals are to be received by the Contracting Officer within 15 days of substantial completion.

***Wage Scale***

This project will fall under prevailing wage rules and regulations.

***As-Built Documentation***

All construction documents such as blueprints, sketches, or design drawings shall be maintained and kept current as follows:

- Highlight completed work to reflect current progress of installation
- Red mark all field modifications and post-design changes to reflect actual locations, layout, and installation of all system equipment and components
- As-built documentation shall include (but not limited to) valve schedule and final electrical source legend
- Submit final project as-built documentation to the Contracting Officer within 15 days of substantial completion.

***Project Overview***

The general scope of this project is to replace the existing HVAC system with a new geothermal system as described by the following scope.

- Vertical Wells and Pipe Installation
- Horizontal Pipe Installation
- Mechanical
- Electrical
- Control Installation

**Vertical Wells and Pipe Installation Scope:**

1. Install a complete geothermal well field according to the following criteria:
    - A vertical well field
    - Each well shall be 250 feet deep
    - Spacing between wells shall be a minimum of 20 feet on center
    - A vault is **not** required
    - Each bore hole shall be a minimum of 6" diameter
    - Each well shall contain (1) 1-1/4" SDR 11 U-Bend and sufficient excess to tie into horizontal well field piping.
    - Geothermal pipe shall be HDPE pipe.
    - Fusing pipe shall adhere to manufacturer's recommendations
    - Pipe to be hydrostatically tested at a pressure no greater than 150% of pipe pressure rating prior to backfilling. Compressed air or gas is prohibited.
    - Test all piping and document results prior to backfill. Documents shall be submitted to the Contracting Officer.
    - Installation shall be in compliance with IGSHPA standards as well as all local, state, and federal codes and regulations.
    - Flush system of debris and purge system of air. The flow rate of each pipe shall be a minimum of 2 ft. /second.
    - Provide well field layout drawings with all additional information

2. Site work responsibilities:
    - Contractor shall adhere to all Ft. Bragg and EPA rules and regulations which include but is not limited to installation of orange construction safety fence around site, silt fences, ground leveling, or other drainage accommodations. Fencing to remain until site work for entire project is complete. Refer to Fort Bragg IDG**.** Erosion control shall be properly maintained until site is turned over to the horizontal pipe installation contractor.
    - Work site shall be maintained in a professional manner. Clean up daily, maintain safety and soil erosion controls, and keep materials stored neat and orderly. Debris and material left on site without being cleanup, removed and or organized will result in a back charge to this

subcontractor for the labor involved to perform this work for you. All Trash, and materials, spoils, drill shavings etc. shall be removed from the site prior to turning the field over to the next subcontractor

- Contractor shall contact all Fort Bragg utilities as required before digging. Call for updated marking as required.
- Damage to underground utilities and communication wiring will be repaired immediately at contractor's expense.
- Backfill of bore holes shall be with # 9 limestone rock.
- Metallic marking tape shall be placed 18" below finished grade.
- Drilling spoils shall be removed from site.
- Finish site work and field markers to be complete within 90 days of backfill.
- Coordinate work with horizontal well field piping subcontractor.
- Stripping of topsoil and reseeding done with the intent to return the site to it's original condition.

3. Provide a well field map indicating locations of wells and corner markers. A sketch is allowed provided it is dimensioned accurately for ACAD reproduction.

4. Schedule of values:
    - Mobilization
    - Site preparation
    - Well drilling
    - Finish (final grading, marker install, debris removal, & final clean up)

**Horizontal Pipe Installation Scope:**

1. Install horizontal piping from geothermal well field to building according to the following criteria:
    - Install horizontal piping for wells in a reverse return layout.
    - Spacing between wells shall be a minimum of 20 feet on center
    - Geothermal pipe shall be HDPE pipe.
    - Horizontal runs of pipe shall be buried at a minimum of 4 feet to the top of piping.
    - Fusing pipe shall adhere to manufacturer's recommendations.
    - Pipe to be hydrostatically tested at a pressure no greater than 150% of pipe pressure rating. Compressed air or gas is prohibited.
    - Test all piping and document results prior to backfill. Documents shall be submitted to the Contracting Officer.
    - Installation shall be in compliance with IGSHPA standards as well as all local, state, and federal codes and regulations.
    - Flush system of debris and purge system of air. The flow rate of each pipe shall be a minimum of 2 ft. /second.
    - Backfill shall be compacted in 12" lifts
    - Provide well field layout drawings and any additional information

- Complete contractor checklist as work is performed

2. Site work responsibilities:
    - Contractor shall adhere to all Ft. Bragg and EPA rules and regulations which include but is not limited to installation of construction safety fence around site, silt fences, ground leveling, or other drainage accommodations as required. Fencing to remain until site work for entire project is complete.
    - Contractor shall contact all Fort Bragg utilities as required before digging. Call for updated markings as required
    - Damage to underground utilities and communication wiring will be repaired immediately at contractor's expense.
    - Metallic marking tape shall be placed 18" below finished grade.
    - Tracer wire shall be installed with piping for future locating
    - Coordinate work with vertical well drilling subcontractor.
    - Contractor is responsible for installing corner field markers. Markers shall be set in concrete at a depth that does not conflict with mowing operations.
    - Well field must be reseeding with the intent to return the site to it's original condition.

3. Schedule of values:
    - Mobilization
    - Trenching
    - Piping material
    - Piping labor
    - Backfill and final grading

**Mechanical Scope:**

1. Demolition
    - Remove the following existing equipment:
        - All other mechanical equipment per demo drawings
    - Remove existing piping, ductwork, and associated hanger systems unless noted to be abandoned or reused.
    - Remove grilles, registers, and diffusers not scheduled for reuse.

2. New work
    - Equipment installation
        - Receive, rig, unload, store and protect all new equipment
        - Install, set, or hang equipment in accordance with contract drawings and manufacturer's recommendations.
        - Furnish and install any additional material not provided with standard delivery that may be required for proper installation.
    - Ductwork

- Furnish and install all new ductwork, flex connections, hangers, supports, dampers, and any other accessories needed for complete supply, return, and ventilation systems also to compile with all fresh air requirements for this type of space.
- Duct with a depth greater than 16” or a width greater than 48” shall have a frame type connection.
- Sheet metal and duct specifications shall comply with SMCNA standards.
- Insulate as required.
- Balancing dampers required at each distribution branch.
- Install new grilles and diffusers.

- Piping
  - Furnish and install new piping, fittings, hangers, supports, isolators, valves, gauges, circuit setters and all other hydronic specialties required to provide complete functioning systems.
  - Pipe to be insulated with 1” fiberglass insulation unless otherwise indicated. Insulation to have continuous vapor barrier cover when exposed to unconditioned spaces. Exterior insulation shall be protected with a continuous, embossed, water-tight aluminum jacket.
  - Pipe shall be clearly labeled every 20’ and at every junction point. Exterior pipe identification shall be weatherproof stenciled painting.
  - Furnish and install temperature and pressure gauges on inlet and outlet to well field piping.
  - Clean and flush piping prior to system start up. System shall be flushed for a minimum of 24 hours with flushing detergent. Flush with water only. Once system is flushed, the startup strainers are to be replaced.

3. Coordination
   - Contractor shall coordinate work with other disciplines to prevent conflicts, ensure logical installation sequence, and maintain a fluid and time efficient project.

4. Quality
   - Installation will be done in a professional and workmanlike manner.
   - Equipment shall be installed square and spaced properly for maintenance access.
   - Duct and pipe systems shall be straight, plumb, and level.

5. As built drawings
   - Provide Micro-station and PDF drawings that reflect actual field installation and incorporate any addendum, sketches, or alterations from original plans.

- Drawings shall include valve schedule.

6. Schedule of values
    - Mobilization
    - Demolition
    - Geo pipe system (includes mechanical room piping, pumps, and main distribution lines)
        - Material
        - Labor
        - Insulation
    - HW/CW pipe system
        - Material
        - Labor
        - Insulation
    - WWHP(s)
        - Equipment install
        - Piping
            - Material
            - Labor
    - Fancoil units
        - Equipment install
        - Piping
            - Material
            - Labor
    - Ventilation system
        - Equipment install
        - Ductwork
            - Material
            - Labor
            - Insulation
    - Finish work
        - Diffusers, registers, & grilles
            - Material
            - Labor

**Electrical Scope:**

1. Demolition
    - Disconnect existing electrical feed to all existing equipment scheduled to be removed. Refer to mechanical scope.
    - Remove all conduits, wiring, boxes, hangers, disconnects, devises or other electrical material associated with removed equipment unless it is reused for new equipment installation.

2. New work
    - Provide necessary wiring for new heat pumps, heat recovery unit, pump station, and all other equipment described in the drawings that require electrical power.
    - Furnish and install all necessary fuses, circuit breakers, disconnects, conduit, wire, fittings, boxes, hangers, devices and any other electrical material needed for a complete and operational system.
    - Electrical wiring shall be run in EMT conduit.
    - Disconnects to equipment shall be installed so that they are easily accessible from service area of the equipment they serve.
    - All work shall comply with governing codes and standards.
    - Contractor is responsible for verifying load, phasing, voltage, and amperage capabilities of existing system are sufficient for new work and building use. Any modifications that may be required to the building services shall be outlined in the contractor's proposal and is otherwise assumed to be part of the electrical proposal.
    - Accurately label all breakers and disconnects.
    - Refer to mechanical schedules and submittals for additional electrical data.

3. Coordination
    - Contractor shall coordinate work with other disciplines to prevent conflicts, ensure logical installation sequence, and maintain a fluid and time efficient project.

4. Quality
    - Installation will be done in a professional and workmanlike manner.
    - Electrical boxes and devices will be square and accessible.
    - Conduit shall be straight, plumb, and level.

5. As Built Drawings
    - Provide Micro-Station and PDF drawings that reflect actual field installation and incorporate any addendum, sketches, or alterations from original plans.
    - Drawings shall include final electrical source legend.

6. Schedule of Values
    - Mobilization
    - Demolition
    - Equipment Power Connection (list values per following equipment):
        - WWHP(s)
        - AHU
        - Fancoils
        - Pump station
        - VAV boxes

        - Electric heaters (includes installation)
    - Other Work (any electrical devices, conduit, or wiring not directly associated with the individual power connection of the above equipment).

**Control Installation Scope:**

1. Demolition
    - Disconnect existing controls to all existing equipment scheduled to be removed.
    - Remove all conduits, wiring, boxes, hangers, compressor, thermostats, and all other control devises and material associated with removed equipment unless it is reused for new equipment installation.

2. New Work
    - Install controls system must be Open LonWorks as defined in UFGS 23 09 23 and tied into the base-wide UMCS.
    - Control system must include electrical and gas metering for the facility that is tied into the control system.
    - All fancoils, heat pumps, ventilation units, and major equipment must be tied into the control system.
    - Provide interconnecting communication wiring for new heat pumps, ERV, and central plant controllers.
    - Control contractor responsible for all source power for control, monitoring, or communication equipment.
    - Mount and wire all sensors, switches, safeties, relays, actuators, interlocks, thermostats, etc. required for a complete control system installation.
    - Provide and install all wiring for thermostats. Install thermostats.
    - Power wiring must be appropriately sized for load.
    - Entire installation must comply with applicable codes and industry standards.
    - Provide start up assistance.

3. Coordination
    - Contractor shall review drawings, submittals, and schedule. Any conflicts, discrepancies, errors, or other noticeable items that may cause potential delays or problems shall be addressed immediately.
    - Contractor shall coordinate work with other disciplines to prevent conflicts, ensure logical installation sequence, and maintain a fluid and time efficient project.

4. Quality
    - Installation will be done in a professional and workmanlike manner.
    - Electrical boxes and devices will be square and accessible.

- Conduit shall be straight, plumb, and level

5. As Built Drawings
    - Provide Micro-Station and PDF drawings that reflect actual field installation and incorporate any addendum, sketches, or alterations from original plans.

6. Schedule of Values
    - Mobilization
    - Demolition
    - Equipment Control Installation (list values per following equipment):
        - WWHP(s)
        - AHU
        - Fancoils
        - Pump station
        - VAV boxes
        - Electric heaters
    - Other Work (any control devices, conduit, or wiring not directly associated with the individual control installation of the above equipment).

**Appendix 16.7: Domestic Hot Water**

The use of hot water has a significant impact on energy consumption. Therefore, it is essential to reduce hot water use. The following should be standard procedure:

Hot Water Temperatures: The following temperatures are the authorized maximum at point of use:

1. Administrative use or general cleaning: 35 °C /95 °F.
2. Shower facilities: 43.3 °C / 110 °F.
3. Automatic dishwashing in dining facilities: 60 °C / 140 °F.
4. Final rinsing of dishes and kitchen utensils in dining and diet kitchen: 82.2 °C / 180 °F.
5. Hot water is not authorized in the following areas:
    a. Retail areas, except for food handling areas.
    b. Warehouses.

For maximum water efficiency and energy conservation:

Shower heads with a flow rate of less than 2.5 gpm shall be used. There are two basic types of low-flow showerheads: aerating and laminar-flow. Aerating showerheads mix air with water, forming a misty spray. Laminar-flow showerheads form individual streams of water. In a humid climate, use of a laminar-flow showerhead is preferable because it won't create as much steam and moisture as an aerating one;

For dishwashing, use low-flow pre-rinse spray valves with a flow rate of 1.6 gallons per minute or less, and a cleanability performance of 26 seconds per plate or less, based on the ASTM *Standard Test Method for Performance of Pre-Rinse Spray Valves*.
Cold water will be used in lieu of hot water whenever possible.
Report all water leaks to the DPW for immediate repair. A faucet dripping at the rate of one drop per second will waste 3,000 gallons of water per year.

**Appendix 16.7.1: Instantaneous DHW (TBD)**

**Appendix 16.8: Air Handling Units (TBD)**

**Appendix 16.8.1: Dedicated Outdoor Air Units (TBD)**

## Appendix 17: HVAC Controls

**1. Background.** A direct digital control (DDC) system consists of microprocessor based hardware used to control a building's mechanical and electrical systems, particularly the Heating, Ventilating and Air Conditioning (HVAC) system. While a DDC system can function independently (or standalone) at the building-level, it is usually combined with a Utility Monitoring Control System (UMCS) consisting of one or more operator workstation computers used to monitor and manage the connected DDC systems. Within the context of this document, the UMCS along with its connected DDC systems is referred to a building automation system (BAS).

A longstanding goal of most Army installations is to implement a single and cohesive post wide BAS as opposed to multiple separate and independent BASs. Unfortunately most Army Installations procure DDC systems on a case-by-case (building-by-building or system-by-system) basis where the controls are installed under separate contracts and by different contractors and without the planning, preparation and training needed to procure a successful post wide BAS. A successful BAS will:

- Provide a single user interface with a consistent "look and feel" even though it consists of DDC products from different manufacturers installed by different contractors. A key requirement is that the DDC systems must inter-operate with each other and with a UMCS through the use of an Open communications protocol.
- Be expandable without sole-source procurement and supportable over the long term without involvement of the original installing contractors.
- Use standardized and consistent control systems and strategies to achieve a degree of commonality and familiarity for designers, construction quality verification staff, and O&M personnel.
- Support the needs of the building occupants, operations and maintenance (O&M) staff, and management. Therefore it must provide reliable environmental control, be useful to the O&M staff, and provide energy savings capability and functions.

Section 109 of the Energy Policy Act of 2005 sets the absolute minimum building control requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.

### 2. Requirements and Guidance

Two unified facilities guide specifications (UFGSs) for BASs were released in 2004. The specifications are geared towards multi-vendor, interoperable, and energy efficient DDC systems that integrate with a UMCS (http://www.wbdg.org/):

- The DDC guide spec, UFGS 23 09 23 (previously UFGS 15951): Direct Digital Control for HVAC and Other Building Systems specifies controls at the building level.

- The UMCS guide spec, UFGS 25 10 10 (previously UFGS 13801): Utility Monitoring and Control System (UMCS) specifies the supervisory and post wide system.

These two specifications are intended to work together such that a single UMCS serves as a base wide interface to many building-level DDC systems, regardless of the manufacturer or installer of the building controls. Related design guidance, control system drawings and UMCS drawings are available at: https://eko.usace.army.mil/fa/bAS/

The DDC and UMCS specifications are based on LONWORKS® technology[1] including the use of ANSI/CEA standards 709.1B and 852 (sometimes referred to as LonTalk®) for Open device communications and, LONWORKS® Network Services (LNS®) network operating system in support of Open network management and the LonMark Interoperability Guidelines. These elements and requirements lead to the procurement of an Open system - one where there is no future dependence on the original installing Contractor. For the purposes of procurement, this means that there is no sole source dependence on any Contractor for future system additions, upgrades, or modifications.

The specifications include energy savings requirements in line with the requirements defined in ANSI/ASHRAE/IESNA Standard 90.1-2004.

The goal of a single BAS translates directly into the one-time procurement of a single UMCS from a single vendor. The specifications require the UMCS to be installed and licensed to the Government such that it remains Open, and in concept all future integration of DDC systems into the UMCS can be competitively procured. In practice, however, the UMCS manufacturer/installer will be best able to perform the integration of DDC systems so in many cases installations will seek to procure integration services through the installing contractor. Regardless of who is performing the integration the building-level DDC systems can and should be procured competitively. A method for procuring and then expanding the UMCS must be identified and is discussed in ERDC/CERL Technical Report TR-07-16.

Some of the benefits and capabilities of an Open multi-vendor BAS include:

- Competitive procurement, most notably at the building and sub-system level.
- Management of base-wide system operations such as: remote alarm reporting, remote scheduling (on/off control), remote set point override, data logging and reports, energy management including load shedding, utilities monitoring/measurement for the purpose of monitoring energy performance contracts, and initial diagnosis of service calls. Section 109 of the Energy Policy Act of 2005 sets the absolute minimum building control requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy

[1] The term LONWORKS® is used to loosely describe a collection of technologies (including hardware, and software), vendors and installers relating to or based on the ANSI/CEA-709.1 communications protocol

consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.

- A graphical user interface that provides for the same look and feel for monitoring and control regardless of which vendor's DDC system or sub-system an operator is viewing. As a result, system operators and managers need only become proficient with one user interface to efficiently and effectively manage base-wide operations.
- A "whole-building" or "intelligent-building" approach to systems integration where multiple building systems are integrated into one, including the efficient inter-connection of HVAC control sub-systems. For example, terminal unit equipment such as VAV boxes can be readily interfaced to the servicing air handler to turn the air handler on when needed. In addition, the whole-building approach provides the capability for integrating HVAC and non-HVAC systems such as lighting. For example, the same occupancy sensor that tells a VAV box to cool a room can also turn on the lights in the room.

## 3. Summary

Army Installation BAS design standards include the use of LONWORKS® technology, LONWORKS® Network Services, ANSI/CEA 709.1 communications protocol, and ANSI/CEA-852 communications protocol, and ANSI/ASHRAE/IESNA Standard 90.1-2004. This approach applies to all HVAC control system and energy monitoring system projects including additions and retrofits. Designers should also strive to include these standards in lighting control projects notably including those where occupancy sensors are used. Designers should consider the use of these standards for water and sanitary sewer systems, electrical systems, and other utility systems.

**Appendix 17.1: Fort Bragg UMCS Overview**

1. Points of Contact
    a. Jennifer McKenzie, Fort Bragg Energy Manager, 910-396-6371, Jennifer.McKenzie@us.army.mil.
    b. Coby Jones, UMCS System Manager (SM), 910-396-1868 office, 704-502-7575 mobile, joseph.c.jones4@us.army.mil
    c. Russ Hayes, Fort Bragg Mechanical Champion, 910-432-5093, Russ.Hayes@us.army.mil
    d. David Taylor, UMCS II Contracting Officer Representative (COR), 910-396-6682, david.taylor9@us.army.mil

2. Utility Monitoring and Control System (UMCS) Description
    a. Ft. Bragg installation UMCS is an LCS-8520 that integrates Non-Proprietary (Open) LonWorks® systems.
    b. UMCS uses the Army Enterprise System (DOIM's network) to connect the UMCS server to the individual buildings. It is on a Virtual Local Area Network (V-LAN) that does not allow communications with other network sites.
        i. UMCS only accessed through PC terminals with a V-LAN connection.
    c. Below is a brief overview of the major parts of the UMCS and building level controls. A more detailed description can be found in Appendix B, page 8.
        i. DDC – Direct Digital Control (Building Level)
            1. Building level control systems and components
            2. Building Control Network (BCN)
            3. LonWorks® Technology
        ii. UMCS – Utility Monitoring and Control System (Front-end)
            1. Central supervisory monitoring and control system
            2. Desktop computer (s) interfaced to building-level DDC systems
        iii. BAS – Building Automation System (Entire system)
            1. UMCS and DDC systems combined
    d. The UMCS ties the DDC systems within each building together to allow users to:
        i. Provide remote maintenance diagnostics
        ii. Energy Savings by controlling occupancy schedules, load shedding, and demand limiting
        iii. Monitor temperatures, CO2 levels, filter alarms
        iv. Create and view trends
        v. View energy usage
        vi. UMCS has capability to expand to monitor all building controls and Supervisory, Control and Data Acquisition Systems (SCADA)

3. Point of Demarcation (POD)
    a. The point of demarcation between the building level controls and the UMCS is the Building Point of Connectivity (BPOC) router installed by the System Integrator contractor. Currently, the Loytec LIP IP-852 and the ILON 600 are allowed by DOIM.
    b. No laptops or computers should be connected to the BPOC router without the permission of the SM.

4. Guidance and References
    *a. UMCS Integration*
        i. UFGS 25 10 10, http://wbdg.org/
    *b. Building Controls*
        *i. UFGS 23 09 23 http://wbdg.org/*
        *ii. IDG, Appendix G, page 25 http://www.bragg.army.mil/dpw/idg/index.htm*
        iii. LonMark Certification, http://www.lonmark.com/
        iv. LON Point Schedules, https://eko.usace.army.mil/fa/bas/
    c. ANSI/CEA, http://www.ce.org/Standards/2502.asp

5. Contract Language
    *a. Please reference the appropriate Appendix for specific contract language*
    b. Integration to UMCS
        i. All buildings that are integrated should use the UMCS Integration SOW contract language located in Appendix C, page 10.
        ii. All UMCS integration contracts are to be performed by Fort Bragg's System Integration Contractor. Please use the System Integrator contract process located in Appendix H, page 27.
    c. MCA Projects (Building Level)
        i. MT RFP Chapter 5 Wizard Appendix D, page 13: When using the wizard for building level controls do not select the option for a new UMCS located in 5.8.3.8 & 5.8.3.9.
        ii. MT RFP Chapter 6 Appendix E, page 19: Provides guidance for Fort Bragg only.
    *d. SRM Projects (Building Level)*
        *i. New construction and/or renovation/retrofit projects that will include HVAC changes/upgrades should use the OMA Project Building Level Controls contract language located in Appendix F, page 21.*
    e. Installation Design Guide (IDG): Appendix G, page 25

*6. Process to Contract System Integrator Contractor*
    a. Specific details are covered in Appendix H, page 27
    b. If you have questions contact the SM for assistance

7. O & M Processes
    a. Accessing the UMCS

i. All users needing access to the UMCS should have an AKO account Log-in and Password, completed the yearly Information Awareness User Training and a UMCS User ID and Password
ii. To receive a UMCS User ID and Password a request should be submitted via email to the SM
iii. Each user may have different levels of access based upon their needs
iv. Workstations are available in the DPW QSI shop

b. Request for additional workstations should be submitted via email to the SM
c. Group training will be performed on as needed bases. Individual training can be scheduled through the SM
d. Changes to the System: All graphical, descriptor changes and system edits (alarm limits, alarm messages, etc) should be submitted to the SM for review and implementation
e. Log Book: Any overrides, schedule changes, set-point changes, trends and problems will be recorded in the System Log Book located in the QSI workstation area. The SM will review these daily.
f. Alarm Reporting and Service Order creation: in the interim OMD personnel will review the alarm log daily with the System Integrator assistance and assign service orders to either the QSI shop or warranty. This function will become the System Operators responsibility at a later date.

8. Utility Meters
   a. In accordance with the Army Metering Implementation Plan any new building with Power and/or Water shall receive a Utility Meter.
   b. The meter installation is included in the General contractors SOW. General or Controls contractors will coordinate with UMCS System Manager and System Integrator as needed.
   c. Fort Bragg will utilize the UMCS system to capture this information from each building.
   d. Data collected can then be shared with our Utility Privatization contractors as well as used to implement Load Shedding and other energy saving programs
   e. Alarm limits will be programmed into the UMCS to notify personnel of power or water issues within the building.
   f. Required Utility Meter monitoring points are part of the Point Schedules that each building contractor is to provide with their submittals

9. Warranty Process
   a. Integrating a LonWorks® DDC system into the UMCS depends on the accuracy of the LNS database. Coordination between the building HVAC contractor, DPW personnel, Government Project Manager (PM) and the SM is critical during the Warranty Period.
   b. LNS database management

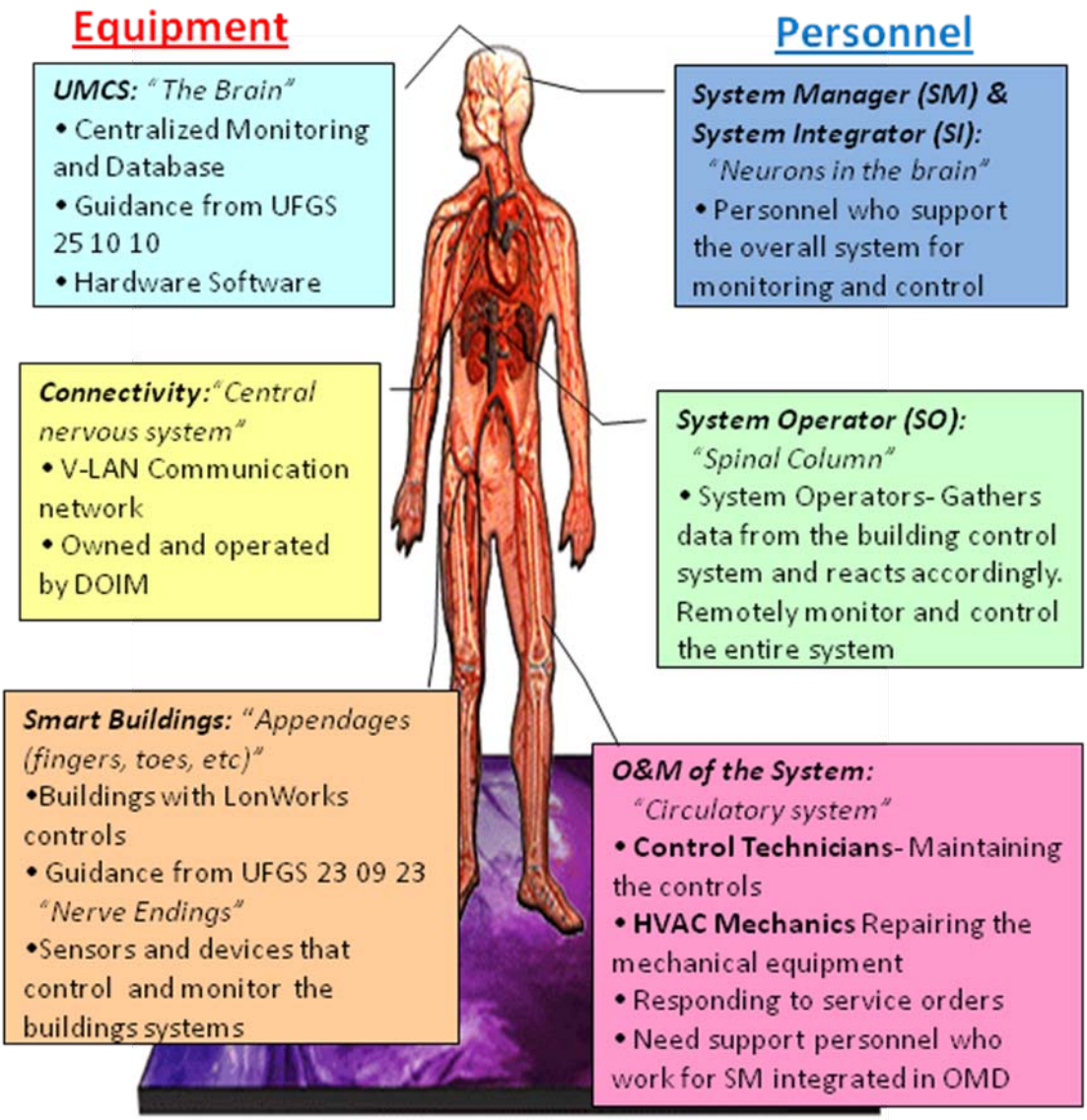
i. The SM will keep all LNS databases that are turned over to the Government during the submittal or QC checklist procedure
ii. If a building is integrated during the warranty period, a separate LNS database will be stored that has not been merged with the UMCS database to insure that the integration does not void any warranties.
iii. If a building HVAC contractor needs to perform warranty work in a building the Project Manager/DPW must request the LNS database from the SM.
iv. After the contractor is finished with their work, an updated LNS database will be delivered back to the SM.

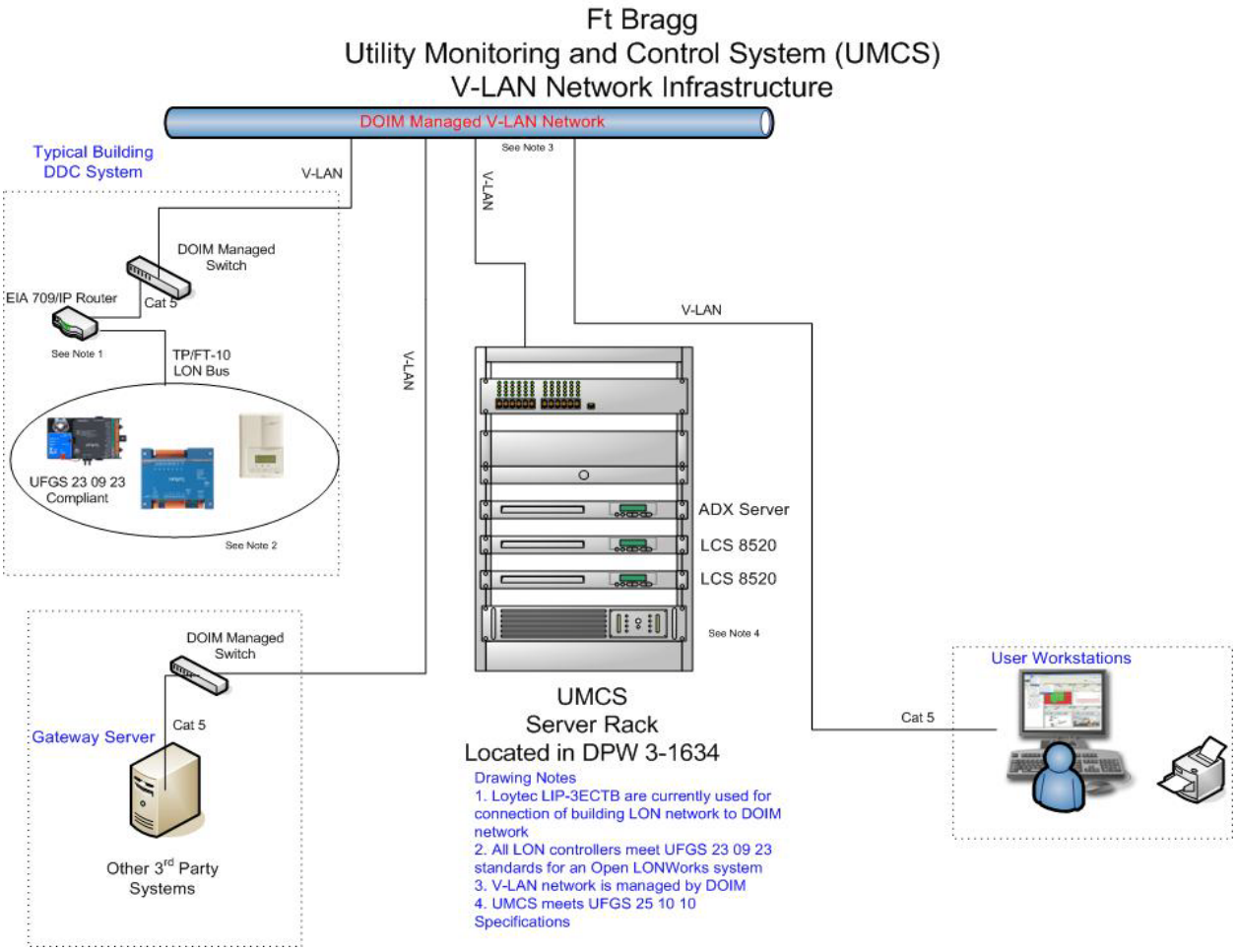
10. System Manager Assistance
    a. The System Manager is the subject matter expert (SME) for LonWorks® and UMCS. The role of the SM is to provide guidance and suggestions for the Government personnel.
    b. The SM would like to help your team make the UMCS and LonWorks® DDC system's a successful project at Fort Bragg. To make this happen the SM needs to be involved in the total process of these projects.
    c. The SM can assist Master Planning with the Future Years Develop Plan (FYDP).
    d. Provide information for existing buildings and like facilities for buildings connected to the UMCS from trending and monitoring data.
    e. DD1391 development; Currently.5% should be set aside for project integration, the SM will evaluate this amount after a couple of test projects to determine if this amount should be changed.
    f. RFP and Design review; The SM should be added to your email list for distribution of review material and meeting schedules.
        i. The SM will not make comments directly into Dr. Checks but only act as a SME to review the material and make comments to the PM.
        ii. The project timeline is a concern to the SM as it is to the PM. All reviews and comments will be made in a timely matter.
    g. During construction, the SM is available to provide assistance with any questions, issues, or concerns including submittal review.
    h. The SM should be invited to any Pre-Final inspection meetings
    i. Commissioning- The SM should be involved with the Performance Verification Test to track and record any problems found during the test.
    j. Submittal / Turnover procedure
        i. The SM shall receive, at a minimum, 1 copy of the submittal documentation. The information should include the items listed in the QC checklist located in Appendix D, page 13 or Appendix F
        ii. The SM should be invited to turnover meetings
        iii. The SM can assist in tracking warranty dates for the DDC system
        iv. SM will ensure QSI receives information needed to service the DDC system

## Appendix 17.2 : Fort Bragg UMCS Description

Appendix B: UMCS Description

- A Utility Monitoring and Control System is part of a larger system, generally referred to as a Building Automation System (BAS).
- The BAS consists of a UMCS (front-end computer and inter-building networking) that is connected to local stand-alone HVAC controls in multiple buildings.
- The Direct Digital Controls (DDC) can be installed by multiple vendors and they all integrate more-or-less seamlessly into a single vendor front end.
- Ideally this UMCS front end would serve as the single front end for all buildings on an installation - or at least all buildings for which DDC controls and a front end is a worthwhile investment.
- UMCS Operational Personnel
    - System Manager;
        - Contract reviews
        - Contract meetings
        - Contract language
        - Software updates
        - User management
        - V-LAN terminal additions
        - DOIM interface
    - System Integrator;
        - Installing BPOC and connecting new buildings
        - LNS database merges
        - Graphics
        - Database management
        - Daily alarm review
        - Log Book review
    - System Operator
        - Day-to-day monitoring and operation of the system
        - Entering Service Orders for maintenance
        - Reviewing and responding to alarms
        - Provide support to QSI shop personnel on connected buildings


Equipment
UMCS: "The Brain"
• Centralized Monitoring and Database
• Guidance from UFGS 25 10 10
• Hardware Software
Connectivity: "Central nervous system"
• V-LAN Communication network
• Owned and operated by DOIM
Smart Buildings: "Appendages (fingers, toes, etc)"
•Buildings with LonWorks controls
• Guidance from UFGS 23 09 23
"Nerve Endings"
•Sensors and devices that control and monitor the buildings systems
Personnel
System Manager (SM) & System Integrator (SI):
"Neurons in the brain"
• Personnel who support the overall system for monitoring and control
System Operator (SO):
"Spinal Column"
• System Operators- Gathers data from the building control system and reacts accordingly. Remotely monitor and control the entire system
O&M of the System:
"Circulatory system"
• Control Technicians- Maintaining the controls
• HVAC Mechanics Repairing the mechanical equipment
• Responding to service orders
• Need support personnel who work for SM integrated in OMD


Ft Bragg
Utility Monitoring and Control System (UMCS)
V-LAN Network Infrastructure
DOIM Managed V-LAN Network
See Note 3
Typical Building
DDC System
V-LAN
V-LAN
DOIM Managed
Switch
EIA 709/IP Router
Cat 5
See Note 1
TP/FT-10
LON Bus
V-LAN
UFGS 23 09 23
Compliant
See Note 2
V-LAN
ADX Server
LCS 8520
LCS 8520
See Note 4
DOIM Managed
Switch
Gateway Server
Cat 5
Other 3rd Party
Systems
UMCS
Server Rack
Located in DPW 3-1634
Drawing Notes
1. Loytec LIP-3ECTB are currently used for connection of building LON network to DOIM network
2. All LON controllers meet UFGS 23 09 23 standards for an Open LONWorks system
3. V-LAN network is managed by DOIM
4. UMCS meets UFGS 25 10 10 Specifications
User Workstations
Cat 5

**Appendix 17.3: Fort Bragg UMCS DDC Integration Scope of Work**

Appendix C:

Ft. Bragg, NC
UMCS DDC Integration
Statement of Work

1.0 SYNOPSIS: The Contractor shall provide the materials and labor required to integrate direct digital control (DDC) systems into the Fort Bragg base-wide Utility Monitoring Control System (UMCS) manufactured by Johnson Controls, Inc, known as the LCS-8520.

2.0 PRICE PROPOSAL: The Contractor shall provide a firm fixed price proposal for the integration of the Direct Digital Control (DDC) systems specified below into the Fort Bragg Utility Monitoring Control System (UMCS).

3.0 SPECIFIC WORK TO BE ACCOMPLISHED: The Contractor shall provide materials and labor required to integrate LNS-based LonWorks® Direct Digital control (DDC) systems specified below into the Fort Bragg Utility Monitoring Control System (UMCS). All work shall be in accordance with the Fort Bragg UMCS System Integration Methodology (SIM), Fort Bragg Installation Design Guide (IDG) **http://www.bragg.army.mil/dpw/idg/index.htm,** Unified Facilities Guide Specification (UFGS) 25 10 10 "LonWorks Utility Monitoring Control System" http://wbdg.org/ and this Statement of Work (SOW). All work performed by the contractor shall ensure that the system is and remains an Open LNS-Based Flat LON system in accordance with UFGS 25 10 10 and UFGS 23 09 23 "LonWorks Direct Digital Control for HVAC and Other Local Building Systems". In cases where UFGS 25 10 10 allows options, the Contractor shall coordinate these options with Fort Bragg.

3.1 The contractor shall integrate the following building(s) DDC systems:

3.1.1 Buildings **< Number>**

3.2 For each DDC system the contractor shall perform all tasks required to fully integrate the system into the UMCS including but not limited to:

3.2.1 Determine if building has a DOIM switch

3.2.1.1 If DOIM switch or spare port is not available proceed with the following;

3.2.1.1.1 Coordinate with the UMCS System Manager to have a survey performed on building to determine cost to install switch.

3.2.1.1.2 Once the survey is complete that cost will be sent to the UMCS Integration contractor to be added to their integration price.

3.2.1.1.3 UMCS Integration contractor will perform work (or sub-contract the work) to add and set-up the switch.

3.2.1.1.4 Once work is complete and accepted by the Government a DD1354 form will be submitted to the appropriate Government representative for transfer of equipment.

3.2.1.2 If DOIM switch is available, including an available port, coordinate with UMCS System Manager to have DOIM install V-Lan port and activate.

3.2.2 Install an ANSI/CEA 709.1 to ANSI/CEA 852 router Building Point of Connection (BPOC) and connect the building DDC system to the UMCS IP backbone.

3.2.2.1 BPOC locations will be provided after contract award.

3.2.2.2 BPOC IP addresses will be provided after contract award.

3.2.2.3 Currently only the Loytec LIP IP-852 Router and the i-Lon 600 are acceptable for use on the UMCS network.

3.2.3 Incorporate each DDC system LNS database into the UMCS database:

3.2.3.1 Merge the building database into the UMCS database or establish a new LNS database at the UMCS as required to maintain UMCS performance and in accordance with the UMCS SIM.

3.2.3.2 If an LNS database does not exist or is unusable for the building DDC system, contractor is responsible for creating a new usable database.

3.2.3.3 Configure Fort Bragg's LNS network configuration tool (NCT):

- Upgrade NCT licensing as required.
- Configure NCT drawings and displays, if applicable, to clearly display building DDC systems.
- Install and update Plug-ins, XIF and Resource files

3.2.4 Incorporate each DDC system into the UMCS Monitoring and Control Software:

3.2.4.1 Create graphic display pages that represent each HVAC system:

- To the greatest extent possible, graphics for similar systems shall be the same.
- Graphics shall provide monitoring and override points as shown on the Points Schedules.
- Graphics shall include duct and zone layouts and controller wiring diagrams, if applicable or available.
- Floorplan graphics showing location and readings for each VAV, etc.

3.2.4.2 Configure Scheduling, Alarming and Trending functionality for the building system as shown on the Points Schedules.

3.2.4.3 Configure supervisory control functions such as demand limiting, load shedding or optimum start/stop, if applicable.

3.2.4.4 Create baseline building energy usage and update Point Schedules to reflect energy alarm limits.

3.2.5 Create network variable bindings for communication between building systems, if applicable.

3.2.6 Reconfigure building DDC devices that poll for network variables, particularly Local Display Panels (LDPs), to use the new domain-subnet-node addressing for the building DDC system.

3.3 Contractor shall demonstrate completed integration to the Government. This demonstration shall show all work performed and shall be sufficient to familiarize the Government with the integrated building's systems.

3.4 Prior to contract award, contractor must meet the following requirements:

3.4.1 Have a Fort Bragg Username and Password for network access

3.4.2 Posses a CAC card

3.4.3 Possess a Secret Security Clearance and Elevated User Privileges for network access

3.4.4 Have a Information Management Officer (IMO) on staff at Fort Bragg

3.4.5 Have a LonMark Certified Professional on staff at Fort Bragg

3.4.6 Posses a Fort Bragg System Administrator certification

4.0 GOVERNMENT FURNISHED INFORMATION:

4.1 Control system drawings notably including the Points Schedule drawing(s)

4.2 Mechanical drawings

4.3 Commissioned LNS database including XIF files and plug-ins

4.4 Network Configuration Tool (NCT) licensing information including NCT model, manufacturer, revision and license status.

4.5 Floor plan drawings

4.6 Ductwork layout drawings

* Note: If none or part of the above items cannot be furnished by the Government, the Contractor will provide pricing to the Government to reproduce, re-create or duplicate such information and/or provide alternate solutions.

5.0 DELIVERABLES:

5.1 Summary listing of all software edits, changes, and updates made to Building Level DDC programming performed as part of system integration. Format shall be: Hardcopy and MS-Word or PDF on CD-ROM.
5.2 Product data including product data sheets and computer software supplied under this contract as specified in UFGS 25 10 10. Format shall be: Hardcopy and MS-Word or PDF on CD-ROM of all data sheets, plus computer software on CD-ROM.
5.3 Licensing information for all software provided or modified under this contract as specified in UFGS 25 10 10. Format shall be: Hardcopy and electronic file on CD-ROM.

6.0 SCHEDULE: The performance period shall be two months. Notice of demonstration of completed integration shall be given to [point of contact] no less than one week before demonstration. Schedule impacts, for any cause, will be brought to the attention of the COR and the Contracting Officer immediately. The contractor shall provide a proposed resolution and basis for delay.

7.0 Warranty: The SI contractor will warranty the integrated building for one year covering the following items:
7.1 UMCS is capable to communicate to the integrated building (exceptions; Destruction by others, communication issues not controlled by contractors)
7.2 Graphics represent correct information
7.3 UMCS programming and/or functions performed as programmed
7.4 Integration of such building listed has not caused problems with previously integrated buildings or surrounding buildings.

**Appendix 17.4: Process to contract UMCS System Integration Contractor**

Appendix H:
Process to contract UMCS System Integration Contractor

1. In the planning stage SAS/DPW PM confirms/assures that there are funds programmed for UMCS integration and sets aside 0.5% of the facility cost to pay for system integration. More definitive/accurate pricing may be identified after the first several projects have been completed.
2. In the planning stage SAS/DPW PM sends an email alert to HNC (Donnie.R.Lambert@usace.army.mil) that a UMCS DDC integration project is being planned.
    a. Email subject line: [Bldg or project number] integration to UMCS
    b. Email content-Notify HNC that a request for UMCS DDC integration services is forthcoming and to provide an estimated date when the integration services SOW (Appendix C) will be sent to HNC.
3. For SRM renovation/retrofit only, SAS/DPW PM, contacts System Manager (SM) (joseph.c.jones4@us.army.mil) to determine if the building has a DOIM switch and connectivity.
    a. If the building has a DOIM switch, the SM submits DOIM service order requesting drop to mechanical room.
    b. If the building does not have a DOIM switch, System Integrator contractor contacts DOIM (larry.nesbit@us.army.mil) for building survey and cost estimate. The project needs to fund the switch installation. This cost usually ranges from $5-15k.
4. Once the design starts, SAS/DPW PM sends the UMCS DDC Integration SOW (see Appendix C) to HNC (Donnie.R.Lambert@usace.army.mil) so that HNC can obtain pricing for the integration.
    a. SAS/DPW PM indicates (in the UMCS DDC Integration SOW or body of the email) the planned/desired location of the IP drop.
    b. SAS/DPW PM is the owner of the UMCS DDC Integration SOW and will maintain/update it as needed.
5. HNC obtains pricing for integration based on the SOW provided by SAS in step 4.
6. HNC provides cost/pricing to SAS/DPW PM including: Cost for Integration, HNC admin/contracting fees, contract management, and any technical assistance/reviews necessary.
    a. HNC technical staff will serve as the HNC contracting officer's technical representative (COTR) and provide quality verification (QV) services including verification that all work described in the UMCS DDC Integration SOW has been performed/accomplished.
    b. HNC shall oversee implementation of all related Integration steps (via in-house staff or Contract) in this System Integration Process (such as coordination with DOIM to obtain IP drop, etc.). It is anticipated that, over time, portions or all of this responsibility may be transferred to Fort Bragg DPW staff (such as an OMD staff member)
7. SAS/DPW MIPRs funds to HNC. MIPR wording: Provide integration services as described in UMCS DDC Integration SOW dated [ ].

8. HNC award contract to System Integrator contractor.
9. DPW accepts the building after the following tasks have been completed:
    a. SAS/DPW PM completes building construction including Performance Verification Test (PVT) and applicable Commissioning of the building control system(s).
    b. SAS/DPW PM verifies that the LonWorks® open system requirements have been met. This may be accomplished using the LonWorks® Compliance Assessment Tool being developed by EMC Engineers via CERL/HNC direction/contract.
10. UMCS Information Management Officer (IMO) (joseph.c.jones4@us.army.mil) requests an IP drop and IP address on the controls VLAN for the BPOC and includes the estimated occupancy date in the request. DOIM installs IP drop after the building has been accepted by the Government. The System Integrator contractor will complete the integration including installing BPOC.

## Appendix 17.5: Contract Language

### Appendix 17.5.1: MTRFP Chapter 5

- 5.8.3. Building Automation System

**Appendix 17.5.2: MTRFP Chapter 6**

Appendix E:

MTRFP Chapter 6 Fort Bragg Specific

6.11 HEATING, VENTILATING, AND AIR CONDITIONING

6.11.1. Integrate the control system to the installation's existing UMCS. The existing UMCS is an LCS-8520 that utilizes the LonWorks® Technology to integrate LNS databases into a single front-end. The UMCS is based on UFGS 25 10 10.

6.11.1.1 Fort Bragg's System Integration (SI) Contractor will integrate the building's BAS in accordance with UFGS 25 10 10 and the Fort Bragg UMCS Integration SOW. Coordinate through Fort Bragg's UMCS System Manager.

6.11.1.2 General Requirements

(a) Do not modify the chiller microprocessor supplied with the equipment. Control and safety functions should be the chiller manufacture's responsibility.
(b) Do not modify the boiler microprocessor supplied with the equipment. Control and safety functions should be the chiller manufacture's responsibility. If heating water systems are used, then design such systems to maintain the boiler manufacture's minimum temperature when in operation but vary the heating water supply temperature as required to meet the buildings requirements.
(c) Provide all DDC software, equipment and devices from a single common manufacturer whenever possible.

6.11.2 Mechanical Equipment Maintenance and Accessibility Requirements

6.11.2.1 Selected mechanical systems must be compatible with the existing systems and composed of standard commercially available items with readily available service and repair parts.

6.11.2.2 Any mechanical rooms above the first floor shall have an external access (door, removable louvers, etc of ample size such that the largest piece of installed equipment could be removed through the opening.

6.11.2.3 Install all piping, except individual fixture pipes, to permit access without requiring removal of permanent walls, floor, or ceilings.

6.11.2.4 Arrange all equipment, piping, etc in mechanical rooms so that each piece of equipment can be removed without having to remove any other piece of equipment. Consider things such as coil pull areas in the mechanical room layouts.

6.11.2.5 Chillers: Chillers shall include as a minimum the following features

(a) Scroll or screw type compressors with 5-year parts warranty
(b) Microprocessor controllers with self-diagnostic capabilities
(c) Low ambient controls to zero (0) degrees F.

6.11.2.6 Fuels

Natural gas is the preferred fuel source for heating.

6.11.2.7 Pumps

(a) Hot Water and Chilled Water pumps shall operate at 1,750 rpm or less
(b) Mechanical Rooms: Heat to 40 F for freeze protection where piping may be subject to freezing.

6.11.3 Site Mechanical Equipment. Design all exterior mechanical equipment to be compatible with existing mechanical equipment within the surrounding area. This includes color and screening.

6.11.4 At Fort Bragg, Local Display Panels (LDPs) shall be installed at a minimum in each mechanical room where an AHU exist and programmed as per the Point Schedules.

**Appendix 17.5.3: OMA_SRM**

Appendix F & G:

Fort Bragg Supplement to
LONWorks Direct Digital Control for HVAC and Other
Local Building Systems

Where this supplement fails to address, UFGS 23 09 23 requirements apply.

1. The building control network shall be a single complete non-proprietary Direct Digital Control (DDC) system for control of the heating, ventilating and air conditioning (HVAC) systems. The building control network shall be an Open implementation of LONWORKS® technology using ANSI/EIA 709.1B as the only communications protocol and shall use only LonMark Standard Network Variable Types (SNVTs), as defined in the LonMark® Resource Files, for communication between DDC Hardware devices to allow multi-vendor interoperability.
2. The building automation system shall be open in that it is designed and installed such that the Government or its agents are able to perform repair, replacement, upgrades, and expansions of the system without further dependence on the original Contractor. This includes, but is not limited to the following:
   - 2.1. Install hardware such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.
   - 2.2. Necessary documentation (including rights to documentation and data), configuration information, configuration tools, programs, drivers, and other software shall be licensed to and otherwise remain with the Government such that the Government or its agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor.
   - 2.3. At Fort Bragg the following systems are prohibited for new installation:
     - 2.3.1. BACNet
     - 2.3.2. Proprietary DDC systems
     - 2.3.3. Pneumatic systems or combination Direct Digital Control (DDC)/Pneumatic systems
   - 2.4. Gateways may be used provided that each gateway communicates with and performs protocol translation for control hardware controlling:
     - 2.4.1. A single major component (chiller, boiler, etc)
     - 2.4.2. Legacy or existing equipment in a building that is to remain
3. DDC Hardware (controllers) Requirements:
   - 3.1. All DDC Hardware shall:

3.1.1. Be connected to a TP/FT-10 ANSI/EIA 709.3 control network.

3.1.2. Communicate over the control network via ANSI/EIA 709.1B exclusively.

3.1.3. Communicate with other DDC hardware using only SNVTs

3.1.4. Conform to the LonMark® Interoperability Guidelines.

3.1.5. Be locally powered; link power (over the control network) is not acceptable.

3.1.6. Be fully configurable via standard or user-defined configuration parameter types (SCPT or UCPT), standard network variable type (SNVT) network configuration inputs (nci), or hardware settings on the controller itself to support the application. All settings and parameters used by the application shall be configurable via standard or user-defined configuration parameter types (SCPT or UCPT), standard network variable type (SNVT) network configuration inputs (nci), or hardware settings on the controller itself

3.1.7. Provide input and output SNVTs required to support monitoring and control (including but not limited to scheduling, alarming, trending and overrides) of the application. Required SNVTs include but are not limited to: SNVT outputs for all hardware I/O, SNVT outputs for all setpoints. SNVT inputs for overrides of all setpoints, and SNVT inputs for overrides of all hardware Outputs.

3.2. Application Specific Controllers have a fixed factory-installed application program (i.e. ProgramID) with configurable settings and do not have the ability to be programmed for custom applications. In addition to the requirements for all DDC Hardware ASCs shall:

3.2.1. Be LonMark Certified unless otherwise approved.

3.2.2. Be configurable via an LNS plug-in unless otherwise approved

3.3. Application Generic Controllers (AGCs) have a fixed application program which includes the ability to be programmed for custom applications. In addition to the requirements for all DDC Hardware ASCs shall:

3.3.1. have a fixed ProgramID and fixed XIF file

3.3.2. be fully programmable and configurable for the application through one or more LNS plug-in unless otherwise approved

3.4. General Purpose Programmable Controllers (GPPCs) are not installed with a fixed factory-installed application program and must be programmed for the application.

3.5. At Fort Bragg, Local Display Panels (LDPs) shall be installed at a minimum in each mechanical room where an AHU exist and programmed as per the Point Schedules.

4. Do not rely on the control network to perform DDC sequence applications unless otherwise approved.

5. Where multiple pieces of DDC Hardware are used to execute one sequence, all DDC Hardware executing that sequence shall be on a common segment and isolated from all other DDC Hardware via a CEA-709.1B Router.
6. Each scheduled system shall accept a network variable of type SNVT_occupancy (which will be provided by the UMCS outside the scope of this work) and shall use this network variable to determine the occupancy mode. If the system has not received a value to this network variable for more than 60 minutes it shall default to [a configured occupancy schedule][the occupied mode].
7. Fort Bragg currently has an Open LonWorks technology Utility Monitoring Control System (UMCS) manufactured by Johnson Controls, Inc. Integration of building DDC system are performed by Fort Bragg's System Integration contractor. This should be coordinated with the UMCS System Manager.
8. Submittals:

   8.1. Prior to DDC system installation the following should be submitted for Government approval:

   8.1.1. Points Schedules: Submit Points Schedules using the Points Schedule template located at https://eko.usace.army.mil/fa/bas/ for each piece of DDC Hardware. Points Schedules shall be submitted in hard copy (11"x17") and electronic format. Electronic submission shall be in [AutoCAD][Microstation][Excel] format and submitted on CD or DVD.

   8.1.2. Control System Schematic diagram and Sequence of Operation for each HVAC system.

9. Deliverables:

   9.1. Upon completion of project the following should be delivered to the Government for acceptance:

   9.1.1. Final (as-built) commissioned Turbo LONWORKS® Network Services (LNS®) database with Lon Credits transferred to the Government.

   9.1.2. eXternal Information Files (XIF), Resource files and Plug-ins for the completed system.

   9.1.3. Point Schedules: Final (as-built) Points Schedules using the Points Schedule template located at https://eko.usace.army.mil/fa/bas/ for each piece of DDC Hardware. Points Schedules shall be submitted in hard copy (11"x17") and electronic format. Electronic submission shall be in [AutoCAD][Microstation][Excel] format and submitted on CD or DVD.

   9.1.4. Control System Schematic diagram and Sequence of Operation for each HVAC system.

   9.1.5. Programming Software: All software, including licensing information and user manuals, necessary to program GPPCs installed under this contract.

   9.1.6. GPPC and AGC Application Source Code: Copies of the installed application programs (all software that is not common to every controller of

the same manufacturer and model) as source code compatible with the supplied programming software.

9.1.7. Operation and Maintenance Instructions including procedures for system start-up, operation and shut-down, a routine maintenance checklist, and a qualified service organization list.

9.1.8. Quality Control (QC) checklist (below) completed by the Contractor's Chief Quality Control (QC) Representative.

10. Perform a Performance Verification Test (PVT) prior to system acceptance. During the PVT, demonstrate to a Government representative that the system performs as specified, including but not limited to demonstrating that the system is Open and correctly performs the Sequences of Operation.

11. Provide a 1 year unconditional warranty on the installed system and on all service call work. The warranty shall include labor and material necessary to restore the equipment involved in the initial service call to a fully operable condition. Subsequent integration of the building control system into a basewide Utility Monitoring and Control System by the Government or its agents shall not void warranty.

12. Provide a minimum of [8 hours] training at the project site on the installed building system. Upon completion of this training each student, using appropriate documentation, should be able to start the system, operate the system, recover the system after a failure, perform routine maintenance and describe the specific hardware, architecture and operation of the system.

Table: QC Checklist

| Instructions: Initial each item, sign and date verifying that the requirements have been met. | | |
|---|---|---|
| # | Description | Initials |
| | | |
| 1 | All DDC Hardware is installed on a TP/FT-10 local control bus. | |
| 2 | Communication between DDC Hardware is only via EIA 709.1B using SNVTs. Other protocols and network variables other than SNVTs have not been used. | |
| 3 | All sequences are performed using DDC Hardware. | |
| 4 | XIF files, Resource files and Plug-in's are up-to-date and accurately represents the final installed system | |
| 5 | Commissioned Turbo LNS database with the understanding that the Lon Credits will be transferred to the Government as a complete system. | |
| 6 | All software has been licensed to the Government | |
| 7 | Local Display Panels (LDPs) have been created for all building systems, including all override and display | |

| | | |
|---|---|---|
| | points indicated on Points Schedule drawings. | |
| 8 | Final As-built Drawings accurately represent the final installed system. | |
| 9 | O&M Instructions have been completed and submitted. | |
| 10 | LonWorks® Network Services (LNS) based M&C software was provided | |

By signing below I verify that all requirements of the contract, including but not limited to the above, been met. Signature:_____
Date:_____

## Appendix 18: Utility Meter Specifications

1. **Purpose.** The purpose of the following specifications is to achieve meter equipment compatibility with the Army metering program pursuant to Public Law 109-58, Section 103 of the Energy Policy Act of 2005. The intent is for all utility meters to report their data to the installations base-wide Utility Monitoring and Control System (UMCS). The utility meters must provide data at least daily and measure at least hourly consumption of electricity. The means for meter data transmission will be by using open-protocols such as ANSI/CEA 709.1b (LONTalk). A key element for success will be integrating these systems with the Army's networks supported by DOIM.
2. **General Specifications.**
    a. All meters will electronically report its data (No visual meter reading required).
    b. The Contractor shall include all disconnects, mounting hardware, enclosures, wiring and conduit, and safety equipment as required and appropriate to complete the task and provide fully functioning meters. The Contractor shall provide all wiring and conduit required to connect the new meter to the building's DDC system that will allow transmission of the metering data to the base-wide UMCS.
    c. All new hardware and software shall be provided IAW the requirements of the specifications and drawings.
    d. All hardware and software shall be installed IAW original software developer's published procedures and documentation, and as required by the specifications.
    e. Perform all Testing, Adjusting, and Commissioning in accordance with manufacturer's recommendations and the Basic Contract requirements. Provide certification of compliance. All electrical meter product certifications shall be performed in accordance with the certification tests described in ANSI C12.20 for 0.5% accuracy class meters.
    f. Provide O&M manuals on meters and contractor supplied equipment. This documentation may be provided on a CD.
    g. Provide all maintenance and service of the new components and equipment that is required by the manufacturer to maintain the warranty in effect for the one year warranty period. This work shall be performed IAW the contract.

**Appendix 18.1: Electrical Meter Specification**

| | |
|---|---|
| Quantities Measured: | Power (kiloWatt), average demand over 15 minute intervals.<br>Energy (kiloWatt-hours)<br>Phase voltage, amps, frequency, true power, reactive power, apparent power and power factor. |
| Measurement Configuration: | For single phase application, 120 – 240V<br>For three phase application, 208 – 600V, 3 wire delta or 4 wire wye |
| Operating Temperatures: | -20 degrees C. to +70 degrees C. For exterior mounting, consider the local ambient temperature extremes and moisture proof enclosures. |
| Humidity Operating Range: | 5% to 90% RH (non-condensing) |
| Accuracy: | ANSI C12.20 (0.5% Accuracy) |
| Frequency: | 50 or 60 Hz +/- 5% (60 Hz for CONUS application) |
| Current Transformers (CTs): | Sized properly so that the meter secondary of the transformer shall output current to ensure at least a plus or minus 0.6% accuracy of current when measured between 10% and 90% of full amperage range. |

**For LonWorks meter applications**

| | |
|---|---|
| Digital Output Only: | ANSI/CEA-709.1b protocol (LonTalk) output for communications using Standard Network Variable Types (SNVTs) for measured values. |

**Note**: Electrical meters shall be installed inside of the building at each service point entry. Split core CT's are acceptable for use. Power outages should be coordinated with DPW and Electrical contractors.

**Appendix 18.2: Water Meter Specification**

| | |
|---|---|
| Quantities Measured: | Gallons of Water |
| Measurement Configuration: | Water Supply to a building. For buildings that already have a water meter with a pulse output, ensure that the pulse output is connected to a data gathering device (i.e. DDC controller). For buildings where a water meter already exists but does not have a pulse output, add a pulse kit to the existing meter and tie the output into a data gathering device. If the existing meter will not accept a pulse kit or if no meter exists, a new water meter will be installed, also requiring a pulse output to a data gathering device. |
| Operating Temperatures: | 32 degrees F to 120 degrees F. When exterior mounting is required, consider the local ambient temperature extremes and protect from freezing with insulated, moisture proof enclosures and heat tracing as required. |
| Humidity Operating Range: | 5% to 90% RH (non-condensing) |
| Accuracy: | 1.5% of scale. |
| Frequency: | Not less than one pulse per revolution. Meter pulser shall be coupled to the meter dial to provide a pulse rate of not less than one pulse per gallon of water. |

**For non-LonWorks meter applications**

| | |
|---|---|
| Digital Output Only: | Pulse Output |

**For LonWorks meter applications**

| | |
|---|---|
| Digital Output Only: | Pulse Output |

Water Meters shall be the turbine, propeller, or displacement type with pulse output chosen to meet the specific application (pipe size, flow, pressure, etc.).

**Turbine Type Meters**
Turbine type meters shall conform to AWWA C701 Class I or Class II depending on the application. The main casing shall be bronze or cast iron protected by corrosion resistant

coating with stainless steel external fasteners. Registers shall be straight-reading type, shall be permanently sealed and shall read in U.S. gallons. Connections shall be suitable to the type of pipe and conditions encountered. Register type shall be a direct reading remote register designed in accordance with AWWA C706 or an encoder type remote register designed in accordance with AWWA C707 but must be compatible with the local Utility Monitoring and Control System. Meters shall comply with the accuracy and capacity requirements of AWWA C701.

**Propeller Type Meters**
Propeller type meters shall conform to AWWA C704. Registers shall be straight-reading type, shall be permanently sealed and shall read in U.S. gallons. Connections shall be suitable to the type of pipe and conditions encountered. Register type shall be a direct-reading remote register designed in accordance with AWWA C706 or an encoder-type remote register designed in accordance with AWWA C707 but must be compatible with the local Utility Monitoring and Control System. Meters shall comply with the accuracy and capacity requirements of AWWA C703.

**Displacement Type Meters**
Displacement type meters shall conform to AWWA C700. Registers shall be straight-reading and shall read in U.S. gallons. Meters in sizes ½ through 1 shall be frost-protection design as required by the local environmental conditions. Connections shall be suitable to the type of pipe and conditions encountered. Register type shall be a direct reading remote register designed in accordance with AWWA C706 or an encoder type remote register designed in accordance with AWWA C707 but must be compatible with the local Utility Monitoring and Control System. Meters shall comply with the accuracy and capacity requirements of AWWA C700.

**Compound Type Meters**
Compound type meters shall conform to AWWA C702 and shall be furnished with strainers. The main casing shall be bronze or cast iron protected by corrosion resistant coating with stainless steel external fasteners. The main casing shall be tapped for field testing purposes. Registers shall be straight-reading type, shall be permanently sealed and shall read in U.S. gallons. The
meter shall be equipped with a coordinating register. Connections shall be suitable to the type of pipe and conditions encountered. Register type shall be a direct reading remote register
designed in accordance with AWWA C706 or an encoder type remote register designed in accordance with AWWA C707 but must be compatible with the local Utility Monitoring and Control System. Meters shall comply with the accuracy and capacity requirements of AWWA C702.

**Fire Service Type Meters**
Provide Fire Service Type Meters as required by the Installation. Fire service type meters shall be proportional type or turbine type conforming to AWWA C703 and shall be furnished with strainers. The main casing shall be bronze or cast iron protected by corrosion resistant coating with stainless steel external fasteners. Any isolation valves

installed as part of the meter assembly shall either have tamper switches or be position indicating valves in accordance with NFPA. Registers shall be straight-reading type, shall be permanently sealed and shall read in U.S. gallons. The meter shall be equipped with a coordinating register. Connections shall be suitable to the type of pipe and conditions encountered. Register type shall be a direct reading remote register designed in accordance with AWWA C706 or an encoder type remote register designed in accordance with AWWA C707 but must be compatible with the local Utility Monitoring and Control System. Meters shall comply with the accuracy and capacity requirements of AWWA C703. When turbine type main line meters are used, the meter shall be supplied with a separate check valve, as a unit.

**Meter Boxes**
Meter boxes shall be of cast iron, concrete, or plastic. The boxes shall be of sufficient size to completely enclose the meter and shutoff valve or service stop. Meter boxes set in paved areas subject to vehicular traffic shall be cast iron, or concrete with cast iron lid and cast iron meter reader lid suitable for vehicle wheel loads. Boxes set in sidewalks, not subject to vehicular traffic, shall be concrete with cast iron lid and cast iron meter reader lid. Plastic boxes and lids can be used in unpaved areas or grass areas not subject to vehicular traffic. Box height shall extend from invert of the meter to final grade at the meter location. The lid shall have the word “WATER” cast in it.

**Dielectric Fittings**
Dielectric fittings shall be installed between threaded ferrous and nonferrous metallic pipe, fittings and valves, except where corporation stops join mains. Dielectric fittings shall prevent metal-to-metal contact of dissimilar metallic piping elements and shall be suitable for the required working pressure.

**Gate Valves Smaller than 3 Inch in Size**
Gate valves smaller than 3 inch size shall meet MSS SP-80, Class 150, solid wedge, nonrising stem. Valves shall have flanged or threaded end connections, with a union on one side of the valve. Provide handwheel operators. Valves shall open by counterclockwise rotation of the valve stem.

**Gate Valves 3 Inch Size and Larger**
Gate valves 3 inch size and larger shall meet AWWA C500 or UL 262 and be of one manufacturer. Valves shall be AWWA C500, nonrising stem type with double-disc gates or UL 262, inside-screw type with operating nut, split wedge or double disc type gate, and designed for a hydraulic working pressure of 175 psi. Valves shall open by counterclockwise rotation of the valve stem.

**EXECUTION:**
**Connections to Publicly or Privately Operated Water Utility Lines**
Contractor shall provide materials for the connections to the existing water lines. Final connections and the turning on of water shall be made by the utility. The Contractor shall notify the Contracting Officer, in writing, 10 days before final connections and turning on of water lines. The Contractor shall make necessary arrangements with the Utility for tie

in and activation of new water lines. Only the Operating Agency/Utility Company may reactivate the system after tie in. The Contractor shall furnish a certification by the Operating Agency/Utility Company that all Utility work has been satisfactorily completed.

**Connection to Government Owned/Operated Water Lines**
Provide the name and location of the utility or operating agency of the existing water lines. Show on the drawings, the location of valves to be operated for existing system deactivation. The Contractor shall provide connections to the existing water lines in accordance with approved procedures. The Contractor's Connection Plan shall be submitted and approved prior to making any connections to existing water lines. This plan shall include the Operating Agency's required procedures which may be obtained from the Contracting Officer. The Contractor shall notify the Contracting Officer, in writing, 10 days before connections to existing lines are to be made. Reactivation of any existing water lines will only be done by the Government.

**Location of Meters**
The location of meters and meter boxes shall be shown on the drawings. The meters shall be centered in the boxes to allow for reading and ease of removal or maintenance.

**Disinfection**
Prior to disinfection, obtain Contracting Officer approval of the proposed method for disposal of waste water from disinfection procedures. Disinfect existing water piping affected by Contractor's operations in accordance with AWWA C651. Fill piping systems with solution containing minimum of 50 parts per million of available chlorine and allow solution to stand for minimum of 24 hours. Flush solution from the systems with domestic water until maximum residual chlorine content is within the range of 0.2 and 0.5 parts per million, or the residual chlorine content of domestic water supply. Obtain at least two consecutive satisfactory bacteriological samples from new water piping, analyze by a certified laboratory, and submit the results prior to the new water piping being placed into service. Disinfection of systems supplying nonpotable water is not required.
Chlorinating materials shall conform to the following:
Chlorine, Liquid: AWWA B301.
Hypochlorite, Calcium and Sodium: AWWA B300.

**Field Tests and Inspections**
Prior to hydrostatic testing, obtain Contracting Officer approval of the proposed method for disposal of waste water from hydrostatic testing. The Contracting Officer will conduct field inspections and witness field tests. The Contractor shall perform field tests, and provide labor, equipment, and incidentals required for testing, except that water and electric power needed for field tests will be furnished. The Contractor shall produce evidence, when required, that any item of work has been constructed in accordance with the approved Statement of Work.

**Testing Procedure**
Test water service lines in accordance with applicable requirements of AWWA C600 for hydrostatic testing. No leakage will be allowed at copper pipe joints, copper tubing joints (soldered, compression type, brazed), plastic pipe joints, flanged joints and screwed joints.

Prior to the pressure test, fill that portion of the pipeline being tested with water for a soaking period of not less than 24 hours. For pressure test, use a hydrostatic pressure 50 psi greater than the maximum working pressure of the system. Hold this pressure for not less than 2 hours. For leakage test, use a hydrostatic pressure not less than the maximum working pressure of the system. Leakage test may be performed at the same time and at the same test pressure as the pressure test.

**CLEANUP**
Upon completion of the installation of water meters, all debris and surplus materials resulting from the work shall be removed.

**Appendix 18.3: Natural Gas Meter Specification**

| | |
|---|---|
| Quantity Measured: | Cubic Feet of Natural Gas |
| Measurement Configuration: | Natural Gas service to a building. For buildings that already have a gas meter with a pulse output, ensure that the pulse output is connected to a data gathering device (i.e. DDC Controller). For buildings where a natural gas meter already exists but does not have a pulse output, add a pulse kit to the existing meter and tie the output to a data gathering device. If the existing gas meter will not accept a pulse kit or if no meter exists a new natural gas meter will be installed, also requiring a pulse output to a data gathering device. Ensure the pulse frequency and electronic characteristics are compatible with the existing data gathering device, if any. |
| Operating Temperatures: | -40 degrees F to +150 degrees F. |
| Humidity Operating Range: | 5% to 90% RH (non-condensing) |
| Accuracy: | ± 1% of scale. |
| Pulse Frequency: | Not less than two pulses per revolution. Meter pulser shall be coupled to the meter dial to provide a pulse rate of not less than one pulse for every 100 cubic feet of gas. |

**For non-LonWorks meter applications**

| | |
|---|---|
| Digital Output Only: | Pulse Output |

**For LonWorks meter applications**

| | |
|---|---|
| Digital Output Only: | Pulse Output |

**NOTE:** Gases are more difficult to measure than liquids, as measured volumes are highly affected by temperature and pressure. Gas meters measure a defined volume, regardless of the pressurized quantity or quality of the gas flowing through the meter. Temperature, pressure and heating value compensation must be made to measure actual amount and value of gas moving through a meter.

Natural Gas Meters shall be the Diaphragm, Rotary, or for high volume applications Turbine type with pulse output chosen to meet the specific application.

**METERS**

Provide gas meters for the natural gas service line to the building.
Diaphragm Gas Meters with flow rates less than 500 cubic feet per hour shall conform to AGA B109.1. Diaphragm Gas Meters with flow rates of 500 cubic feet per hour and higher shall conform to AGA B109.2. Rotary Type Gas Meters shall conform to AGA B109.3. Turbine Type Gas Meters shall conform to ASME MFC-4M. Meters shall be pipe or pedestal mounted and be provided with a strainer immediately upstream. Meters shall be provided with over-pressure protection as specified in ASME B31.8. Include tamper-proof protection, frost protection and fungus-proof protection as applicable. Meters shall be suitable for accurately measuring and handling gas at pressures, temperatures, and flow rates present. Meters shall have a pulse switch initiator capable of operating up to speeds of 500 pulses per minute with no false pulses and shall require no field adjustments or calibration. Initiators shall provide the maximum number of pulses up to 500 per minute that is obtainable from the manufacturer. The minimum pulse rate shall not be less than one pulse per 100 cubic feet of gas.

**Valves and pressure regulators are necessary at all points where pressure reduction or regulation is required by the user. Install a shut-off valve upstream of the regulator and both upstream and downstream of the meter. Provide a gas meter bypass line with a lockable valve for buildings with critical service.**

**VALVES**

Valves shall be suitable for shutoff or isolation service and shall conform to the following: Steel valves 1-1/2 inches and smaller installed aboveground shall conform to ASME B16.34, carbon steel, socket weld or threaded ends with handwheel or wrench operator. Steel valves 2 inches and larger installed aboveground shall conform to API Spec 6D, carbon steel, buttweld or flanged ends, with handwheel or wrench operator.

**SERVICE LINE REGULATORS**

Pressure regulators for individual service lines shall have ferrous bodies. Regulator shall be capable of reducing distribution line pressure to pressures required for users. Regulators shall be provided where gas will be distributed at pressures in excess of 10 inches of water column. Pressure relief shall be set at a lower pressure than would cause unsafe operation of any connected user. Regulator shall have single port with orifice diameter no greater than that recommended by the manufacturer for the maximum gas pressure at the regulator inlet. Regulator valve vent shall be of resilient materials designed to withstand flow conditions when pressed against the valve port. Regulator shall be capable of regulating downstream pressure within limits of accuracy and shall be capable of limiting the buildup of pressure under no-flow conditions to 50 percent or less of the discharge pressure maintained under flow conditions. Regulator shall have a self contained service regulator. Regulator pipe connections shall not exceed 2 inch size.

**EXECUTION:**
A shutoff valve, meter set assembly, and service regulator shall be installed on the service line outside the building, 18 inches above the ground on the riser. An insulating joint (dielectric connection) shall be installed on the inlet side of the meter set assembly and service regulator and shall be constructed to prevent flow of electrical current. A 3/8 inch tapped fitting equipped with a plug shall be provided on both sides of the service regulator for installation of pressure gauges for adjusting the regulator. All service regulator vents and relief vents shall terminate in the outside air in rain and insect resistant fittings. The open end of the vent shall be located where gas can escape freely into the atmosphere, away from any openings into the building and above areas subject to flooding.

Meters shall be installed in accordance with ASME B31.8. Permanent gas meters shall be installed with provisions for isolation and removal for calibration and maintenance, and shall be suitable for operation in conjunction with an energy monitoring and control system.

**Connections to Publicly or Privately Operated Gas Utility Lines**
Contractor shall provide materials for the connections to the existing gas lines. Final connections and the turning on of gas shall be made by the utility. The Contractor shall notify the Contracting Officer, in writing, 10 days before final connections and turning on of gas lines. The Contractor shall make necessary arrangements with the Utility for tie in and activation of new gas lines. Only the Operating Agency/Utility Company may reactivate the system after tie in. The Contractor shall furnish a certification by the Operating Agency/Utility Company that all Utility work has been satisfactorily completed.

**Connection to Government Owned/Operated Gas Lines**
Provide the name and location of the utility or operating agency of the existing gas lines. Show on the drawings, the location of valves to be operated for existing system deactivation. The Contractor shall provide connections to the existing gas lines in accordance with approved procedures. Reactivation of any existing gas lines will only be done by the Government. The Contractor's Connection Plan shall be submitted and approved prior to making any connections to existing gas lines. This plan shall include the Operating Agency's required procedures which may be obtained from the Contracting Officer. The Contractor shall notify the Contracting Officer, in writing, 10 days before connections to existing lines are to be made.

**Pressure and Leak Tests**
Prior to returning the gas line back to service it shall be tested in accordance with ASME B31.8. Test pressures should recognize the weakest component of each system tested for the actual pressure, the maximum allowable operating pressure, and the gas supplier's maximum operating pressure. The test pressure will be 150 percent of the maximum operating pressure or 50 psig, whichever is greater. However, the maximum test pressure must not be more than three times the design pressure of the pipe.
The service lines shall be tested after modifications and before being placed in service using air as the test medium. Prior to testing the system, the interior shall be blown out,

cleaned and cleared of all foreign materials. All meters, regulators, and controls shall be removed before blowing out and cleaning and reinstalled after clearing of all foreign materials. Testing of gas
service lines shall be done with due regard for the safety of employees and the public during the test. Persons not working on the test operations shall be kept out of the testing area while testing is proceeding. The test shall be made on the system as a whole or on sections that can be isolated. The test shall continue for at least 24 hours from the time of the initial readings to the final readings of pressure and temperature. The initial test readings of the instrument shall not be made for at least 1 hour after the pipe has been subjected to the full test pressure, and neither the initial nor final readings shall be made at times of rapid changes in atmospheric conditions. The temperatures shall be representative of the actual trench conditions. There shall be no indication of reduction of pressure during the test after corrections have been made for changes in atmospheric conditions in conformity with the relationship T(1)P(2)=T(2)P(1), in which T and P denote absolute temperature and pressure, respectively, and the numbers denote initial and final readings. During the test, the entire system shall be completely isolated from all compressors and other sources of air pressure. Each joint shall be tested by means of soap and water or an equivalent nonflammable solution prior to backfilling or concealing any work. The testing instruments shall be approved by the Contracting Officer. All labor, materials and equipment for conducting the tests shall be furnished by the Contractor and shall be subject to inspection at all times during the tests. The Contractor shall maintain safety precautions for air pressure testing at all times during the tests.

Gas distribution equipment shall be installed in accordance with all applicable federal, state and local codes and regulations. Gas distribution equipment shall be installed in conformance with the manufacturer's recommendations and applicable sections of ASME B31.8, AGA XR0104 and 49 CFR 192. Gas distribution equipment installed in areas where they will be subject to damage will be protected by appropriate physical barriers (i.e. bollards). The Contractor shall provide installation details including catalog cuts and installation drawings for each gas service to be modified for approval by the Contracting Officer or the Contracting Officer’s Representative.

## Appendix 18.4 Meter Contract Language

**Appendix 19: Central Energy Plants (CEP)**

## Appendix 19.1: CEP Controls and Monitoring Guidelines

### 1. Background

This chapter discusses, describes, and provides recommendations for implementing a long-term strategy for supervisory monitoring and control of Fort Bragg's various Central Energy Plant (CEP) boilers and chillers.

Fort Bragg DPW implemented a Utility Monitoring and Control System (UMCS) Workgroup dedicated to the development and implementation of a base-wide building automation system (BAS) strategy. The Workgroup's overall goal was to obtain a base-wide BAS consisting of a UMCS (front-end) and local (building-level) direct digital control (DDC) systems that functions as a single integrated system. The BAS must be manageable and maintainable and must also be usable by and functional for the Operations Maintenance Division (OMD), the energy manager, and others. Over the long term, the BAS must grow with the needs of the DPW and evolve into a fully functional tool that is supportable by and useful to OMD.

Fort Bragg DPW has decided to standardize on LONWORKS® as outline by UFGS 23 09 23 for all building level DDC controls and the LCS-8520 Flat Lon Front-end manufactured by Johnson Controls, Inc as their base-wide UMCS. The UMCS shall meet UFGS 25 10 10.

For a variety of reasons the UMCS Workgroup decided to support and use the ANSI/CEA 709.1-b communications protocol (otherwise known as LonTalk), which is essentially a standard for control networking (hereafter referred to as ANSI 709.1b). Therefore this chapter describes an implementation approach and issues based on ANSI 709.1b as the underlying communications protocol.

While ANSI 709.1b is the protocol, LONWORKS® is the term that is used to refer to the technology related to use of ANSI 709.1b. LONWORKS includes the various devices (such as controllers), software tools, and guidelines.

Fort Bragg has a variety of brands and types of boilers and chillers. A recent study indicates that the most common brand of chillers are of the "Trane" brand, followed by an even mix of "York," "Carrier," and "McQuay" (85, 38, 34, and 27 chillers respectfully) and a small number of other brands. A 2005 Air Emissions Survey did not consistently record boiler brands, however the majority that were reported were of the brands "Peerless," "Burnham," "Weil McLain," and "English Boiler and Tube Co." The fuel type for most boilers appears to be either natural gas or fuel oil.

The interconnection of Bragg's boilers and chillers to the basewide BAS is a logical component of the Fort Bragg BAS strategy. Minimally, in the event that central plants would stand alone (function independently from the basewide BAS), the plant boiler and chiller controls would benefit from having Local Display Panels at the building level.

Most if not all boiler/chiller (B/C) equipment manufacturers provide 'networkable' equipment, but in most cases the networking capability is based on a communications

protocol that is specific or exclusive to the manufacturer and is thus proprietary or 'closed'. Alternatively, industry standard communications protocols are available such as LonTalk®, BACnet®, and Modbus®. When such a standard is properly used, equipment can then openly communicate with each other if needed, but more importantly, with a supervisory monitoring and control system. At the same time, it is not a simple matter to properly or effectively adopt and implement a standard communications protocol so careful planning is required to avoid (or more practically to minimize) problems.

**2. Boiler and Chiller 'functional profiles'**

LonMark® International is an industry organization that, among other things, defines Functional Profiles (FP) for a variety of LONWORKS control devices and hardware including boilers and chillers and certifies devices against these profiles. One of the things that a Functional Profile defines is the Standard Network Variable Types or 'SNVTs' that devices must accommodate as inputs-and-outputs to-and-from the network. These SNVTs are data (in the form of network variables) generated by control hardware and made available over the communications network so that they are accessible for monitoring and control. LonMark has created FPs specific to a variety of equipment including boilers and chillers. Tables 6.1 and 6.2 list SNVTs available according to the Boiler and Chiller Functional Profile. Note that only a few of the listed SNVTs are "mandatory." For a boiler or chiller control device to be LonMark Certified, it must only provide the mandatory SNVTs. Many of the optional SNVTs, especially outputs, are points Fort Bragg should require to prepare for integration of the boiler or chiller into the BAS. It is important to note that devices meeting these profiles may provide SNVTs in addition to those listed in the FP, and most do. Fort Bragg's familiarity with the FPs and SNVTs is important as part of understanding what data exchange functionality is available with commercial boiler and chiller products. While FPs contain information beyond a listing of SNVTs, additional description is not provided here nor considered important to this effort.

**Table i.1. Boiler SNVT details (from LonMark 'Boiler Controller' functional profile).**

| No. | Mandatory or Optional | SNVT Name | SNVT Type | Description |
|---|---|---|---|---|
| 1 | Mandatory | nviBoilerEnable | SNVT_switch | Boiler Enable Input |
| 2 | Mandatory | nvoBoilerState | SNVT_switch | Boiler State Output |
| 3 | Mandatory | nvoEffectSetpt | SNVT_temp_p | Effective Setpoint Output |
| | | | | |
| 4 | Optional | nviApplicMode | SNVT_hvac_mode | Application Mode Input |
| 5 | Optional | nviPumpSpeedCmd | SNVT_switch | Pump Speed Command Input |
| 6 | Optional | nviSupplyTemp | SNVT_temp_p | Supply Temperature Input |
| 7 | Optional | nviOutdoorTemp | SNVT_temp_p | Outside Air Temperature Input |

| No. | Mandatory or Optional | SNVT Name | SNVT Type | Description |
|---|---|---|---|---|
| 8 | Optional | nviReturnTemp | SNVT_temp_p | Return Temperature Input |
| 9 | Optional | nviSetpoint | SNVT_temp_p | Temperature Setpoint Input (absolute) |
| 10 | Optional | nviBoilerCmd | SNVT_switch | Boiler Command Input |
| 11 | Optional | nvoBoilerLoad | SNVT_lev_percent | Boiler Load Output |
| 12 | Optional | nvoSupplyTemp | SNVT_temp_p | Supply Temperature Output |
| 13 | Optional | nvoLocalSupTemp | SNVT_temp_p | Local Supply Temperature Output |
| 14 | Optional | nvoReturnTemp | SNVT_temp_p | Return Temperature Output |
| 15 | Optional | nvoLocalRetTemp | SNVT_temp_p | Local Return Temperature Output |
| 16 | Optional | nvoPumpSpeed | SNVT_switch | Pump Speed Output |
| 17 | Optional | nvoBypassValve | SNVT_lev_percent | Ram Bypass Valve Output |
| 18 | Optional | nvoOutdoorTemp | SNVT_temp_p | Outdoor Air Temperature Output |
| 19 | Optional | nvoLocalOATemp | SNVT_temp_p | Local Outdoor Air Temperature |
| Source: http://www.lonmark.org/technical_resources/guidelines/functional_profiles.shtml. | | | | |

**Table i.2. Chiller SNVT details (from LonMark 'Chiller' functional profile).**

| No. | Mandatory or Optional | SNVT Name | SNVT Type | Description |
|---|---|---|---|---|
| 1 | Mandatory | nviChillerEnable | SNVT_switch | Request Start/Stop Chiller |
| 2 | Mandatory | nviCoolSetpt | SNVT_temp_p | Temperature of Leaving Chilled Water |
| 3 | Mandatory | nvoOnOff | SNVT_switch | Chiller On / Off run state |
| 4 | Mandatory | nvoActiveSetpt | SNVT_temp_p | Active Cool or Heat Setpoint |
| | | | | |
| 5 | Optional | nviCapacityLim | SNVT_lev_percent | Capacity Limit of Chiller |

| No. | Mandatory or Optional | SNVT Name | SNVT Type | Description |
|---|---|---|---|---|
| 6 | Optional | nviEntChwTemp | SNVT_temp_p | Accommodates Remote Temperature Sensor input |
| 7 | Optional | nviMode | SNVT_Hvac_mode | Chiller Modes |
| 8 | Optional | nviHeatSetpt | SNVT_temp_p | Heating Setpoint |
| 9 | Optional | nvoActualCapacity | SNVT_lev_percent | Actual Running Capacity of Unit |
| 10 | Optional | nvoCapacityLim | SNVT_lev_percent | Current Capacity Limit Setting of Chiller |
| 11 | Optional | nvoLvgChwTemp | SNVT_temp_p | Leaving Chilled Water Temp |
| 12 | Optional | nvoEntChwTemp | SNVT_temp_p | Entering Chilled Water Temp |
| 13 | Optional | nvoEntCndWTemp | SNVT_temp_p | Entering Condenser Water Temp |
| 14 | Optional | nvoLvgCndWTemp | SNVT_temp_p | Leaving Condenser Water Temp |
| 15 | Optional | nvoAlarmDescr | SNVT_str_asc | Alarm annunciation text |
| 16 | Optional | nvoChillerstat | SNVT_chlr_stat | Chiller States , modes |
| Source: http://www.lonmark.org/technical_resources/guidelines/functional_profiles.shtml. | | | | |

**3. LonWorks Boiler and Chiller Hardware Availability**

**In addition to defining Functional Profiles such as those for boilers and chillers, LonMark International also certifies commercially available devices that adhere to LonMark guidelines including the FPs described previously. Certified devices are permitted to bear the LonMark logo or stamp. LonMark maintains a listing of certified devices at their website (www.lonmark.org).**

Table **i.3** lists the commercially available boiler and chiller products as of August 2007.

**Table i.3. LonMark-certified boiler and chiller device availability.**

| Manufacturer | Equipment | Notes |
|---|---|---|
| Trane | Chiller | Multiple units / packages |
| McQuay | Chiller | MicroTech II |
| Carel SpA | Chiller | Bridge/gateway |
| FieldServer | Boiler/Chiller | Bridge/gateway. Multiple vendors: (York, McQuay, Carrier, Fireye, Cleaver Brooks, etc.) |
| RayPak | Boiler | Cleaver-Brooks |
| Source: http://www.lonmark.org/certifications/device_certification/product_catalog/ | | |

The data in

Table **i.3** suggest that LonMark-certified boiler and chiller controls are not as widely available as one might hope. Instead, boiler and chiller manufacturers tend to prefer to provide proprietary controls on their equipment, and in the case where an open interface is desired, they can provide a bridge or gateway that translates their proprietary communications to the ANSI 709.1b protocol. Of particular interest is that FieldServer can provide an ANSI 709.1b (LonTalk) bridge that will interface to a large number of commercially available proprietary boiler and chiller devices/equipment. During a meeting with FieldServer, they indicated that some of these include: YorkTalk (three different versions), McQuay, Carrier, Fireye, and Cleaver-Brooks. Interaction and dialog is ongoing as CERL researchers continue to obtain additional information.

## 4. Fort Bragg's Monitoring and Control Requirements

As with any LonWorks device, a key to ensuring that boiler and chiller controls are functional and useful to Fort Bragg is to specify the SNVTs that are needed to support monitoring and control requirements. At issue is the functionality needed by Fort Bragg to control chillers and boilers. Unfortunately there is no way to predict every control strategy that might be used with the chillers or boilers as ESPC contracts and changing energy guidance introduce new constraints. The goal, then, is to require sufficient SNVTs so that a wide array of control schemes can be implemented.

While

Table **i.**1 lists the LonMark Functional Profile SNVTs for a boiler,

Table **i.**4 lists other possible boiler-related SNVTs. These other possible SNVTs are not defined by the LonMark functional profile, but may be useful or needed in a special application.

**Table i.4. Boiler: Other possible monitored and controlled variables.**

| | |
|---|---|
| Fuel Pressure | Boiler Steam (Water) Temperature |
| Fuel Temperature | Boiler Steam (Water) Pressure |
| Fuel Btu Input Rate | Supply Steam (Water) Temperature |
| Fuel Btu Input Total | Supply Steam (Water) Pressure |
| Outdoor Air Temperature | Supply Steam (Water) Flow Rate |
| Temperature of Combustion Air into Burner | Supply Steam (Water) Flow Total |
| Furnace Pressure | Feed (Return) Water Temp |
| Temperature of Furnace Gas | Feed (Return) Water Press |
| Oxygen Content of Furnace Gas | Blowdown Flow Total |
| Stack Pressure | Makeup Water Temp |
| Temperature of Stack Gas | Makeup Water Flow Total |
| Oxygen Content of Stack Gas | |

**5. Boiler and Chiller 'points schedules'**

Points Schedules (Tables 6.5 through 6.8) for two types of boilers and two types of chillers have been developed. These Points Schedule are drawings that show points and other related information are intended to be used as a contract drawing and should be used to help specify and procure boiler and chiller controls.

The Points Schedules show common points (and SNVTs) that should provide Fort Bragg flexibility in the implementation of boiler and chiller control strategies. Be advised that the recommended Points Schedules do not show every point that can be monitored. For example, the steam boiler Points Schedule does not include some of the more "detailed" points that could be monitored such as:

- temperature of furnace gas
- oxygen content of furnace gas
- temperature of combustion air into boiler
- fuel pressure
- furnace pressure
- fuel temperature.

These points should only be included if Fort Bragg expects to monitor the boiler in detail. Fort Bragg should review the proposed boiler and chiller Points Schedules to determine

if the listed points are sufficient for the level of monitoring Fort Bragg expects to perform. In doing so, a comparison with Tables 6.1, 6.2, and 6.4 should prove helpful.

The recommended Points Schedules (Tables 6.5 through 6.8) do not correspond directly to the LonMark boiler and LonMark chiller controller Functional Profiles. Instead, they are a compilation of the information from Tables 6.1, 6.2, and 6.4 and are intended to encompass more of the SNVTs needed to effectively monitor this equipment. There are three main reasons why simply specifying the use of the LonMark Chiller Functional Profile or Boiler Functional Profile is insufficient:

1. As discussed above, the Functional Profiles have few mandatory variables and most of the required points are actually “optional” network variables.
2. LonMark Functional Profiles tend to confine themselves to a small part of a system. A cooling tower for example is considered to be separate from a chiller (currently there is no cooling tower Functional Profile).
3. LonTalk-based boiler and chiller interfaces tend to be accomplished most commonly by using a third-party bridge or gateway. These third-party devices, as discussed previously, provide many more variables than those defined by the LonMark Functional Profiles. Some manufacturers, such as Trane and McQuay provide an extensive set of SNVTs with their chiller controls that extends well beyond the LonMark FP.

## 6. Boiler and Chiller Monitoring and Control Recommendations

For all future procurement, Fort Bragg will:

1. Require that all boilers and chillers, if available come standard with ANSI 709.1 protocol, otherwise provide an ANSI 709.1 interface
2. Require that all control strategy by implemented using only LONWORKS controllers and not rely on supervisory controllers such as Network Automation Engine (NAE), Java Application Control Engine (JACE) or equivalent
3. Require that all boilers and chillers be integrated into the base-wide UMCS using Tables 6.5 through 6.8 template Points Schedules to specify LONWORKS point interface requirements
4. Ensure that all boiler and chiller controls are based on UFGS 23 09 23, “Direct Digital Controls (DDC) for HVAC and Other Local Building Systems”, in addition to the Point Schedules (http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2023%2009%2023.pdf).

**Appendix 19.2: CEP Mechanical Equipment (TBD)**

**Appendix 19.3: Centralized vs. Decentralized**

Central Vs decentralized Systems. Heating and cooling generation and distribution are among the major contributors to the installations' energy waste and inefficiency. With new construction and major retrofits projects as well as major utility modernization projects central systems are economical and shall be used for the whole installation or a part of it if the heating density is higher than 40,000 MBtu/ (h × sq. mile), and the cooling density is higher than 68,700 MBtu/ (h × sq. mi.) or 5,750 tons/ (h × sq. mile).

When not proven otherwise, central plants shall be designed for combined heat and power (CHP) generation or tri-generation (heating, cooling and power generation), which has an enormous potential for increased thermal efficiency, fuel reliability and reduced environmental impacts.

Central plants with multiple cooling units are preferred, to permit loss of the largest unit while maintaining at least 65% design capacity. Where the master plan calls for multiple buildings in an area, in the design provide for future expansion of the central plant. Water cooled compressors are preferred over air cooled systems and when feasible rejected heat shall be utilized.

**Appendix 19.3.1: CEP Boilers**

With utility modernization projects, existing heating systems currently using steam as a heating media shall be converted to variable-temperature-variable-flow medium (<270$^{o}$F) or low temperature (<190$^{o}$F) hot water. Thus reducing operation and maintenance costs, and allowing the use of less expensive, more efficient piping material. Systems with condensing boilers are to be designed with lower operating return hot water temperatures, i.e. <55 C (130 °F), and use hot water reset to take advantage of the higher efficiencies of condensing boilers.

Steam needs shall be evaluated and, when absolutely necessary, provided by local steam boilers. Use onboard steam generators on equipment requiring steam or a small steam boiler just for the year-round steam load. Hot water system experience fewer problems related to expansion and contraction, have fewer corrosion problems, and are much easier to control, all of which result in low maintenance costs. Use boiler with the thermal efficiency ≥ 90% $E_t$. Solar-assisted systems shall be considered as alternatives or to compliment conventional boiler systems.

Conversion of steam systems may require some changes in the pipe distribution and new requirements for heat exchange equipment at the customer interface and in the central heating plant. In new construction and steam to hot water conversion projects, a so-called indirect compact substation shall be used. Figure 5-1 shows an example of the building interface installation:

The main parts of the customer interface are:

1. DH control for the secondary side (Figure 5-1, component a)
2. Control valve (Figure 5-1, component b)
3. Differential pressure control, flow rate control (Figure 5-1, component c)
4. Heat meter (Figure 5-1, component d)
5. Plate heat exchanger (Figure 5-1, component e).

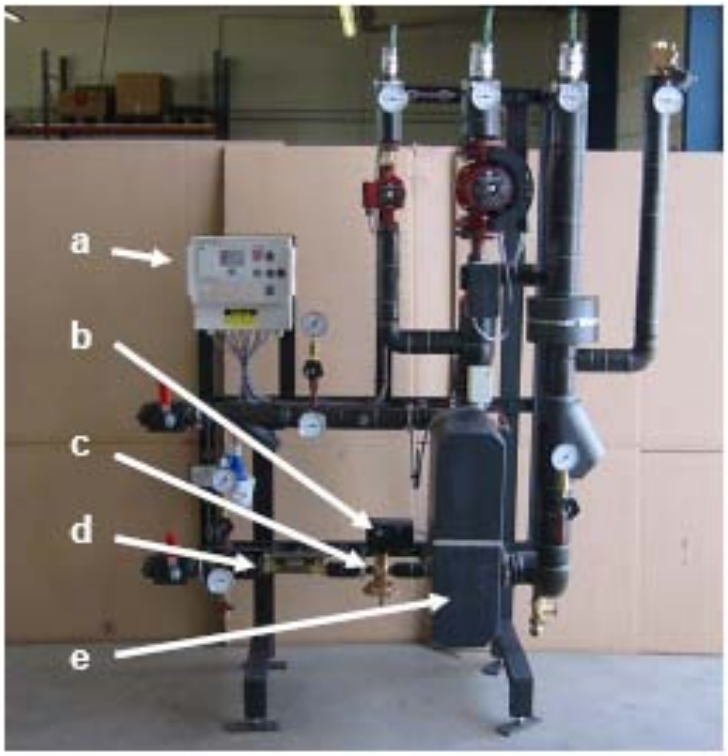



Figure 5-1. Photo of a modern, state-of-the-art DH compact station.

Both the DH control for the secondary side (a) and the control valve (b) regulate the secondary system flow according to the ambient temperature.

Furthermore, the control valve is used to program a time-dependent adjustment, e.g., the day/night shift, the so called night-time heating reduction.

The differential pressure control, flow rate control (c), is used to control the flow rate. Therefore, a certain flow rate limitation is fixed while the differential pressure is variable. When the differential pressure increases, the controller shuts according to its setpoint; similarly when the differential pressure decreases, the controller opens.

The heat meter (d) is used both for billing and to control the flow rate. Typically, at OCONUS installations, the utility owns the heat meter while the customer owns the compact station.

The plate heat exchanger (e) is used to decouple the primary DH distribution system from the secondary building side. This is important since the secondary building piping cannot bear up the relative high temperatures and pressures of the primary DH side.

Hot water in the building can be supplied either to radiators or to coils of the air heating systems. An “admix control” reduces the flow temperature in the secondary loop according to the ambient temperature. The secondary loop can handle different control programs, e.g., for weekend or nighttime heating reduction.

With the central heating system, domestic hot water preparation is also an “admix” operation controlled by the DH control unit for the secondary loop (e). In this loop, the lowest temperature is limited by hygienic conditions. Thus, the lowest flow temperature in the DH system is limited to 160 °F (70 °C) since the domestic hot water must have a temperature higher than 140°F (60 °C). The flow temperature must periodically be raised to 175°F (80 °C) to boost the domestic hot water to 160 °F (70 °C) (the required temperature to kill legionella) for thermal disinfection.

**Pipes for Hot Water Distribution Systems**. Pre-insulated bounded pipes shall be used for both medium and low temperature hot water systems. These pipes consist of a steel medium pipe and a plastic (i.e., polyethylene) jacket pipe. The insulation between the two pipes is made from a polyurethane (PUR) heat insulation foam. The pipes are pre-insulated in the factory and the PUR foam is a rigid material that bonds the outer jacket with the intermedium pipe.

Using these pipes will reduce the number of manholes and the size of the manholes which are currently about 15×15 Fort In addition, the manholes can be covered by an iron cap. Currently the existing manholes are open due to ventilation. Thus surface water and rain can easily flood the manholes and reduce the lifetime of the pipes due to external corrosion.

Figure 5-2 shows a photo of pre-insulated bounded pipes (pipe on the left is unused and is equipped with a leak detection system; pipe on the right was in use for about 30 years in a DH system with sliding flow temperatures [about 80 °C/130 °C]). The unused pipe is equipped with a leak detection system, indicated by the two wires seen on the far end of the pipe.

The most important limitation of the pipe is its maximum temperature restriction of 285 °F, which minimizes the aging of the PUR foam caused by exposure to the high temperatures.

The pipes are buried in frost-free depth in an open trench (Figure 5-3). After the laying of the pipe with a length of some 15 to 30 ft, the single pipes are connected through welding. Those weld joins are tested with radiation and evacuation tests. Afterwards, the PE jacket pipes are connected with shrinking bushings. Finally, the space between the medium pipe and bushings is foamed in place. Figure 5-4 shows different precast fittings, elbows and branches. Finally, the trench is filled with sand and compressed to bury the pipes. When the pipes are completely buried, the trench is further filled and prepared for the desired surface, which may be a street, pathway or grassland.

Figure 5-2. Pre-insulated bounded pipes (new and used)

Figure 5-3. Trench/canal for a buried pre-insulated pipe.

Figure 5-4. Pre-cast fittings and elbows of pre-insulated bounded pipes.

It is absolutely critical, that QC and QA be provided during the pipe installation to ensure the proper installation. Sensible issues are the bevel seams, the bushings and the foaming in back, the sand bed, the proper connection of the leak detection system and the expansion cushions.

**Appendix 19.3.2: CEP Chillers (TBD)**

**Appendix 19.4: CEP Operations (TBD)**

**Appendix 19.5: CEP Water Treatment**

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes the following HVAC water-treatment systems:
    1. Bypass chemical-feed equipment and controls.
    2. Biocide chemical-feed equipment and controls.
    3. Chemical treatment test equipment.
    4. HVAC water-treatment chemicals.

1.2 PERFORMANCE REQUIREMENTS

A. Water quality for HVAC systems shall minimize corrosion, scale buildup, and biological growth for optimum efficiency of HVAC equipment without creating a hazard to operating personnel or the environment.
B. Base HVAC water treatment on quality of water available at Project site, HVAC system equipment material characteristics and functional performance characteristics, operating personnel capabilities, and requirements and guidelines of authorities having jurisdiction.
C. Closed hydronic systems, including hot-water heating and chilled water shall have the following water qualities:
    1. pH: Maintain a value within 9.0 to 10.5.
    2. "P" Alkalinity: Maintain a value within 100 to 500 ppm.
    3. Boron: Maintain a value within 100 to 200 ppm.
    4. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.
    5. Soluble Copper: Maintain a maximum value of 0.20 ppm.
    6. TDS: Maintain a maximum value of 10 ppm.
    7. Ammonia: Maintain a maximum value of 20 ppm.
    8. Free Caustic Alkalinity: Maintain a maximum value of 20 ppm.
    9. Microbiological Limits:
        a. Total Aerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
        b. Total Anaerobic Plate Count: Maintain a maximum value of 100 organisms/ml.
        c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
        d. Sulfate Reducers: Maintain a maximum value of 0. organisms/ml.
        e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.
D. Open hydronic systems, including condenser water, shall have the following water qualities:

    1. pH: Maintain a value within 8.0 to 9.1.
    2. "P" Alkalinity: Maintain a maximum value of 100 ppm.
    3. Chemical Oxygen Demand: Maintain a maximum value of 100 ppm.

4. Soluble Copper: Maintain a maximum value of 0.20 ppm.
5. TDS: Maintain a maximum value of 10 ppm.
6. Ammonia: Maintain a maximum value of 20 ppm.
7. Free "OH" Alkalinity: Maintain a maximum value of 0 ppm.
8. Microbiological Limits:
    a. Total Aerobic Plate Count: Maintain a maximum value of 10,000 organisms/ml.
    b. Total Anaerobic Plate Count: Maintain a maximum value of 1000 organisms/ml.
    c. Nitrate Reducers: Maintain a maximum value of 100 organisms/ml.
    d. Sulfate Reducers: Maintain a maximum value of 0 organisms/ml.
    e. Iron Bacteria: Maintain a maximum value of 0 organisms/ml.
9. Polymer Testable: Maintain a minimum value within 10 to 40.

E. Passivation for Galvanized Steel: For the first 60 days of operation.
1. pH: Maintain a value within 7 to 8.
2. Calcium Carbonate Hardness: Maintain a value within 100 to 300 ppm.
3. Calcium Carbonate Alkalinity: Maintain a value within 100 to 300 ppm.

## 1.3 SUBMITTALS

A. Product Data: For each type of product indicated.

B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to HVAC systems. Include plans, elevations, sections, details, and attachments to other work.
1. Wiring Diagrams: Power and control wiring.

C. Field quality-control test reports.

D. Other Informational Submittals:
1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in the "Performance Requirements" Article above.
2. Water Analysis: Illustrate water quality available at Project site.
3. Passivation Confirmation Report: Verify passivation of galvanized-steel surfaces, and confirm this observation in a letter to Architect.

## 1.4 QUALITY ASSURANCE

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-treatment service provider capable of analyzing water qualities, installing water-treatment equipment, and applying water treatment as specified in this Section.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

# PART 2 - PRODUCTS

## 2.1 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
    1. Ampion Corp.
    2. Anderson Chemical Co, Inc.
    3. Aqua-Chem, Inc.; Cleaver-Brooks Div.
    4. Barclay Chemical Co.; Water Management, Inc.
    5. Boland Trane Services.
    6. GE Betz.
    7. GE Osmonics.
    8. H-O-H Chemicals, Inc.
    9. Metro Group. Inc. (The); Metropolitan Refining Div.
    10. ONDEO Nalco Company.
    11. Watcon, Inc.
    12. Approved equal.

## 2.2 MANUAL CHEMICAL-FEED EQUIPMENT

A. Bypass Feeders: Steel, with corrosion-resistant exterior coating, minimum 3-1/2-inch fill opening in the top, and NPS 3/4 bottom inlet and top side outlet. Quarter turn or threaded fill cap with gasket seal and diaphragm to lock the top on the feeder when exposed to system pressure in the vessel.
    1. Capacity: 5 gal..
    2. Minimum Working Pressure: 125 psig

## 2.3 AUTOMATIC CHEMICAL-FEED EQUIPMENT

A. Water Meter:
    1. AWWA C700, oscillating-piston, magnetic-drive, totalization meter.
    2. Body: Bronze.
    3. Maximum Pressure Loss at Design Flow: 3 psig
    4. Registration: Gallons
    5. Controls: Flow-control switch with normally open contacts; rated for maximum 10 A, 250-V ac; and that will close at adjustable increments of total flow.
B. Inhibitor Injection Timers:
    1. Microprocessor-based controller with LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface with the DDC system using LONWorks in Division 23 Section "Instrumentation and Control for

HVAC."

2. Programmable timers with infinite adjustment over full range, and mounted in cabinet with hand-off-auto switches and status lights.
3. Test switch.
4. Hand-off-auto switch for chemical pump.
5. Illuminated legend to indicate feed when pump is activated.
6. Programmable lockout timer with indicator light. Lockout timer to deactivate the pump and activate alarm circuits.
7. LCD makeup totalizer to measure amount of makeup and bleed-off water from two water meter inputs.

C. pH Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 14 units. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door. Interface with the DDC system using LONWorks as described in Division 23 Section "Instrumentation and Control for HVAC."
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal pH indication.
5. High or low pH alarm light, trip points field adjustable; with silence switch.
6. Hand-off-auto switch for acid pump.
7. Internal adjustable hysteresis or deadband.

D. TDS Controller:

1. Microprocessor-based controller, 1 percent accuracy in a range from zero to 5000 micromhos. Incorporate solid-state integrated circuits and digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door Interface with the DDC system using LONWorks as described in Division 23 Section "Instrumentation and Control for HVAC."]
2. Digital display and touch pad for input.
3. Sensor probe adaptable to sample stream manifold.
4. High, low, and normal conductance indication.
5. High or low conductance alarm light, trip points field adjustable; with silence switch.
6. Hand-off-auto switch for solenoid bleed-off valve.
7. Bleed-off valve activated indication.
8. Internal adjustable hysteresis or deadband.
9. Bleed Valves:
   a. Cooling Systems: Forged-brass body, globe pattern, general-purpose solenoid with continuous-duty coil, or motorized valve.

E. Biocide Feeder Timer:

1. Microprocessor-based controller with digital LCD display in NEMA 250, Type 12 enclosure with gasketed and lockable door Interface with the DDC system using LONWorks as described in Division 23 Section "Instrumentation and Control for HVAC."
2. 24-hour timer with 14-day skip feature to permit activation any hour of day.
3. Precision, solid-state, bleed-off lockout timer and clock-controlled biocide

pump timer. Prebleed and bleed lockout timers.
4. Solid-state alternator to enable use of two different formulations.
5. 24-hour display of time of day.
6. 14-day display of day of week.
7. Battery backup so clock is not disturbed by power outages.
8. Hand-off-auto switches for biocide pumps.
9. Biocide A and Biocide B pump running indication.

F. Chemical Solution Tanks:
1. Chemical-resistant reservoirs fabricated from high-density opaque polyethylene with minimum 110 percent containment vessel.
2. Molded cover with recess for mounting pump.
3. Capacity: 30 gal.

G. Chemical Solution Injection Pumps:
1. Self-priming, positive-displacement; rated for intended chemical with minimum 25 percent safety factor for design pressure and temperature.
2. Adjustable flow rate.
3. Metal and thermoplastic construction.
4. Built-in relief valve.
5. Fully enclosed, continuous-duty, single-phase motor. Comply with requirements in Division 23 Section "Common Motor Requirements for HVAC Equipment."

H. Chemical Solution Tubing: Polyethylene tubing with compression fittings and joints.

I. Injection Assembly:
1. Quill: Minimum NPS 1/2 with insertion length sufficient to discharge into at least 25 percent of pipe diameter.
2. Ball Valve: [Three] [Two]-piece, stainless steel; selected to fit quill.
3. Packing Gland: Mechanical seal on quill of sufficient length to allow quill removal during system operation.
4. Assembly Pressure/Temperature Rating: Minimum 200 psig at 200 deg F

## 2.4 CHEMICAL TREATMENT TEST EQUIPMENT

A. Test Kit: Manufacturer-recommended equipment and chemicals in a wall-mounting cabinet for testing pH, TDS, inhibitor, chloride, alkalinity, and hardness; sulfite and testable polymer tests for high-pressure boilers, and oxidizing biocide test for open cooling systems.

B. Corrosion Test-Coupon Assembly: Constructed of corrosive-resistant material, complete with piping, valves, and mild steel and copper coupons. Locate copper coupon downstream from mild steel coupon in the test-coupon assembly.
1. Two station rack for closed-loop systems.
2. Four station rack for open systems.

## 2.5 CHEMICALS

A. Chemicals shall be as recommended by water-treatment system manufacturer

that are compatible with piping system components and connected equipment, and that can attain water quality specified in Part 1 "Performance Requirements" Article.

B. Water Softener Chemicals:
   1. Mineral: High-capacity, sulfonated-polystyrene ion-exchange resin that is stable over entire pH range with good resistance to bead fracture from attrition or shock. Resin exchange capacity minimum 30,000 grains/cu. ft. of calcium carbonate of resin when regenerated with 15 lb of salt.
   2. Salt for Brine Tanks: High-purity sodium chloride, free of dirt and foreign material. Rock and granulated forms are not acceptable.

## PART 3 - EXECUTION

### 3.1 WATER ANALYSIS

Perform an analysis of supply water to determine quality of water available at Project site.

### 3.2 INSTALLATION

A. Install chemical application equipment on concrete bases, level and plumb. Maintain manufacturer's recommended clearances. Arrange units so controls and devices that require servicing are accessible. Anchor chemical tanks and floor-mounting accessories to substrate.
B. Install water testing equipment on wall near water chemical application equipment.
C. Install interconnecting control wiring for chemical treatment controls and sensors.
D. Mount sensors and injectors in piping circuits.
E. Bypass Feeders: Install in closed hydronic systems, including hot-water heating and chilled water , and equipped with the following:
   1. Install bypass feeder in a bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   2. Install water meter in makeup water supply.
   3. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
   4. Install a gate or full-port ball isolation valves on inlet, outlet, and drain below feeder inlet.
   5. Install a swing check on inlet after the isolation valve.
F. Install automatic chemical-feed equipment for condenser water and include the following:
   1. Install makeup water softener.
   2. Install water meter in makeup water supply.
   3. Install inhibitor injection pumps and solution tanks with injection timer sensing contacts in water meter.

a. Pumps shall operate for timed interval on contact closure at water meter in makeup water supply connection. Injection pump shall discharge into boiler feedwater tank or feedwater supply connection at boiler.

4. Install test equipment and provide test-kit to Owner. Install test-coupon assembly in bypass circuit around circulating pumps, unless otherwise indicated on Drawings.
5. Install TDS controller with sensor and bleed valves.
   a. Bleed valves shall cycle to maintain maximum TDS concentration.
6. Install pH sensor and controller with injection pumps and solution tanks.
   a. Injector pumps shall operate to maintain required pH.
7. Install biocide feeder alternating timer with two sets of injection pumps and solution tanks.
   a. Injection pumps shall operate to feed biocide on an alternating basis.

## 3.3 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.
B. Install piping adjacent to equipment to allow service and maintenance.
C. Make piping connections between HVAC water-treatment equipment and dissimilar-metal piping with dielectric fittings. Dielectric fittings are specified in Division 23 Section "Hydronic Piping."
D. Install shutoff valves on HVAC water-treatment equipment inlet and outlet. Metal general-duty valves are specified in Division 23 Section "Hydronic Piping."

Refer to Division 22 Section "Plumbing" for backflow preventers required in makeup water connections to potable-water systems.

## 3.4 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.
B. Perform tests and inspections and prepare test reports.
   1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.
C. Tests and Inspections:
   1. Inspect field-assembled components and equipment installation, including piping and electrical connections.
   2. Inspect piping and equipment to determine that systems and equipment have been cleaned, flushed, and filled with water, and are fully operational

before introducing chemicals for water-treatment system.

3. Place HVAC water-treatment system into operation and calibrate controls during the preliminary phase of HVAC systems' startup procedures.
4. Do not enclose, cover, or put piping into operation until it is tested and satisfactory test results are achieved.
5. Test for leaks and defects. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.
6. Leave uncovered and unconcealed new, altered, extended, and replaced water piping until it has been tested and approved. Expose work that has been covered or concealed before it has been tested and approved.
7. Repair leaks and defects with new materials and retest piping until no leaks exist.

D. Remove and replace malfunctioning units and retest as specified above.
E. Comply with ASTM D 3370 and with the following standards:
   1. Silica: ASTM D 859.
   2. Acidity and Alkalinity: ASTM D 1067.
   3. Iron: ASTM D 1068.
   4. Water Hardness: ASTM D 1126.DEMONSTRATION
F. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

**Appendix 19.6: Thermal Energy Storage (TES) (TBD)**

**Appendix 20: Surveys and Audits (TBD)**

## Appendix 21: Prescriptive and optional energy saving technologies for barracks

### 14.1 Prescriptive Technology Solution Sets

As part of the EPACT 2005 energy study discussed in Appendix 1, a prescriptive technology solution set was developed for the UEPH barracks for each climate zone to achieve at least a 30% energy consumption reduction compared to an ASHRAE 90.1-2004 minimum baseline building. The general energy conservation measures used to achieve the 30% reduction are listed in Table 14-1.

Table 0-1. General energy conservation measures used to achieve the 30% reduction

| ECM | Baseline Models | Efficient Models |
|---|---|---|
| Wall Insulation | Standard 90.1-2004 | Higher R-Values (see Tables 3-1 to 3-5). |
| Roof Insulation | Standard 90.1-2004 | Higher R-Values (see Tables 3-1 to 3-5). |
| Roof Solar Reflectance | 0.08 | 0.27 |
| Window-to-Wall Ratio | 20% | 20% |
| Window Construction | Standard 90.1-2004 | ASHRAE AEDG 30% Small Offices |
| Infiltration | 0.4 cfm/ft$^2$ @ 75 Pa | 0.25 cfm/ft$^2$ @ 75 Pa |
| Ventilation | Exhaust plus make-up air for infiltration at 5 Pa | Same as baseline but reduced make-up air for the tighter building |
| Lighting | 1.1 W/ft$^2$ in rooms, 0.5 in corridors, 0.6 in stairwells | 0.9 W/ft$^2$ in rooms, 0.45 in corridors, 0.54 in stairwells |
| SWH Boiler Efficiency | 80% | 95% |
| Grey water heat recovery | None | Assumed 30% savings on shower hot water |
| HVAC Systems | Packaged Single Zone with DX coil (3.05 COP) for cooling and natural gas coil (80% efficient) for heating | DOAS with DX coil (3.5 COP) and ERV (75%-70% sensible effectiveness) and hot water coil, 4-pipe fan coil with central chiller and boiler |

The specific prescriptive technology solution set for UEPH in each climate zone is shown below:

## Climate Zone 3A, Prescriptive Technology Solution Table

| Item | Component | Baseline (1) | 30% Solution |
|---|---|---|---|
| **Roof** | Attic | R-30 | R-40 |
| | Surface reflectance | 0.08 | 0.27 |
| **Walls** | Light Weight Construction | R-13 | R-20 |
| **Exposed Floors** | Mass | R-4.2 c.i. | R-10 c.i. |
| **Slabs** | Unheated | NR (2) | NR (2) |
| **Doors** | Swinging | U-0.70 | U-0.70 |
| | Non-Swinging | U-1.45 | U-1.45 |
| **Infiltration** | | 0.4 cfm/ft$^2$ @ 75 Pa | 0.25 cfm/ft$^2$ @ 75 Pa (3) |
| **Vertical Glazing** | Window to Wall Ratio (WWR) | 10% - 20% | 10% - 20% |
| | Thermal transmittance | U-0.57 | U-0.45 |
| | Solar heat gain coefficient (SHGC) | 0.37 | 0.31 |
| **Interior Lighting** | Lighting Power Density (LPD) | 1.1 W/ft$^2$ | 0.9 W/ft$^2$ |
| | Ballast | | Electronic ballast |
| **HVAC** | Air Conditioner | PSZ-AC 12.0 SEER (3.05 COP) | 4-Pipe Fan Coil with central chiller and boiler<br>plus<br>DOAS (4) with 14.0 SEER DX coil (3.52 COP) and HHW coil on central boiler<br>SAT control 55ºF – 62ºF with OAT 75º – 54ºF |
| | Gas Furnace | 80% $E_t$ | none |
| | ERV | None | 70% - 75% sensible effectiveness |
| **Economizer** | | no | no |
| **Ventilation** | Outdoor Air Damper | Motorized control | Motorized control |
| | Demand Control | NR | NR |
| | Laundry Room | | Decoupled (5) |
| **Ducts** | Friction Rate | | 0.08 in. w.c./100 feet |
| | Sealing | | Seal class B |
| | Location | | Interior only |
| | Insulation level | | R-6 (6) |
| **Service Water Heating** | Gas storage | 80% $E_t$ | 90% $E_t$ |

Prescriptive Technology Solution Table Notes (#):

1. Baseline requirements are from ANSI/ASHRAE/IESNA Standard 90.1-2004.
2. NR means there is no requirement or recommendation for a component in this climate.
3. **Increased Building Air tightness.** Building air leakage (measured in cfm/ft$^2$) is the average volume of air(measured in cubic feet per minute) that passes through a unit area of the *building envelope* (measured in square feet) when the building is maintained at a specified internal pressure (measured in Pascals). Testing requirements are specified in Chapter 5..
4. **Dedicated Outdoor Air System**. A central dedicated outdoor air system (DOAS) providing the following:
   a. outside air for building indoor air quality and humidity control, (the amount needed is typically less than the amount exhausted from the bathroom and kitchen)
   b. make-up air for bathroom and kitchen exhausts
   c. Building pressurization to prevent infiltration which allows for reduction of heating/cooling and moisture loads on the system.
   NOTE: The Central DOAS does not provide sensible heating or cooling. Sensible loads are provided by a complementing heating and cooling system
5. **Decoupling exhaust and supply systems for laundry rooms**. To reduce unneeded energy use for heating and cooling of the make-up air and for air transportation of supply and exhausted air from the dryers, laundry exhaust and supply systems are separated in the efficient building model from the rest of the building exhaust and supply systems. Laundry exhaust system and corresponding make-up systems operate only when dryers are operating.
6. The duct and pipe insulation values are from the ASHRAE Advanced Energy Design Guide for Small Offices.

## 14.2 Energy Savings Results Achieved

Table 14-2 shows the energy consumption reductions (without plug/process loads) achieved using the above prescriptive technology solution sets compared to a minimum ASHRAE 90.1-2004 compliant UEPH.

Table 0-2. Energy consumption reductions achieved using prescriptive technology solution sets described.

| Zone | City | Baseline (kBtu/ft$^2$) | Prescriptive Technology Solution Set | |
|---|---|---|---|---|
| | | | (kBtu/ft$^2$) | Savings |
| 1A | Miami, FL | 82 | 40 | 51% |
| 2A | Houston, TX | 82 | 37 | 55% |
| 2B | Phoenix, AZ | 45 | 32 | 30% |

| | | | | |
|---|---|---|---|---|
| 3A | Memphis, TN | 71 | 35 | 51% |
| 3B | El Paso, TX | 42 | 30 | 30% |
| 3C | San Francisco, CA | 47 | 26 | 45% |
| 4A | Baltimore, MD | 75 | 32 | 57% |
| 4B | Albuquerque, NM | 48 | 29 | 40% |
| 4C | Seattle, WA | 60 | 27 | 55% |
| 5A | Chicago, IL | 77 | 32 | 58% |
| 5B | Colorado Springs, CO | 54 | 28 | 48% |
| 6A | Burlington, VT | 83 | 32 | 61% |
| 6B | Helena, MT | 68 | 29 | 57% |
| 7A | Duluth, MN | 91 | 33 | 64% |
| 8A | Fairbanks, AK | 123 | 42 | 66% |

The following are descriptions of some of the technologies used in the prescriptive solution sets described above:

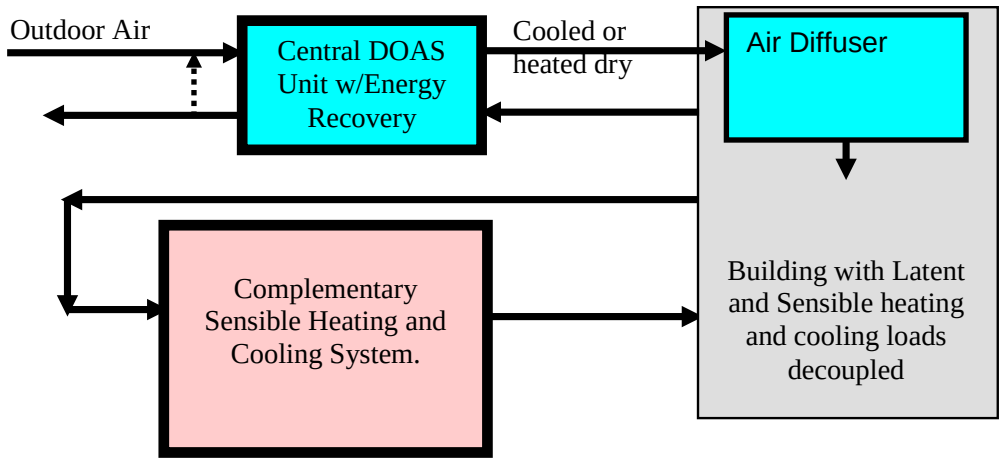
### 14.3 Dedicated outdoor air system

Three fundamental requirements for elimination of mold in Army facilities are:

- Minimize air leakage through the building envelope (discussed in a separate section of this document)
- Control the dew point temperature/relative humidity of the space with a central Dedicated Outdoor Air System (DOAS)
- Provide only room dry bulb temperature control with the in-room air conditioning system.

Figure 14-1 shows a central dedicated outdoor air system (DOAS). The DOAS will provide the following:

- outside air for building indoor air quality and humidity control, (the amount needed is typically less than the amount exhausted from the bathroom and kitchen)
- make-up air for bathroom and kitchen exhausts
- building pressurization to prevent infiltration which allows for reduction of heating/cooling and moisture loads on the system.




DOAS Schematic

Figure 0-1. Central dedicated outdoor air system (DOAS).

Central DOAS does not provide heating or sensible cooling. This is provided by a complementing heating and cooling system, which will be taking care of only sensible loads. Complementing system can be radiant ceiling system or a conventional convective HVAC system. If a convective HVAC system is used, the system must not deliver conditioned air to any space in the building at a dry bulb temperature which is below the dew point temperature in the space. All chilled water piping in the building must be properly insulated and all air conditioning units with ANY potential for condensation on the unit must have full coverage condensate drain systems.

Dedicated outdoor air system shall operate and provided the dew point temperature/relative humidity and a positive building pressure when building spaces are occupied or non-occupied for a short or long periods of time. Indoor conditions to be maintained in all spaces in all climate zones are shown in Appendix 2..

DOAS can have different configurations capable of providing deep outdoor air dehumidification. Figure 14-2 shows a detailed schematic of all-electric DX/desiccant DOAS unit installed in the Building 637 at Fort Stewart. In the figure, the leaving dew point temperature (DPT) from the DX coils is shown to be 50 F (10.0 C). This assumes that the air leaving the DX coils is saturated. The desiccant wheel further dehumidifies and reheats the air, resulting in a supply air dry bulb temperature (DBT) of 64.9 F (18.3 C) and a supply air relative humidity of 39.8% (which is equivalent to a supply air dew point temperature of 39.9 F (4.4 C). This dry air is then delivered to the occupant rooms via air distribution ductwork. This system delivers 4500 CFM, about 25 percent more ventilation air than the original system in an effort to maintain positive pressurization of the occupant rooms and prevent infiltration of hot, humid outdoor air.

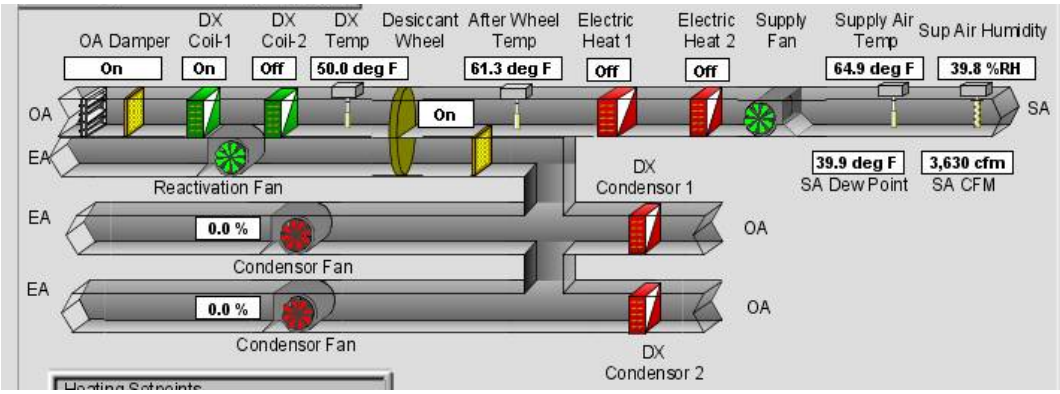



Figure 0-2. All-electric DX/desiccant DOAS unit installed in the Building 637 at Fort Stewart

Figure 14-3 shows schematic of a DOAS system used in a retrofit project of the Barrack 631 at Fort Stewart with a York Solutions AHU. Downstream of air filters, a preheat coil and a chilled water cooling coil, the AHU includes a DX cooling coil and an air-cooled condenser. The leaving dew point temperature (DPT) from the chilled water cooling coil is about 58 F (14.4 C). The DX cooling coil further dehumidifies the air, with a leaving DPT of approximately 40 F (4.4 C). This dry air is then reheated by the air-cooled condenser coil before being delivered to the occupant rooms at approximately 62 F (16.7 C) dry bulb temperature (DBT) and 40 F (4.4 C) DPT. As in the case with the system installed in the Building 637, this system delivers 4500 CFM, about 25 percent more ventilation air than the original system in an effort to maintain positive pressurization of the occupant rooms and prevent infiltration of hot, humid outdoor air.

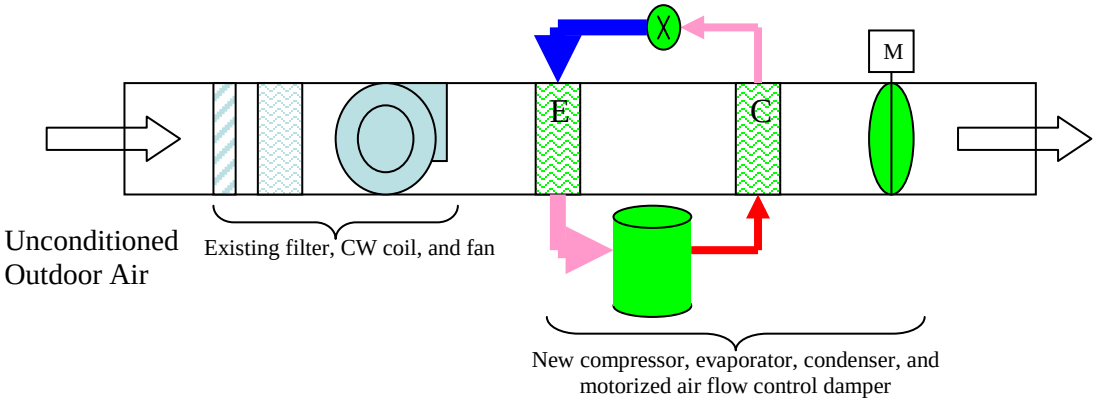



Figure 0-3. DOAS system used in a retrofit project of the Barrack 631 at Fort Stewart with a York Solutions AHU

## 14.4 Grey Water Heat Recovery

Domestic hot water (DHW) is one of the major heating energy users in the Army barrack buildings. Approximately 80-90% of hot water energy goes down the drain. Gravity Film heat eXchanger (GFX) technology was developed on a US Department of Energy (DOE) grant to capture heat carried by hot water and in 2002 received a Green Product Award. This technology is compatible with all types of water heating systems, including solar water heating systems. While shower water usage per a single shower head in

Permanent Party Barracks may be comparable with a shower water usage in residential buildings, it may be significantly higher in training barracks. Same applies to billets with common shower area. Thus, one can expect a payback period for such barracks to be shorter.

Gravity-Film Heat Exchanger (GFX) is a vertical counterflow heat exchanger that extracts heat out of drain water and applies it to preheat the cold water be mixed with hot water to be used in the shower (Figure 14-4). The CFX consists of a 2 to 4-inch central cooper pipe (that carries the warm wastewater) with ½-in.cooper coils wound around the central pipe. Heat is transferred from the wastewater passing through the large, central pipe to the cold water simultaneously moving upward through the coils on the outside of the pipe. The coils are flattened a little to increase the contact area and improve heat transfer. The system is beneficial for use with showers where the use of hot and cold water and the production of waste-water from the shower occur at the same time.

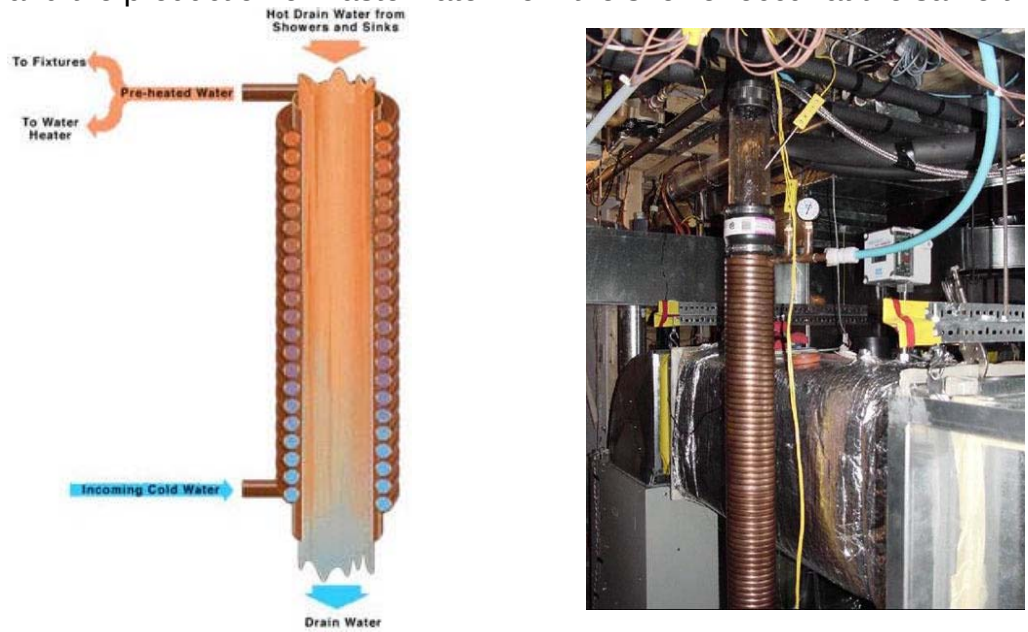



Figure 0-4. GFX system schematics and installation example

Energy savings occur due to use of waste water heat to preheat the cold water be mixed with hot water to be used in the shower. Cold water preheating results in reduction of the hot water usage. In addition to energy conservation GFX allows size reduction of the hot water storage tanks and (in the case of solar water heating) size reduction of solar water heaters.

According to Oak Ridge National Laboratory, this technology has been found to save 25–30 percent of total water-heating energy needed for showers. With an average usage rate of 30gal/day per occupant at 110$^{o}$F (43$^{o}$C), depending upon location and climate, DHW can consume more up to 60% of the total annual heating energy supplied to barrack buildings and be the dominant hot water consumer during the non-heating season.

An annual energy use and savings were analyzed for a barrack/dormitory baseline building built to meet the minimum requirements of ASHRAE Standard 90.1-1989. The

prototype building is three stories high, has an area of 30,465 $ft^2$, 40 2-bedroom apartment units, lobby on the main floor, and laundry rooms on each floor. For the payback calculations, it was assumed, that each GFX system serves 20 apartments and the average cost of each of two systems' retrofit including the cost of 4" heat recovery unit and drain lines, its transportation and installation is about $850.

Energy savings (Figure 14-5) differ between climates varying between 3% and 7% of the total barrack building energy use (at 25% energy recovery). While placing of GFX system for each shower is not cost efficient, installation of one heat exchanger for a group of showers produce a reasonable pay-back of 2 to 5 years (Figure 14-6).

Gravity Film heat eXchanger (GFX) technology has been developed over the last 7 years.

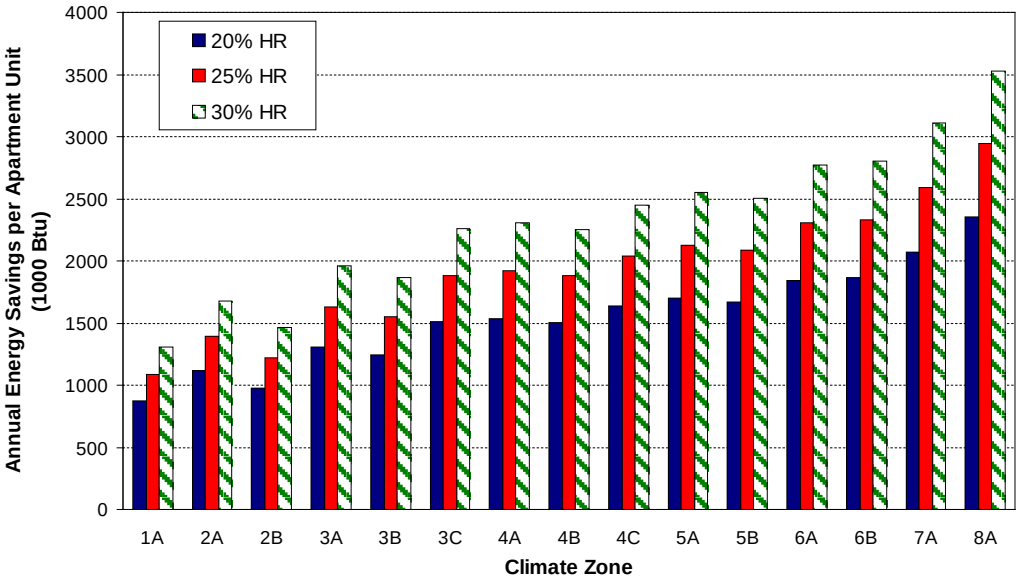



Figure 0-5. Annual energy savings per apartment unit with different heat recovery efficiency.

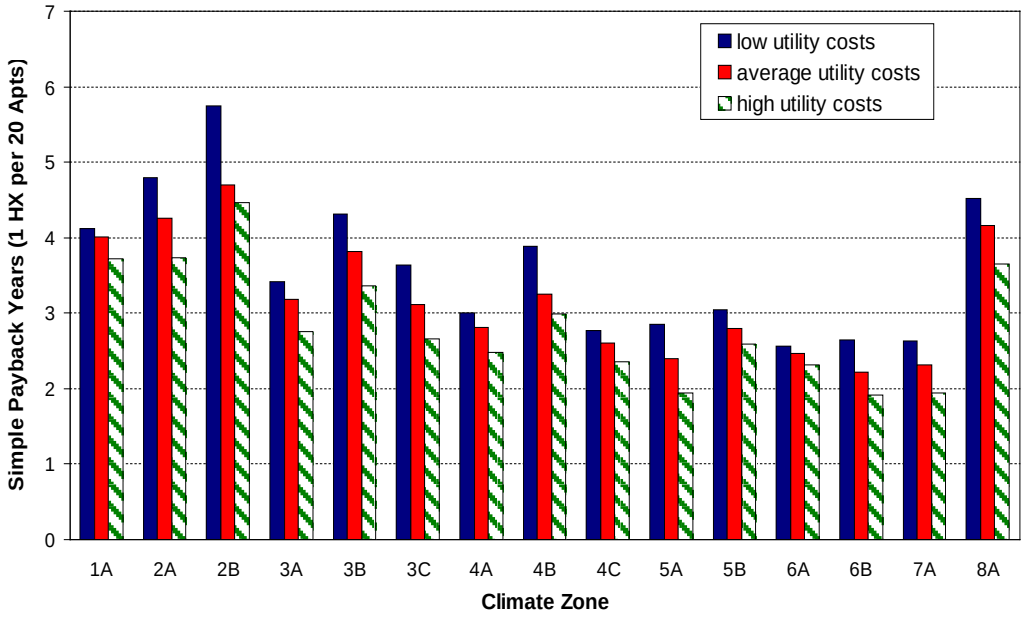



Figure 0-6. Simple payback, years with low, average and high utility rates for the heat recovery system servicing 20 apartments.

## Appendix 22: Prescriptive and optional energy saving technologies for Tactical Equipment maintenance Facilities

### 16.1 Prescriptive Technology Solution Sets

As part of the EPACT 2005 energy study discussed in Appendix 1, a prescriptive technology solution set was developed for the TEMF for each climate zone to achieve at least a 30% energy consumption reduction compared to an ASHRAE 90.1-2004 minimum baseline building. The general energy conservation measures used to achieve the 30% reduction are shown below:

| Building Component | Baseline Building Model | Efficient Building Model |
|---|---|---|
| Area | 49,920 $ft^2$ (4,638 $m^2$) | Same as baseline |
| Floors | 2 | Same as baseline |
| Aspect ratio | 4.4 | Same as baseline |
| Fenestration type | Standard 90.1-2004 | Improved |
| Wall construction | steel frame | Metal building |
| Wall insulation | Standard 90.1-2004 steel frame | Improved |
| Roof construction | Flat built up roof | Metal building roof |
| Roof insulation | Standard 90.1-2004 equal to the "insulation entirely above deck" | Improved |
| Roof albedo | 0.3 | 0.65 (CZ 1-5) 0.3 (CZ 6-8) |
| Infiltration | 0.5 ACH | 0.5 ACH |
| Temp set points | 70°F heating; 75°F cooling – set back when unoccupied to 55°F heating; 91°F cooling<br>Repair bays, vehicle corridor, and storage 1: 55°F heating, no cooling | Same as baseline |
| HVAC | PSZ with DX-AC (3.05 COP) and gas furnace (0.8 $E_t$); packaged make-up air units for exhaust make-up air and gas fired unit heaters for the repair bays, vehicle corridor, and consolidated bench | Increased efficiency of the baseline HVAC system to 3.52 COP, 0.9 $E_t$, and efficient fans. Energy recovery on repair bay, vehicle corridor, and consolidated bench exhaust systems. Assumed sensible heat recovery at 70% to 75% effectiveness. Reduced ventilation requirement using demand controlled ventilation. |
| DHW | Natural gas boiler (0.8 $E_t$) | Natural gas boiler (0.9 $E_t$) |

The specific prescriptive technology solution set for TEMF in each climate zone is shown below:

Climate Zone 3A, Prescriptive Technology Solution Table

| Item | Component | Baseline[1] | Recommendation |
|---|---|---|---|
| **Roof** | Insulation above deck | R-15 ci | |
| | Metal building roof | | R-13 + R-13 |
| | Surface reflectance | 0.3 | 0.65 |
| **Walls** | Steel-framed | R-13 | |
| | Metal building | | R-13 |
| **Slabs** | Unheated | NR[2] | NR |
| | Heated | R-7.5 for 12 in | R-10 |
| **Doors** | Swinging | U-0.70 | U-0.70 |
| | Non-Swinging | U-1.45 | U-0.25 |
| **Infiltration** | | 0.5 ACH | 0.5 ACH |
| **Vertical Glazing** | Window to Wall Ratio (WWR) | < 10% | < 10% |
| | Thermal transmittance | U-0.57 | U-0.45 |
| | Solar heat gain coefficient (SHGC) | 0.37 | 0.44 – N; 0.31 – S, E, W |
| | South Overhangs | None | NR |
| **Skylights** | Percent roof area | None | 2% |
| | Thermal transmittance | | U-0.69 |
| | SHGC | | 0.19 |
| **Interior Lighting** | Lighting Power Density | See Note 3 | See Note 3 |
| | Ballast | | Electronic ballast |
| | Daylighting controls [4] | none | Yes |
| | Occupancy controls | NR | all unoccupied spaces |
| **HVAC** | Make up Air Unit Fans | See Fan Efficiency Table | See Fan Efficiency Table |
| | Air Conditioner | PSZ-AC 12.0 SEER | PSZ-AC 14.0 SEER |
| | Gas Coil | 80% $E_t$ | 90% $E_t$ |
| | Hydronic radiant floor heat | None | Ground floor |
| | ERV | None | Yes |
| **Economizer** | | NR | NR |
| **Ventilation** | Outdoor Air Damper | Motorized control | Motorized control |
| | Demand Control | NR | NR |
| | Transpired Solar Coll. | None | Yes |
| **Ducts** | Sealing | | Seal class B |
| | Location | | Interior only |
| | Insulation level [5] | | R-6 |
| **Service Water Heating** | Gas storage | 80% $E_t$ | 90% $E_t$ |
| | | | |

Notes about prescriptive technology solution sets:

Baseline requirements are from ANSI/ASHRAE/IESNA Standard 90.1-2004.

1. NR means there is no requirement or recommendation for a component in this climate.
2. Lighting levels in accordance with the following table:

| Zone | Baseline | Recommendation |
|---|---|---|
| Repair Bay | 0.7 W/ft$^2$ (7.5 W/m$^2$) | 0.7 W/ft$^2$ (7.5 W/m$^2$) |
| Vehicle Corridor | 0.7 W/ft$^2$ (7.5 W/m$^2$) | 0.7 W/ft$^2$ (7.5 W/m$^2$) |
| Showers | 0.6 W/ft$^2$ (6.5 W/m$^2$) | 0.6 W/ft$^2$ (6.5 W/m$^2$) |
| Storage 1 | 0.9 W/ft$^2$ (9.7 W/m$^2$) | 0.9 W/ft$^2$ (9.7 W/m$^2$) |
| Consolidated Bench | 1.9 W/ft$^2$ (20.5 W/m$^2$) | 1.3 W/ft$^2$ (14.0 W/m$^2$) |
| Storage 2 | 0.9 W/ft$^2$ (9.7 W/m$^2$) | 0.9 W/ft$^2$ (9.7 W/m$^2$) |
| Office | 1.0 W/ft$^2$ (10.8 W/m$^2$) | 0.9 W/ft$^2$ (9.7 W/m$^2$) |

3. Daylighting should be included in the repair bays, vehicle corridor, and office.
4. The duct and pipe insulation values are from the ASHRAE Advanced Energy Design Guide for Small Offices.

## 16.2 Energy Savings Results Achieved

The following table shows the energy consumption reductions (without plug/process loads) achieved using the above prescriptive technology solution sets compared to a minimum ASHRAE 90.1-2004 compliant UEPH:

Table 0-1. Energy consumption reductions using prescription technology tables (without plug loads)

| CZ | City | Baseline (kBtu/ft$^2$) | Final Energy Efficient Solution (kBtu/ft$^2$) | Energy Savings |
|---|---|---|---|---|
| 1A | Miami, FL | 36 | 15 | 59% |
| 2A | Houston, TX | 45 | 19 | 58% |
| 2B | Phoenix, AZ | 42 | 17 | 59% |
| 3A | Memphis, TN | 56 | 25 | 56% |
| 3B | El Paso, TX | 47 | 20 | 58% |
| 3C | San Francisco, CA | 43 | 17 | 59% |
| 4A | Baltimore, MD | 75 | 35 | 53% |
| 4B | Albuquerque, NM | 61 | 27 | 56% |
| 4C | Seattle, WA | 64 | 29 | 54% |
| 5A | Chicago, IL | 93 | 45 | 52% |
| 5B | Colorado Springs, CO | 80 | 36 | 55% |
| 6A | Burlington, VT | 108 | 54 | 50% |
| 6B | Helena, MT | 99 | 49 | 50% |
| 7A | Duluth, MN | 134 | 65 | 51% |
| 8A | Fairbanks, AK | 207 | 105 | 49% |

Descriptions of technologies used in the prescriptive technology solution sets follow:

### 16.3 Cool Roofs

In TEMF, which are conditioned in warm season only by ventilation, cool roofs do not save energy. However they can improve comfort conditions (and hence productivity) in the space (Figure 16-1). In cold climates, a cool roof can increase the heating load, since the solar radiation reflected by the cool roof would otherwise be absorbed, resulting in a warmer roof. Cool roof materials are available as

- white coatings
- single-ply white membrane or
- painted metal (white, cool colored).

The EPA and DOE established the ENERGY STAR Roof Products Program to distinguish those products that are energy efficient. The criteria for an ENERGY STAR labeled roof product are based on the initial and aged total solar reflectance (TSR) the initial and aged total solar reflectance (TSR). The ENERGY STAR criteria vary for low and steep slope applications. Table 16-2 lists the Total Solar Reflectance (TSR) required.

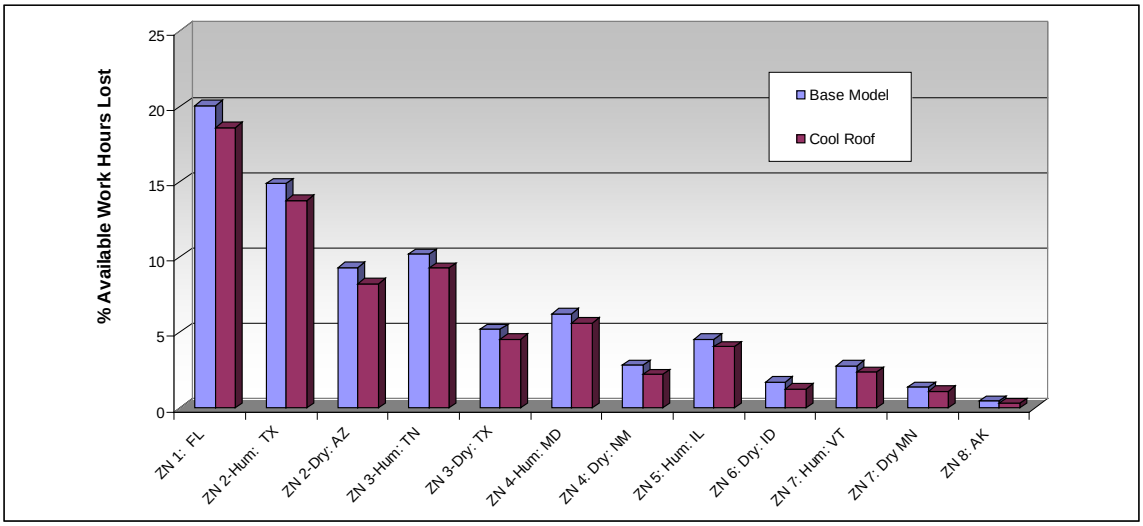



Figure 0-1. Percent of work hours lost in the base industrial building and in the building with a "cool roof" (based on the analysis under the Annex 46 study).

Table 0-2. Total Solar Reflectance (TSR) required.

| | Minimum initial TSR | 3-year Aged TSR |
|---|---|---|
| Low slope roofing (≤ 2:12) | 0.65 | 0.50 |
| Steep slope roofing (>2:12) | 0.25 | 0.15 |

Based on the analysis conducted by CERL and NAVFAC, the first cost of most of Energy Star Roof Products that can be used for TEMF does not exceed the cost of regular (not "cool" roofing materials). For TEMF roofs with high reflectivity (0.65) are recommended for climate zones 1–5.

### 16.4 Lighting Density Reduction and Daylighting

The lighting power density in the office and consolidated bench spaces and daylighting controls were included in the office, repair bay, and in the east half of the vehicle corridor. Repair bays and warehouses are good candidates for hybrid lighting systems, which include a combination of electrical lighting and daylighting (Figure 16-2). Installing skylights to reducing lighting costs is not a new concept. Skylight technology, however, has advanced significantly in recent years (Figure 16-3). Modern 'passive' skylights include a reflective tube that channels the light into the work area and a lens that diffuses the light evenly to produce a uniformly illuminated area (Figure 16-4). 'Active' systems may include a rotating mirror assembly that tracks the sun.

Figure 0-2. Maintenance facility with a daylighting system.

Figure 0-3. Warehouse application without (left) and with (right) skylights.

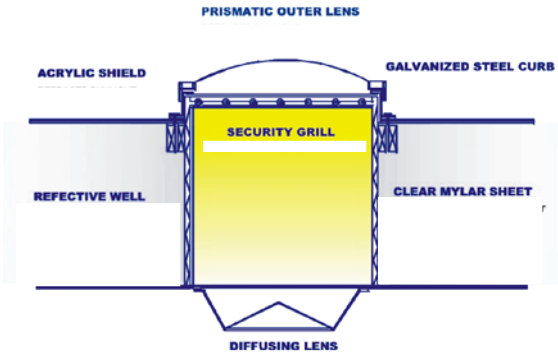



Figure 0-4. Schematic of modern skylight installation details (Source: www.daylighttechnology.com).

To automatically dim the lights, a photoelectric sensor measures the amount of light in a zone. If the specified amount of light has been reached, the controller turns off a bank of lights. Systems can be obtained to control only lights near windows or an entire building.

Small controllers can control the banks of lights near windows and larger systems can control an entire building that is illuminated by natural lighting. The controls can be set to dim the lights once a certain level of light has been achieved. Proper lighting levels can be found in the IESNA Lighting Ready Reference. Controls systems can typically either perform “step” dimming, which simply turns off certain banks of lights or linear dimming, and which linearly dims the lights until a minimum power level has been reached. Linear dimming, however, requires special dimming ballasts that are quite expensive and less efficient than standards ballasts above 50 percent. Figure 16-5 shows energy savings for a hybrid system. Based on the simulation results from the Annex 46 study, for the ventilated industrial building with no air conditioning, average pay-back ranges from 4–9 years (Figure 16-5).

### 16.5 Close Capture Evacuation System for Vehicle Exhaust Fumes

Vehicle exhaust ventilation system can mitigate and reduce exposure to Diesel and gasoline fumes generated by moving vehicles. Vehicle exhaust ventilation systems can be adapted to specific conditions of the maintenance facility (e.g., maintenance bay, drive-through corridor) and allow a range of exhausted air volume and withstand temperature ranges specific to variety of vehicles/tactical equipment serviced or repaired in these facilities. For the biggest vehicles the military needs to service, exhaust flow varies from 1700 to 3300cfm at temperatures of 650 up to 1200 °F.

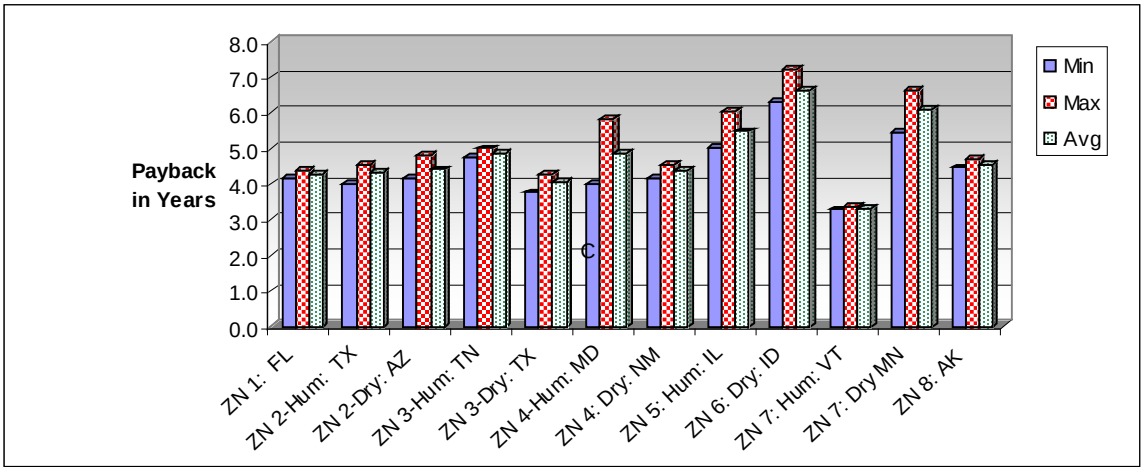



Figure 0-5. Estimated payback in years for hybrid lighting system.

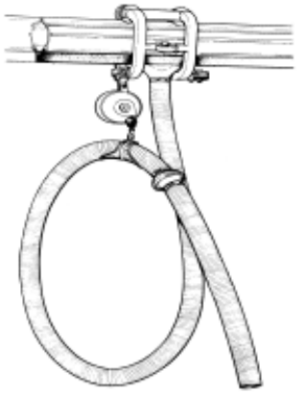
Vehicle exhaust capture systems trap and remove by-products of the engine combustion process (gas or Diesel) without contaminating the building air. Vehicle exhaust fumes contain hydrocarbons (HC), nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxides (SOx), carbon dioxide (CO2) and approximately 100 other volatile organic and acidic compounds.

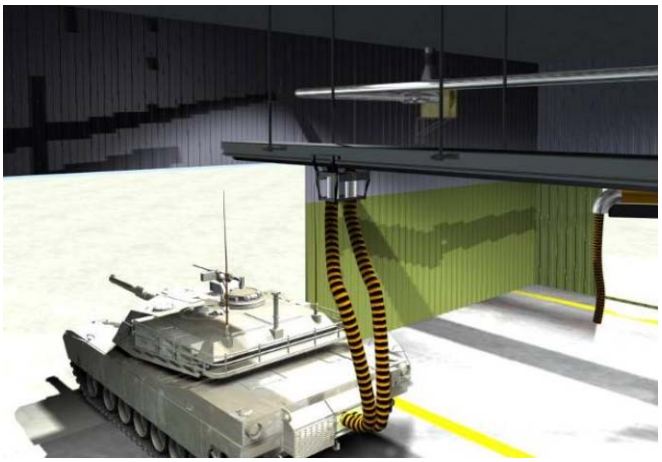
Traditional ventilation systems for maintenance facilities include a general dilution system sized for approximately 1.5 cfm of outside air per sq ft of floor area. This flow rate is based on ASHRAE Std. 62 and assumes that running vehicles are entering the building prior to attachment of the stationary close capture exhaust system. If the close capture system is attached before the vehicle enters the building, the general dilution rate can be assumed to be similar to mechanical or assembly shops (~0.75 cfm/sq ft) (Ventilation Guide for Automotive Industry, HPAC Engineering, 2000). The reduction could be achieved through demand controlled exhaust and make-up air systems and using the exhaust air from the office space as part of the make-up air. Conditioning the make-up air is the largest single energy use in the TEMF. This ECM results in the most significant energy savings in all climate zones.

Figure 16-6 shows a stationary hose reel type system (requiring ~1.5 cfm/sq ft of outside air).

Figure 0-6. Stationary hose reel type system.

Reduction in the general dilution rate can be achieved by means of well designed suction rail or pivoting boom systems (Figure 16-7). Vehicles are connected to these systems prior to entering the facility and remain attached while moving in and out of the facility.





**Suction Rail Systems**

**Boom Systems**

Figure 0-7. Well designed suction rail or pivoting boom systems.

Vehicle Exhaust Extraction systems can be classified as non-enclosing or enclosing. Enclosing type exhaust systems typically have a flexible hose with a tail-pipe adapter. The hose can be mounted on a stationary reel, an overhead rail extraction system or a swinging boom. Enclosing systems are normally classified as ‘sealed’ or ‘non-sealed’.

Sealed type exhaust systems use a tailpipe adapter, which makes an airtight seal between the exhaust tailpipe and the flexible exhaust ventilation hose. The attachment of this nozzle is usually through the use of an air-filled bladder made of synthetic rubber, which conforms to the size of the vehicle’s tailpipe. This eliminates the escape of exhaust gases when the vehicle is being accelerated or run at high idle. This system has a low operating air volume flow rate. Table 16-3 lists approximate airflow rates to be extracted per vehicle from the exhaust pipe using a sealed-fit tailpipe adapter. The capture effectiveness of sealed exhaust systems is high and for design purposes can be considered 90 percent or higher.

Table 0-3. **Airflow rates to be extracted per vehicle from the tail pipe using a sealed fit tailpipe adapter (Source: Ventilation Guide for Automotive Industry, HPAC Engineering, 2000).**

| Sealed Fit Tailpipe Adapter | | | |
|---|---|---|---|
| **Veh. Type **** | **Engine Power (h.p.)** | **Airflow rate cfm (m3 /h)** | **Hose size (in.)** |
| LDGV | <130 | 300 (510) | 3 |
| LDGT | < 175 | 450 (765) | 4 |
| HDGV | < 250 | 500 (850) | 4 |
| LDDV | < 325 | 500 (850) | 4 |
| LDDT | < 400 | 500 (850) | 4 |
| HDDV | < 500 | 750 (1275) | 5 |
| ORV | < 600 | 1000 (1700) | 6-8 |

Non-sealed systems use a loosely fitting tailpipe adapter. This system requires a higher air flow rate than a sealed system to maintain negative pressure control of the exhaust gases emitted by the vehicle. The nozzle is usually attached by means of a mechanical device such as a vice-grip clamp or spring clip.

For non-sealed exhaust systems, the capture effectiveness is below 75 percent. Table 16-4 lists approximate airflow rates to be extracted per vehicle from the exhaust pipe using a non-sealed fit tailpipe adapter.

Table 0-4. **Airflow rates to be extracted per vehicle from the exhaust pipe using an open-fit non-sealing tailpipe adapter (Source Ventilation Guide for Automotive Industry, HPAC Engineering, 2000).**

| Non-sealed Fit Tailpipe Adapter | | | |
|---|---|---|---|
| Veh. Type* | Engine Power (h.p.) | Airflow rate cfm (m3 /h) | Hose size (in.) |
| LDGV | < 130 | 450 (765) | 4 |
| LDGT | < 175 | 600 (900) | 5 |
| HDGV | < 250 | 750 (1250) | 5 |
| LDDV | < 325 | 750 (1275) | 5 |
| LDDT | < 400 | 750 (1275) | 5 |
| HDDV | < 500 | 1125 (1910) | 6 |
| ORV | < 600 | 1500 (2500) | 8 |

*Notes:
LDGV: Light-duty gasoline-fueled vehicles, up to 6000 lb GVW
LDGT: Light-duty gasoline-fueled trucks, up to 8500 lb GVW
HDGV: Heavy-duty gasoline-fueled vehicles, 8501+ lb GVW
LDDV: Light-duty Diesel vehicles, up to 6000 lb GVW
LDDT: Light-duty Diesel trucks, up to 8500 lb GVW
HDDV: Heavy-duty Diesel vehicles, 8501+ lb GVW

Selection of the hose for a particular application depends on exhaust temperature and flow rate. Selection of the nozzle depends on the size and configuration of the tail-pipe or exhaust grill (cf. Appendix D).

In most small vehicle maintenance and repair facilities, it is uncommon for several vehicles to drive in or out of the facility simultaneously. Likewise, it is uncommon to run all the engines in the facility at the same time. Typically a demand controlled local exhaust system is sized for a maximum duty cycle of 50 percent of the total available capacity thereby reducing the size of the exhaust duct, fan as well as its operating airflow rate. The exhaust airflow rate is controlled using a variable frequency drive (VFD) and a pressure sensor installed in the main duct.

Demand based control of the local exhaust system is initiated by a mechanical damper that opens when the hose is pulled down from the reel. Each of these mechanical dampers initiates the activation of air flow from a specific hose reel during maintenance operations. The system fan ramps up or down to accommodate the number of hose reels activated without affecting the airflow through other reels.

Figures 16-8 and 16-9 show the simple payback for both the rail and boom systems based on the simulation results conducted under the Annex 46 study. For both systems in all climates, the payback is less than 4.5 years. The significant reduction in outside air flow rate is responsible for the savings.

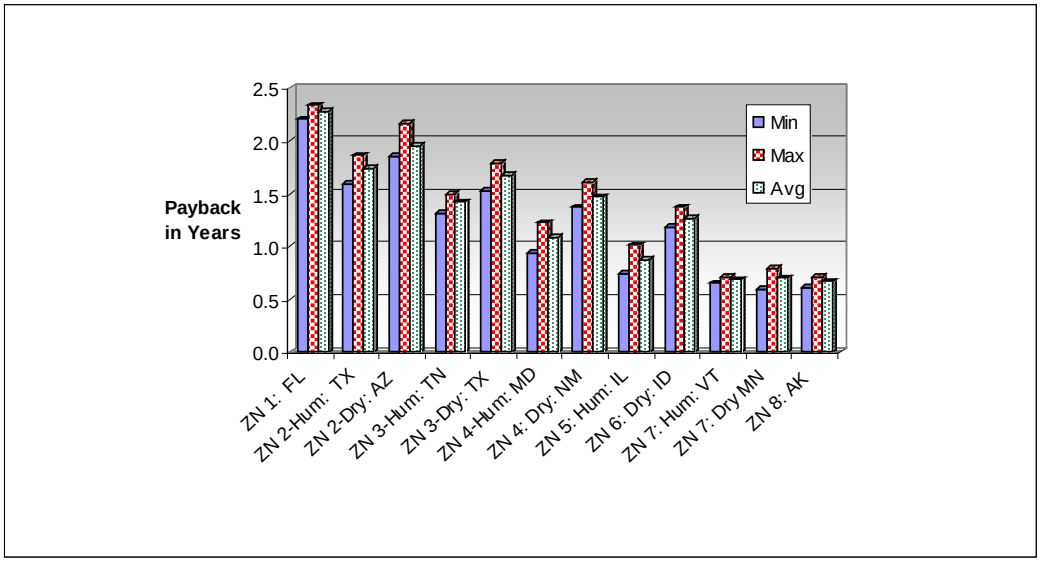



Figure 0-8. Estimated simple payback for rail system.

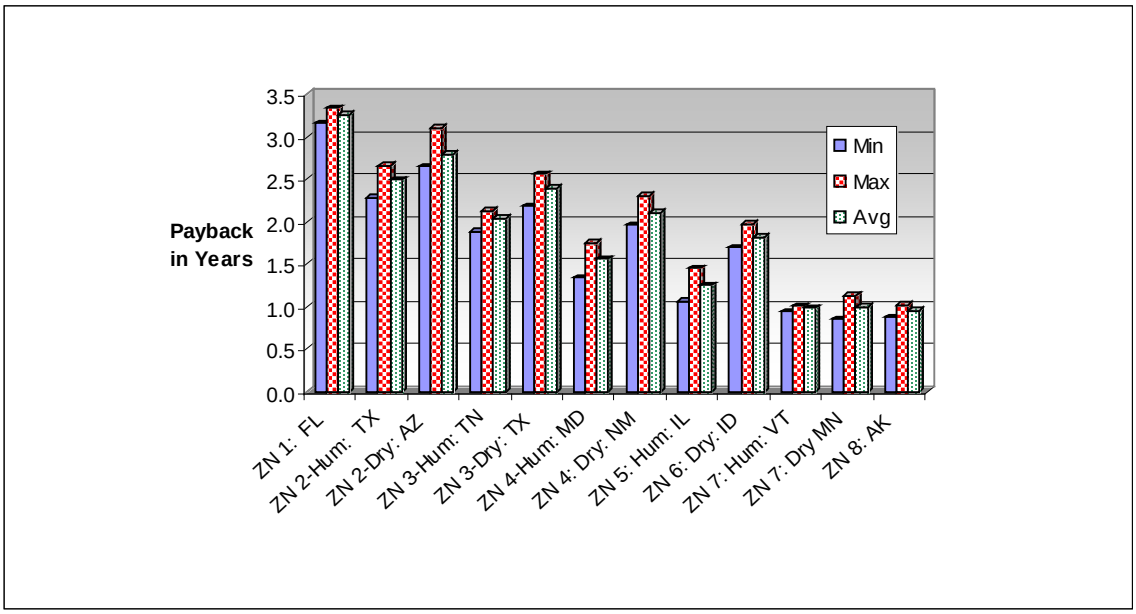



Figure 0-9. Estimated simple payback for boom system.

## 16.6 General Ventilation

General supply and exhaust ventilation shall be designed to respond maintain indoor air quality and provide a make-up air for local exhaust systems. Demand controlled ventilation with variable frequency drives (VFD) and CO and NOx sensors to control residual fumes from gasoline, can be implemented following the indoor air quality (IAQ) procedure in ASHRAE Standard 62.1-2007.

Cascading air from offices to maintenance bays and vehicle corridor pressurizes office areas and prevents odors/contaminants from more polluted zones to office spaces. It also provides heated or cooled air for the repair bays area and results in energy

conservation. Since vehicle exhaust fume are heavier that the air and tend to stay close to the floor, two-thirds of air shall be exhausted by general exhaust system from within 1 ft from the floor level, and the rest from the upper zone. If TEMF has a pit, it shall be ventilated by supplying air directly into the pit and have an exhaust from its bottom.

### 16.7 HVAC equipment efficiency improvement

Compared to the ASHRAE Standard 90.1 minimum requirement, the cooling equipment efficiencies were increased by 20 percent, the gas burner efficiencies were increased to 0.9, and the fan efficiencies were improved (Table 16-5).

The improved efficiency fan performance numbers are based on available high efficiency fans. The last column shows the pressure increase in the fan system for the inclusion of the energy recovery ventilator (ERV). The fan pressure was increased by 50 Pa when the transpired solar collector was included. For the cases with reduced ventilation, the pressures were reduced by 15 percent for the repair bays, vehicle corridor, and the consolidated bench.

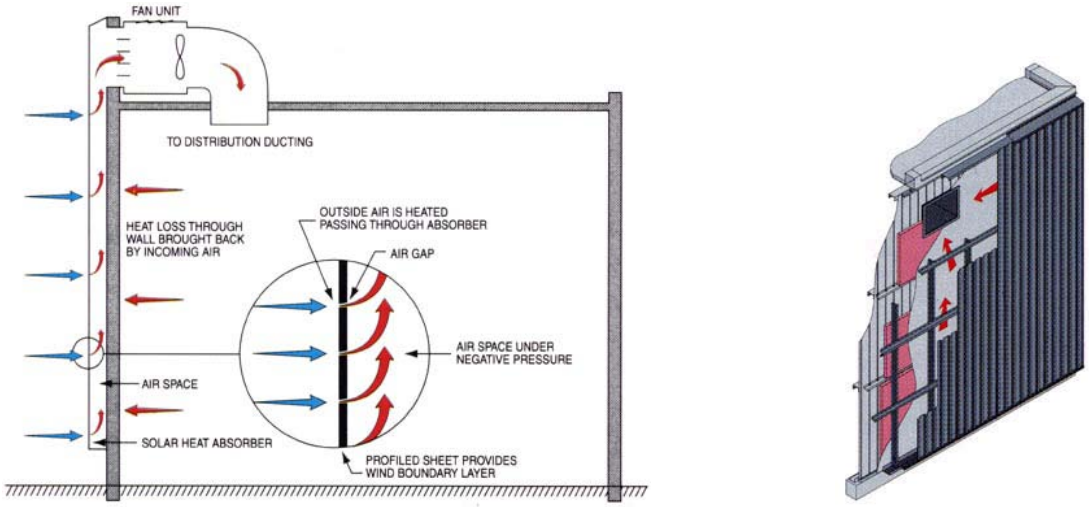
Table 0-5. **Improved fan model assumptions.**

| System | Flow ($m^3/s$) | Pressure Rise (Pa) | Baseline Efficiency | | Improved Efficiency | | ERV Pressure Drop (Pa) |
|---|---|---|---|---|---|---|---|
| | | | Fan Motor | Total Fan | Fan Motor | Total Fan | |
| Repair bay | 15.52 | 400 | 0.8 | 0.27 | 0.9 | 0.45 | 200 |
| Vehicle corridor | 4.28 | 300 | 0.8 | 0.19 | 0.9 | 0.45 | 150 |
| Showers | 0.78 | 250 | 0.8 | 0.20 | 0.85 | 0.34 | |
| Storage 1 | 0.54 | 250 | 0.8 | 0.20 | 0.85 | 0.34 | |
| Consolidated bench | 2.14 | 300 | 0.8 | 0.19 | 0.9 | 0.45 | 150 |
| Storage 2 | 1.19 | 250 | 0.8 | 0.20 | 0.85 | 0.34 | |
| Office | 2.49 | 250 | 0.8 | 0.20 | 0.85 | 0.34 | |
| Fan coil units | Varies | 75 | 0.8 | 0.30 | 0.85 | 0.34 | |

The fan improvements had the larges affect in the climate zones 1 to 3.

### 16.8 Ventilation air preheating in transpired solar collector

A transpired solar collector or a “solar wall” preheats ventilation air by drawing make-up air through a perforated steel or aluminum plate that is warmed by solar radiation. The solar wall consists of perforated steel or aluminum cladding attached to the south façade of a building with an air gap between the existing wall and the cladding. The solar wall is dark-colored to absorb the maximum amount of solar radiation. Air is drawn through the small holes in the wall and heated at the same time (Figure 16-10). The warm air rises to the top of the wall and is drawn into the building’s ventilation system as shown in the figure below. Figure 16-11 shows a solar wall installed on the maintenance facility at Fort Drum, NY.




**a.** **b.**

Figure 0-10. Schematic of air flows through (a) a solar wall and (b) typical installation.

**a.** **b.**

Figure 0-11. Solar wall installed on (a) the maintenance facility at Fort Drum, detail showing (b) perforated panel element

The performance of a “solar wall” depends primarily on four parameters: the solar reflectance of the wall, the orientation of the wall, the size and spacing of the perforations in the wall, and the pressure drop maintained by the ventilation system across the wall. The solar reflectance is primarily affected by the coating applied to the solar wall. In general, darker colors have a lower reflectance, and thus absorb a greater fraction of incident solar radiation.

The orientation of the wall also greatly affects its performance The intensity of the incident solar radiation is dependent on the cosine of the ‘angle of incidence’, the angle between the outward facing normal of the surface and the ‘line of sight’ to the sun. Walls that more directly face the sun will receive more solar radiation. In winter months in the northern hemisphere, south facing walls perform best. The cost effectiveness of applying solar collectors to East and West facing walls (to catch morning and afternoon sun) must be analyzed on a case by case basis.

The size and spacing of the perforations along with the pressure drop across the wall due to the operation of the ventilation system largely determines the impact of wind speed and wind direction on the solar wall performance. For a properly designed wall with small closely spaced perforations and a relatively high pressure drop, the laminar boundary layer created by suction at the wall will largely negate the effects of changing wind speed and wind direction. For the improved model building a 2,280 sq ft transpired solar collector on the south wall of the repair bays was simulated. This collector occupies the top 10 ft of the wall and is slightly undersized for the exhaust air requirements of this zone. The collector should be sized for the flow to be 7 to 10 cfm/sq ft.

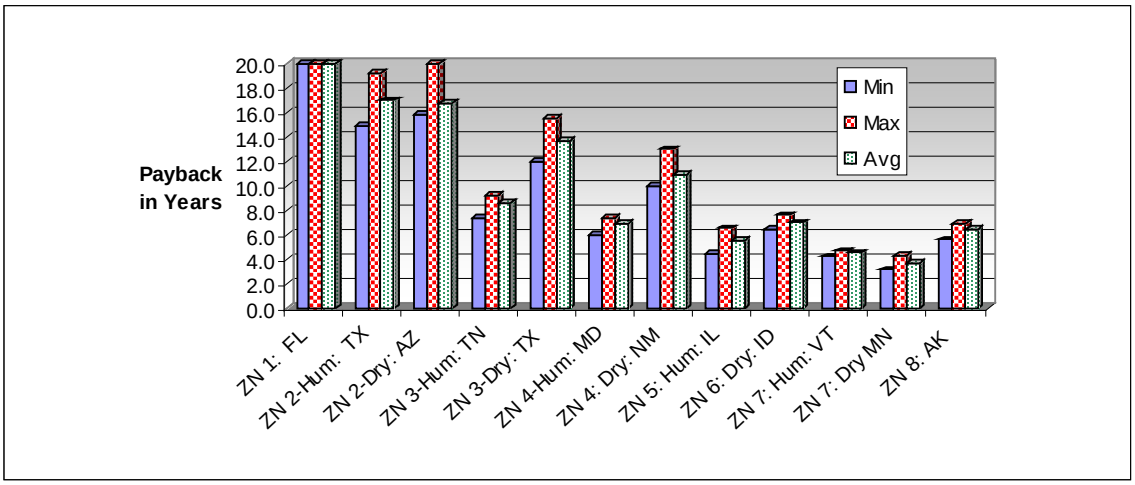



Figure 0-12. Transpired solar wall estimated payback shown for high, medium and low energy rates.

Figure 16-12 shows a simple payback from installation of the “solar wall.” The data was received through simulation of “solar wall” conducted under the IEA Annex 46 study. The simple pay back is under 6 years for all heating dominated climates.

### 16.9 Energy recovery ventilators

Heating energy recovery from the stream of air exhausted from repair bays, vehicle corridor, and consolidated bench can be used to preheat supply air. Use of ERV results in the increased pressure drop in the supply air system. There is also a need for better duct insulation to reduce heat losses in the return duct. Given these additional costs and losses, according to Airways [2002] ERVs are not cost efficient in mild climates (with HDD < 2500). Considering that exhaust air may contain sticky particulates, ERVs were selected with a plate heat exchangers (Figure 16-13), which are 75 to 70 percent effective for flows ranging from 70 to 100 percent.

Figure 0-13. Plate heat exchanger.

## 16.10 Hydronic radiant floor heating

Low intensity hydronic radiant floor heating systems are commonly used in industrial facilities, hangars, warehouses, garages, gymnasiums, hospitals, kindergartens, apartments, and in different other types of buildings. Heat to the space is provided by hot water supplied through pipes embedded in floors. Thermal energy is exchanged by at least 50% by radiation between the room and people present in the space and the heated floor surface. Transfer from the hot water pipes to the surface of the floor is the important consideration. Figure 16-14 shows the installation of plastic piping for a radiant floor heating system, and Figure 16-15 shows a radiant floor heating system installed in a TEMF at Fort Lewis, WA.

The uniform temperature distribution from floor heating increases comfort and reduces room air temperature stratification especially in high ceiling buildings. Low intensity radiant heating provides greater comfort for mechanics working near or on the floor. Radiant energy transmitted to the cold (sometimes snow-covered) vehicles results in rapid conditioning of the vehicles for service, which improves workers' productivity and adds to their comfort.

Figure 0-14. Installation of plastic piping for the radiant floor heating system (Uponor, 2007)

Figure 0-15. Radiant floor heating system installed in a TEMF at Fort Lewis, WA.

Radiant floor systems are more energy efficient.

7. Compared to warm air heating systems traditionally used in TEMF, a radiant floor system provides the same comfort level in the working zone at a lower room air temperature during the heating season. This results in reduced ventilation and infiltration losses.
8. In hydronic radiant floor systems, energy is transported by water instead of air. Auxiliary energy for circulation pumps is less than for fans.
9. The system uses lower water temperature for heating, than the warm air heating systems. This allows for using return water for radiant floor system, which increases energy performance of boilers (condensing boilers) and heat pumps.
10. Reduced air temperature stratification along the room height results in heating energy saving, typically at least by 25 to 30 percent.

With the introduction of polybutelene tubing and new design techniques, as well as reduced energy losses due elimination of room air temperature stratification, the first cost of radiant floor system became comparable or even lower than the warm air system.

Application of radiant floor systems requires under the slab insulation with 2 in. of EPS insulation (R-10) for climate zones 1 to 7 and 3 in. (R-15) for climate zone 8 (Figure 16-16).

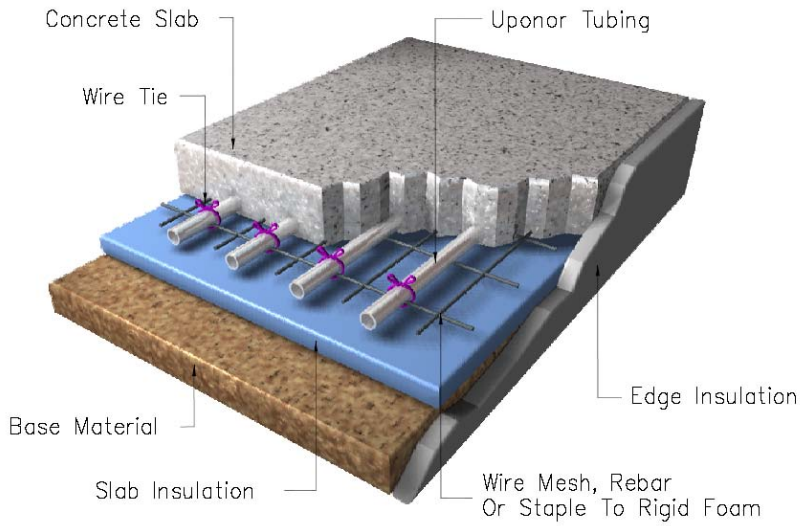



Figure 0-16. Concrete floor radiant heating system with edge and slab insulation (Uponor 2008).

### *16.11 Optional ECMs*

#### 16.11.1 Vestibules with airlocks

Vestibule with an air lock (Figure 16-17) prevents cold air drafts into the building and allows heating the vehicle prior to bringing it in. The building is protected from outdoor air by two sequentially installed doors with an enclosed space ("air lock"). There is only one door open at a time to let a vehicle in or out the building. After the vehicle enters the "air lock" the first door closes and the second one opens.

Figure 16-18 shows a simple payback from installation of the vestibule. The data was received through simulation of "vehicle vestibules" conducted under the IEA Annex 46 study. The simple pay back is under 4 years for all heating dominated climates.

Figure 0-17. Example vestibule at auto manufacturing plant.

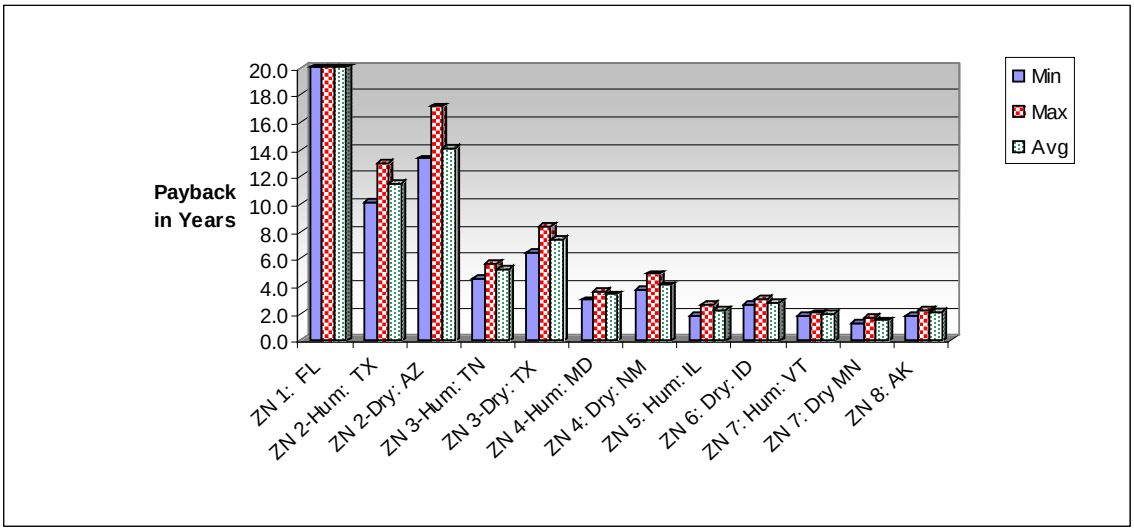



Figure 0-18. Simple payback from installation of the vestibule.

### 16.11.2 Evaporative Cooling

The Wet Bulb Globe Temperature (WBGT) offers a useful first order index of the environmental contribution to heat stress. It is influenced by air temperature, radiant heat, and humidity. WBGT values are calculated using one of the following equations: with direct exposure to sunlight:

$$WGBT_{out} = 0.7\ T_{nwb} + 0.2\ T_g + 0.1\ T_{db}$$

without direct exposure to the sun:

$$WBGT_{in} = 0.7\ T_{nwb} + 0.3\ T_g$$

where:

$T_{nwb}$ = natural wet bulb temperature (sometimes called NWB)
$T_g$ = globe temperature (sometimes called GT)
$T_{db}$= dry bulb (air) temperature (sometimes called DB).

Because WBGT is only an index of the environment, the screen criteria are adjusted for the contributions of work demands and clothing as well as state of acclimatization. Table 16-6 lists ACGIH (American Conference of Governmental Industrial Hygienists) rest-work guidelines for hot-humid climates. It provides screening criteria for heat stress exposure (WBGT values in °F).

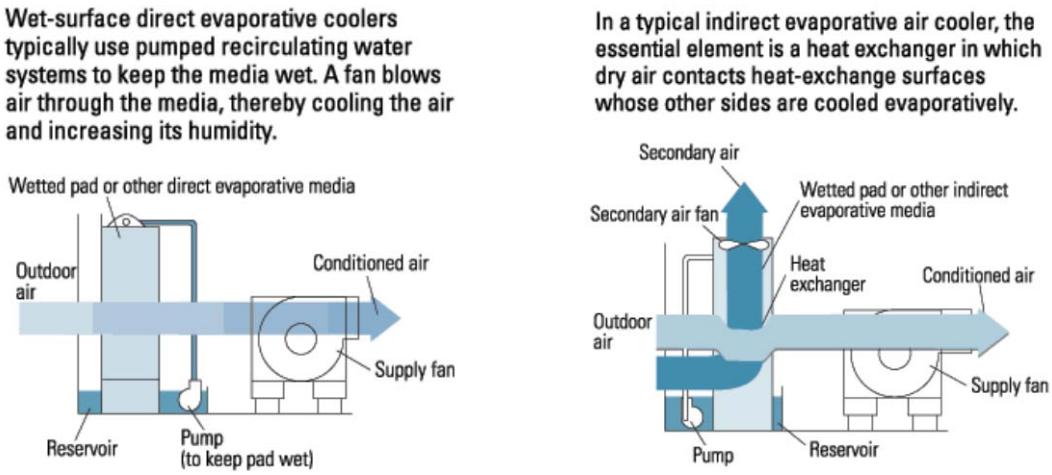
Table 0-6. **ACGIH rest-work guidelines for hot-humid climates.**

| | Acclimatized Employee | | Unacclimatized Employee | |
|---|---|---|---|---|
| **Work Demands** | **Light (WBGT °F)** | **Moderate (WBGT, °F)** | **Light (WBGT, °F)** | **Moderate (WBGT, °F)** |
| 100% Work | 85.1 | 81.5 | 81.5 | 77 |
| 75% Work 25% Rest | 86.9 | 83.3 | 84.2 | 79.7 |
| 50% Work 50% Rest | 88.7 | 85.1 | 86 | 82.4 |
| 25% Work 75% Rest | 90.5 | 87.8 | 87.8 | 84.2 |

Based on the information provided in Table 16-6, to avoid heat stress in an environment where the humidity and temperature exceeds 85 °F wet bulb globe temperature, workers should be given rest time of 15 minutes per hour or more. Thus, height WBGT results not only in workers discomfort but in a reduced productivity.

For TEMF cooled only by ventilation, an evaporative cooler installed in the outside air duct can improve indoor working conditions during the cooling season. For this type of system, a comfort analysis allows to see the effect of the technology. Evaporative coolers can also be used to pre-cool outside air used by a mechanical cooling system. For this type of system, an energy analysis shows the cost/benefit of the system.

There are two main categories of evaporative coolers; direct and indirect (Figure 16-19). Direct coolers spray water through the incoming air stream, cooling the air to a temperature much closer to the wet bulb temperature. The largest draw back of a direct evaporative cooler is that it dramatically increases the relative humidity of the incoming air. In hot, working conditions, a direct evaporative cooler can lower the thermal comfort by creating a warm, humid environment. Indirect coolers, on the other hand, operate much more like a common heat exchanger. Water is sprayed on a water-proof membrane letting outside air evaporate on it, while the intake air is passed on the other side of the membrane. Unlike a direct cooler, the humidity of the inlet air is unchanged. Figure 16-19 shows the two types of evaporative coolers. Many companies produce roof-top evaporators to temper incoming air. The indirect evaporative cooler shown in Figure 16-19 is an evaporative heat recovery heat exchanger.




**a. Direct Evaporative Cooler** **b. Indirect Evaporative Cooler**

Figure 0-19. Two types of evaporative coolers (source: http://www.xcelenergy.com).

During the cooling season, water misters in the relief air stream evaporatively cool the relief air before it leaves the system. The Fresh air is drawn through a counterflow heat exchanger and heat is transferred from the fresh air stream to the evaporatively cooled relief air stream. Evaporative coolers do not save energy if the building is cooled by ventilation only. More than that, application of evaporative cooling results in increased water and electrical energy usage.

However, significant cost reduction results from improved thermal environment and respective increase in worker productivity. The indirect evaporative cooler lowers the dry bulb temperature in the space resulting in a corresponding improvement in both worker comfort and productivity. The annual savings in man-hours is shown in the plot below for the indirect evaporative cooler.

The data received through simulation of indirect evaporative cooling conducted under the IEA Annex 46 study, shows, it is cost efficient in every climate except for the climate zones 7 and 8 with a simple payback under 2 years (Figure 16-20).

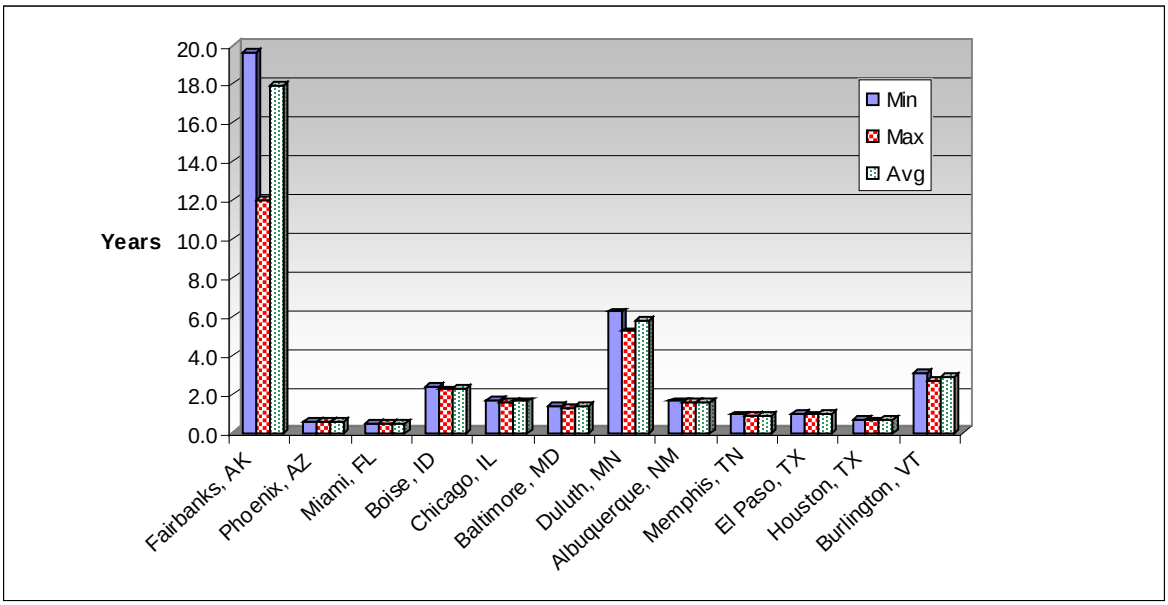



Figure 0-20. Simple payback for indirect evaporative cooling in various climate zones.

## Appendix 23: Prescriptive and optional energy saving technologies for dining facilities

### 17.1. Prescriptive Technology Solution Sets

As part of the EPACT 2005 energy study discussed in Appendix 1, a prescriptive technology solution set is being developed for dining facilities for each climate one to achieve at least a 30% energy consumption reduction compared to an ASHRAE 90.1-2004 minimum baseline building. These prescriptive sets will be included here when completed. The general prescriptive energy saving technologies for dining facilities include:

Building envelope air tightness: 0.25 cfm/ft$^2$ at 0.3 in w.g. The savings from this measure are significant in climate zones 6 to 8.

Building envelope insulation: buildings located in climate zones 1 and 2 have the same insulation values as required by the ASHRAE Standard 90.1-2004, in other location – per the ASHRAE 30% Small Office Advanced Energy Design Guide. This measure produces insignificant savings in the climate zone 3 and significant energy savings in colder climates.

The windows are per the ASHRAE 30% Small Office Advanced Energy Design Guide. They have a lower U-value and a higher SHGC than Standard 90.1-2004 windows.

“Cool Roof” with a solar reflectance = 0.65 for buildings in climate zones 1, 2, 3A and 4B. There are no requirements to use “cool roof” in other climate zones due to negative energy savings.

Reduced LPD: in buildings located in all climates zones

Table 0-1. Daylighting and reduced LPD in the dining, servery, carryout, and office areas.

| Zone | Baseline | | Efficient Model | | 90.1-2004 Space Type |
|---|---|---|---|---|---|
| | W/ft$^2$ | W | W/ft$^2$ | W | |
| Dining | 0.9 | 7,183 | 0.8 | 6,383 | Dining area |
| Storage/Receiving | 0.8 | 2,098 | 0.8 | 2,098 | Active Storage |
| Dishwash | 1.2 | 1,344 | 1.0 | 1,120 | Food Preparation |
| Kitchen | 1.2 | 3,315 | 1.1 | 3,039 | Food Preparation |
| Servery | 1.2 | 5,131 | 1.0 | 4,276 | Food Preparation |
| Entry/Circulation | 1.3 | 4,277 | 1.0 | 3,290 | Lobby |
| Carryout | 1.2 | 1,253 | 1.0 | 1,044 | Food Preparation |
| Office | 1.1 | 1,588 | 0.9 | 1,300 | Office |
| Utility | 1.5 | 1,580 | 1.0 | 1,053 | Elec/Mech |
| **Total** | | **27,759** | | **23,596** | |

This measure results in energy savings in all climate zones; however, the savings gets smaller as the climate gets colder.

Install partial end panels on the kitchen hood and all wall-mounted hoods in the servery, bake shop, and carryout areas. This measure shows significant energy savings in all climate zones, especially in the cold climates.

Replace Single-Island Hoods with Wall-Mounted Hoods in Servery. This measure ECM shows smaller energy savings in the warm climates and significant savings in the cold climates.

Use Demand Controlled Ventilation Hoods in the Servery and Carryout. Use of DCV technology in hoods located in the Servery and Carryout allows reduction of the airflow by half and fan power by one fourth (e.g., for 2 hours in the morning and 2 hours in the afternoon.) This technology saves energy in every climate, especially in warm and the cold climates. Savings associated with this measure strongly depend on the number of hours with reduced flow and the rate of the airflow reduction.

Use Demand Controlled Ventilation Hoods in the Kitchen allows reduction of the airflow by half and the fan power by one fourth (e.g., for three hours in the morning, two hours midmorning, and two hours in the afternoon.). This technology shows significant energy savings in climate zones 3 through 8 and smaller savings in climate zones 1 and 2.

High Efficiency HVAC. : PSZ-AC, 12.0 EER (3.52 COP); 0.9 $E_t$ gas heater; 0.94 $E_t$ gas boiler Vs PSZ-AC, 9.7 EER (2.84 COP); 0.8 $E_t$ gas heater; 0.8 $E_t$ gas boiler in the baseline case per the ASHRAE Standard 90.1-2004 requirements. This measure shows significant energy savings in all climates. It shows the highest savings for climate zones 1 through 3 and 4B.

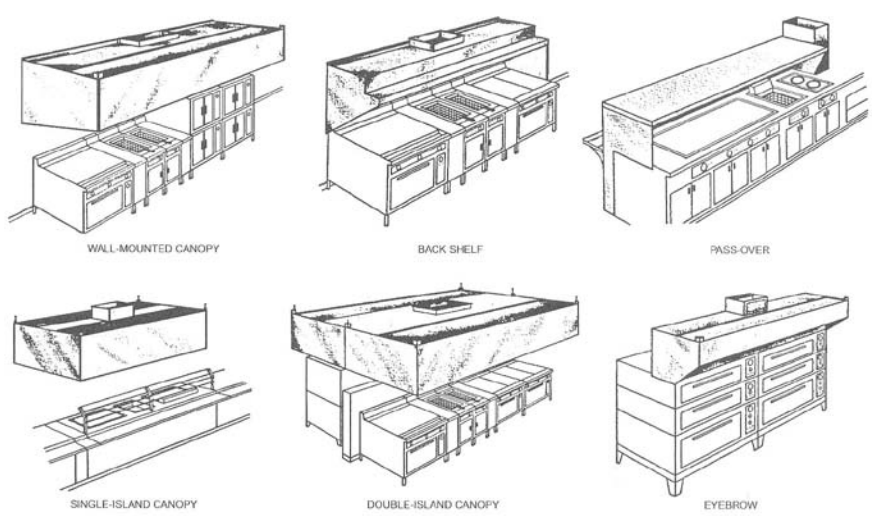
Low-Flow Pre-Rinse Nozzles. Use 1.2 gpm rinsing nozzles in each of the storage and receiving, dish wash, and kitchen zones. This ECM is very easy to implement and shows energy savings in all climates.

## 17.2. Energy Efficient Kitchen Ventilation

### 17.2.1. Optimized Selection and Installation of UL Listed Exhaust Hoods

**Description**

The design exhaust rate for kitchen ventilation systems depends on the hood style along with subtle construction features and enhancements (e.g., return flanges along the inside edge of the hood, integral side skirts). Wall-mounted canopy hoods, island (single or double) canopy hoods, and proximity (backshelf, pass-over, or eyebrow) hoods all have different capture areas and are mounted at different heights and horizontal positions relative to the cooking equipment (see Figure 17-1). Generally, for the identical (thermal plume) challenge, a single-island canopy hood requires more exhaust than a wall-mounted canopy hood, and a wall-mounted canopy hood requires more exhaust than a proximity (backshelf) hood. The performance of a double-island canopy tends to emulate the performance of two back-to-back wall-canopy hoods, although the lack of a physical barrier between the two hood sections makes the configuration more susceptible to cross drafts.




*Source:* ASHRAE Standard 154

Figure 0-1. Types of kitchen ventilation systems

Building codes distinguish between cooking processes that create smoke and grease (e.g., frying, griddling, or charbroiling) and those that produce only heat and moisture (e.g., dishwashing and some baking and steaming operations). Cooking that produces smoke and grease requires liquid-tight construction with a built-in fire suppression system (Type I hood), while operations such as dishwashers that produce only heat and moisture do not require liquid-tight construction or a fire suppression system (Type II hood).

ASHRAE Standard 154 categorizes cooking appliances as light-, medium-, heavy-, and extra heavy-duty, depending on the strength of the thermal plume and the quantity of grease, smoke, heat, water vapor, and combustion products produced. The strength of the thermal plume is a major factor in determining the exhaust rate. By their nature, these thermal plumes rise by natural convection, but they are turbulent and different cooking processes have different “surge” characteristics.

Mechanical codes recognize exceptions for hoods that have been tested against a recognized standard, such as Underwriters Laboratories (UL) Standard 710. Part of the UL standard is a “cooking smoke and flair up” test. This test is essentially a cooking effluent capture and containment (C&C) test where “no evidence of smoke or flame escaping outside the exhaust hood” must be observed. Hoods bearing a recognized laboratory mark are called *listed* hoods, while those constructed to the prescriptive requirements of the building code are called *unlisted* hoods.

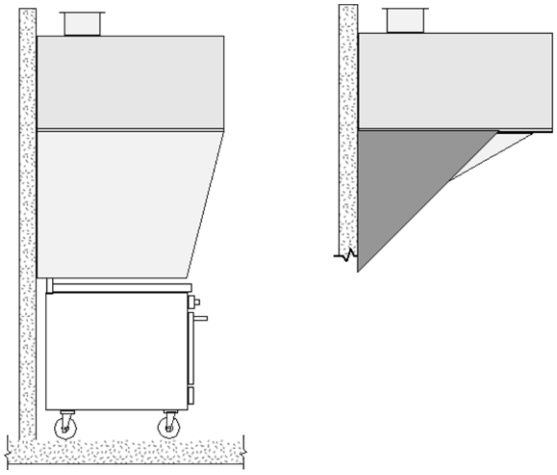
As reflected by the range in exhaust rates in the Table 7-1, a *listed* hood can be operated at a lower exhaust rate than an *unlisted* hood of comparable style and size over the same cook line. Lower exhaust rates may be proven by laboratory testing with specific hood(s) and appliance lineup using the test protocol described in ASTM Standard F-1704, *Test Method for Performance of Commercial Kitchen Ventilation Systems*. This process is sometimes referred to as “custom-engineering” a hood and is the foundation of this ECM. Within the specification to maximize hood performance and minimize exhaust rate are construction or installation details that include the addition of partial side panels, minimizing the gap between the appliances and the back wall and, in the case of canopy hoods, increasing the amount of overhang (e.g., from 6 to 18 in). These detailed specifications can permit a listed hood to operate satisfactorily at the lower end of the cfm range show (e.g., 200 cfm vs. 300 cfm) for a <u>30% or more saving</u> over the Code values and or standard design practice).

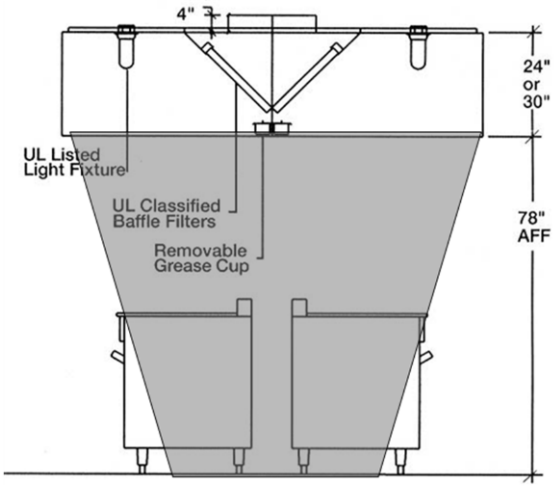
**Energy Efficiency Specifications**

Specify exhaust hoods based on performance data provided by the manufacturer of a *listed* hood that will minimize the exhaust ventilation rate for a given cooking equipment line or duty (as reflected in the above table). In general, this will permit exhaust ventilation rates that are at least 30% below the prescriptive code requirements with proportional energy savings.

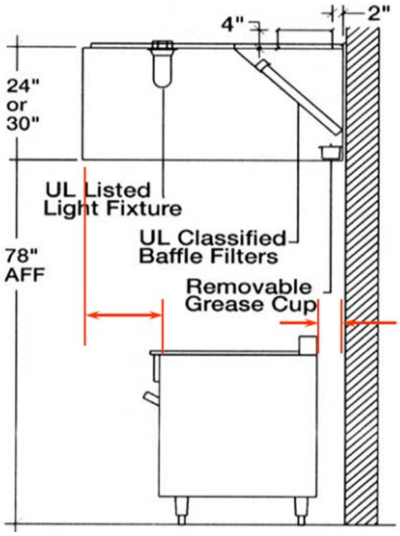
Where applicable, the following best-design practices should be incorporated within the exhaust system design and specifications to ensure that capture and containment performance of the hood is satisfactorily at the reduced exhaust rate:

1. Incorporate partial side panels or end walls.






2. Maximize overhang and minimize clearance between appliance and rear wall.



3. Positioning heavy duty equipment (e.g., broilers) in middle of the hood and light duty (e.g., ovens, kettles) at the end of the cook line.
4. Specifying walk-mounted canopy hoods instead of single-island canopies.
5. Specifying back-shelf (i.e., proximity hoods) over short-order equipment such as griddles and fryers.

6. Low-velocity introduction of makeup air near hoods (e.g., no 4-way diffusers in kitchens).
7. Maximize transfer air (detailed within 17.2.3.).
8. Incorporate demand ventilation controls (detailed within 17.2.4.).

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## Appendix 1: **HVAC Equipment Performance Efficiencies Considerations**

**9.1. Regulatory requirements for HVAC Systems.** HVAC system requirements address the heating, ventilating, and air-conditions in the building. These systems typically are the largest energy users in most buildings and the proper design of these systems is necessary to achieve minimal energy usage. Section 109 of the Energy Policy Act of 2005 sets the absolute minimum HVAC system requirements for commercial buildings at the level of ANSI/ASHRAE/IESNA Standard 90.1-2004. However, Federal agencies are also required to achieve 30% lower energy consumption, if cost-effective, so the levels in Standard 90.1-2004 really only provide the basis for this calculation.

ASHRAE Standard 90.1-2007 provides two types of requirements for HVAC systems – mandatory and simplified, prescriptive, some of them are more stringent than the ones in the previous, 2004, addition. Standard has different requirements for systems installed in new buildings and to additions and replacements of HVAC systems in existing buildings, *Standard 90.1-2007 Mandatory HVAC Requirements include minimum* HVAC equipment performance efficiencies (Section 6.4.1). *Standard 90.1-2007 Prescriptive HVAC Requirements* discussed in Section 6.5 are a function of HVAC system.

ASHRAE Advanced Energy Design Guides include requirements to HVAC systems, that are considerably more stringent than Standard 90.1-2007, although not necessarily 30% better as required for Federal agencies by EPAct 2005. These requirements are also a function of HVAC system. The guides recommend higher HVAC efficiencies for air conditioners, gas furnaces, and heat pumps. (THESE EFFICIENCIES NEED TO BE CHECKED AGAINST FEMP-DESIGNATED AND ENERGY STAR AS REQUIRED FOR FEDERAL AGENCIES). For HVAC systems, the guides recommend economizers for air conditioners and heat pumps if the cooling capacity is greater than 54 kBtuh.

HVAC equipment must meet or exceed the seasonal energy efficiency ratio (SEER) or energy efficiency ratio (EER) values of Energy Star or FEMP designated products, which are considerably more stringent than Standard 90.1-2007 (http://www1.eere.energy.gov/femp/procurement/eep_requirements.html)

US Army Corps of Engineers Prescriptive Requirements to HVAC equipment which are listed in design guides to achieve 30 percent energy savings over a baseline built to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004 for new buildings to be constructed under Military Transformation Program. These requirements are listed in Tables ???