FAA-HDBK-001
September 30, 1997

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

DESIGN HANDBOOK

Infrastructure AND-100

ENERGY EFFICIENCY AND WATER CONSERVATION IN NAS FACILITIES

This Handbook is for guidance only. Do not cite this document as a requirement.

AREA FACR

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HANDBOOK

Design Handbook for Energy Efficiency and Water Conservation in NAS Facilities

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FOREWORD

This handbook was created to provide definitive energy efficiency and water conservation design criteria for the design of NAS facilities. FAA-HDBK-001 provides implementation strategies and tools to comply with E.O. 12902, Energy and Water Conservation at Federal Facilities, which was issued on March 8, 1994.
FAA-HDBK-001 was developed through the coordinated efforts of ASD, ANS, ASU, AEE, ASW and FAA regions and should be used by FAA personnel in both Headquarters and the Regions.
Whenever technically feasible and economically justifiable, the design criteria set forth in this document should be used to develop task orders and contracts for the design of NAS facilities. Specific subsections, or whole sections, of this document can be incorporated into task orders or contracts, and will thus become contractually binding. This handbook should not be referenced, however, since handbooks are not contractually binding documents. If this handbook is referenced, in whole or in part, contractors do not have to comply. Only when the design criteria from this handbook are placed in a contractual documents to they become contractually binding.

CONTENTS

1. SCOPE

This handbook applies to all buildings, real property, and integral equipment that is owned, leased, operated or under the constructive control of the Federal Aviation Administration (FAA).

In any facility lease, with a term that exceeds five years, including renewals, the cost effectiveness of the provisions of FAA-HDBK-001 should be evaluated for inclusion in the leasing of an existing structure. In FAA space leasing actions that directly result in new lease construction, FAA-HDBK-001 will apply. Nothing should prohibit the implementation of FAA-HDBK-001 any time it is determined to be cost effective or in the best interest of the Government; and, the lease does not prohibit implementation of conservation modifications.

This handbook identifies requirements for energy management and conservation that should be incorporated into the designs of new facilities and modifications to existing facilities in the NAS. Specific technical requirements for these facilities will be defined in subsystem or project specifications and in facility development specifications for each subsystem or project. This handbook is primarily for use in the development of national standard designs; and, should also be used for site adaptations by FAA Washington D.C. and Regional Offices in the development of engineering requirements and task orders. This handbook should be used by FAA Washington in preparation of the physical specifications and by architects and engineers in the design and construction of new facilities and modifications to existing NAS facilities. This handbook should not be used to abridge any federal safety, health, or environmental code requirements.
Whenever technically feasible and economically justifiable, the design criteria set forth in this document should be used to develop task orders and contracts for the design of NAS facilities. Specific subsections, or whole sections, of this document can be incorporated into task orders or contracts, and will thus become contractually binding. This handbook should not be referenced, however, since handbooks are not contractually binding documents. If this handbook is referenced, in whole or in part, contractors do not have to comply. Only when the design criteria from this handbook are placed in a contractual documents to they become contractually binding.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

The following documents, in effect on the date of invitation for bids or request for proposal, form a part of this handbook to the extent specified herein.

STANDARDS:

FAA

FAA-STD-032 Design Standards for National Airspace System Facilities

OTHER PUBLICATIONS:

FAA Orders

6980.26.1 Battery Backup Power System - Theory and Selection Guidelines

MANUALS:

Department of Energy (DOE)

DOE/AD-0006-1 DOE Facilities Solar Design Handbook

DOE/CS-0011 Introduction to Solar Heating and Cooling Design and Sizing

DOE/CS-0132 Architects and Engineers Guide to Energy Conservation in Existing Buildings

DOE/CS-0133 Identifying Retrofit Projects for Buildings

SOLAR/0811-79-01 Engineering Concerns in Solar System Design and Operation

General Services Administration (GSA)

Energy Conservation Guidelines for Existing Office Buildings

Energy Conservation Design Guidelines for New Office Buildings

Regulations, Codes and Executive Orders

10 CFR 400 to 499 Energy Federal Register

Executive Order 12902 Energy Efficiency and Water Conservation at Federal Facilities.

HANDBOOKS:

National Bureau of Standards (NBS)

NBS Handbook 135 Life-cycle Cost Manual for the Federal Energy Management Program

Office of Management and Budget

Circular A-94 Discount rates to be used in evaluating time distributed Costs and Benefits

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Non-government documents.

The following documents of the issue in effect on the date of invitation for bids or request for proposal, form a part of this handbook to the extent referenced herein.

OTHER PUBLICATIONS:

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

ASHRAE Handbook, HVAC Applications Volume

ASHRAE Handbook, HVAC Systems and Equipment Volume

ASHRAE Handbook, Fundamentals Volume

ASHRAE 62 Ventilation for Acceptable Indoor Air Quality

ASHRAE/IES 90.1 Energy Efficient Design of New Buildings Except New Low-Rise Residential Buildings

American National Standards Institute (ANSI) / National Fire Protection Association (NFPA)

ANSI/NFPA 70 National Electrical Code (NEC)

American Society of Mechanical Engineers (ASME)/American National Standards Institute(ANSI)

National Electrical Manufacturers' Association (NEMA)

MG-10 Energy Guide for Selection and Use of Polyphase Motors

MG-11 Energy Management Guide for Selection and Use of Single Phase Motors

Council of American Building Officials (CABO)

CABO Model Energy Code

Building Officials and Code Administrators International (BOCA), Inc.
BOCA Basic/National Energy Conservation Code

Brick Institute of America (BIA)
1750 Old Meadow Road, McLean, VA 22102

4, 4a - 4h Technical Notes on Brick Construction

Commercial/Industrial Committee, Edison Electric Institute (EEI),

111 19th Street, N.W., Washington, D.C. 20036

IEEE Energy Management Handbook

IEEE Standard 141-1993

Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using federal agencies.

3. DEFINITIONS

3.1 Acronyms, abbreviations and definitions.

3.1.1 Acronyms and abbreviations.

The following are definitions of acronyms and abbreviations used in this handbook.

A/E	Architect/Engineer
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ATC	Air Traffic Control
BIA	Brick Institute of America
BOCA	Building Officials and Code Administrators
BTU	British Thermal Unit
CABO	Council of American Building Officials
CCMS	Central Control Monitoring Systems
CFR	Code of Federal Regulations
COP	Coefficient of Performance
DOE	Department of Energy
EEI	Edison Electric Institute
°F	Degrees Fahrenheit
FAA	Federal Aviation Administration
GSA	General Services Administration
HVAC	Heating, Ventilating, and Air Conditioning
KW	Kilowatt
KWH	Kilowatt Hours
LCCA	Life-cycle Cost Analysis
NAS	National Airspace System
NBS	National Bureau of Standards
NEMA	National Electrical Manufacturers Association
RMMS	Remote Maintenance Monitoring System
SIR	Savings-to-Investment Ratio

3.1.2 Definitions.

ALTERNATIVE ENERGY SOURCES.
Alternative energy sources are those which are neither strictly classed as renewable nor non-renewable. These sources include thermoelectric generators, fuel cells, and thermionic generators, etc.

BIOMASS ENERGY SYSTEM.
Generation of limited amounts of power by utilizing the energy that exists in trash piles and garbage heaps. The energy is generally used to drive steam powered generators.

CLIMATIC ZONE.
A geographic area with a defined range of summer and winter conditions. Climatic zones are further defined in FAA-STD-032.

CONSIDER.
The word "consider" and all derivations, such as "considerations" and "should be considered" mean that a candidate energy management and conservation measure is to be evaluated and analyzed for technical merit, practicality, and economic feasibility. "Consider" does not mean to give a candidate measure a passing thought, but rather, to perform an in-depth analysis on it and include the analysis in the report.

ECONOMIZER.
Economizer or economizer cycle is a process in heating, ventilating and air conditioning, whereby outside air is used to condition the interior space rather than using the mechanical systems, except fans. Economizer cycle is used under specific temperature and humidity ranges and is employed to save energy.

ENERGY CONSUMPTION BASELINE.
An energy consumption baseline is a tabulation of the estimated quantities of fuel and energy sources required to meet the needs of a new or modified facility. The tabulation can be for hourly, daily, or annual energy consumption as needed to fulfill the requirements of the task. Energy consumption baselines can be provided for national standard and site adapted designs and are based upon specified interior/exterior conditions. The information may be used in FAA's energy management reporting system as reference data.

ENERGY CONSUMPTION PROFILE.
An energy consumption profile is similar to an energy consumption baseline, except that the profile is based upon hourly changes in the interior/exterior conditions. An energy consumption profile can be developed for a 24-hour period or the entire year (8760 hours). Profiles can only be developed for site adapted designs; and, may also be used as a data reference by the FAA in its energy management reporting system.

ENERGY MANAGEMENT AND CONSERVATION MEASURE.
An energy management and conservation measure is a means or method which is primarily intended to reduce energy consumption, or to result in reduced energy consumption; or, to allow the use of alternate and renewable energy sources.

EVALUATE.
For words such as "evaluate", "evaluation", and "should be evaluated", see "consider".

EXAMINE.
Examine means to consider for technical merit.

FACILITY.
The total plant required for a subelement or subsystem to function. The facility will house, support or protect the subelement or subsystem at a particular geographic location. The facility will have various physical characteristics in accordance with the function of the subelement or subsystem. The facility can be of the following types depending on the required function:

a. **BUILDING**. Consists of walls and a roof, either single-story or multi-story, constructed of various materials, usually fixed in location, and housing personnel and equipment. The building may include air conditioning, power, etc.; if required for the particular application.
b. **STRUCTURE**. Composed of interrelated parts, which together form a structural entity, usually fixed in location, containing equipment; and, which may be attended or unattended. The structure may include air conditioning, power, etc.; if required for the particular application.
c. **ENCLOSURE**. Interrelated parts, which surround or shut in equipment, fixed or movable, usually unattended. The enclosure may include air conditioning, power, etc.; if required for the particular application.

FUEL CELL.
A fuel cell converts energy generated by chemical reaction into electrical energy. Its function is similar to a battery, except that the chemicals generally are supplied from outside the cell.

GRAYWATER SYSTEMS.
Graywater systems include water generated by bathroom sinks, showers, and clothes washing machines; and, that is available for recycling.

HEAT REMOVAL CAPABILITY (LIGHTING FIXTURES).
Lighting fixtures, that are designed to dissipate heat, by means of ventilation ports, louvers, or radiator type fins.

HOT WATER MAINTENANCE TAPE.
Electric resistance cable, installed under the insulation of domestic hot water piping, to maintain desired water temperature. This system is used in lieu of recirculating hot water through the piping.
LIFE-CYCLE COST.
Life-cycle cost (LCC) means the total costs of owning, operating, and maintaining a building over its useful life, including its fuel and energy costs. LCC is determined on the basis of a systematic evaluation and comparison of alternative building space-conditioned systems. In the case of leased buildings, the life-cycle cost should be calculated over the effective remaining term of the lease.

LIGHTING POWER BUDGET.
A lighting power budget is the upper limit of power to be available to provide the lighting needs in accordance with criteria and calculation procedures provided in ASHRAE/IES Standard 90.1.

MOBILE LIGHTING FIXTURES.
Portable lighting fixtures that are usually cord and plug connected. Portable lighting is often utilized as temporary lighting.

NON-RENEWABLE ENERGY SOURCE.

Non-renewable energy source refers to resources such as fuel oil, gasoline, natural gas, liquefied petroleum gas, coal, and purchased steam; or, electricity generated from such resources.

PEAK LOAD SHAVING.
Peak load shaving is a process, by which the electrical demand is reduced, by paralleling the generator with the utility power and using that system to carry the electrical demand, when it reaches a predetermined level. This process will reduce the electrical utility premium charges which may be imposed for periods of dramatic power consumption.

PEAK LOAD SHEDDING.
Peak load shedding is the procedure, by which predetermined loads are shut off or shifted to the emergency generators, until the peak subsides. This process will reduce the electrical utility premium charges, which may be imposed for dramatic rates of electrical consumption. Peak load shedding applies only to non-critical, low priority loads.

PHOTOVOLTAIC.
A photovoltaic system converts sunlight directly into electricity.

RENEWABLE ENERGY SOURCE.
Renewable energy source refers to resources such as sunlight, wind, geothermal, biomass, solid waste, or other regenerating sources.

REQUIREMENT.
A specified capability, which must be provided by the system, subsystem, end item, contractor, etc. Types of requirements include: operational, functional, performance, interface, facility, and verification requirements.

SOLAR ENERGY.
Energy derived from the sun directly through the solar heating of air, water, or other fluids, by electricity produced from solar photovoltaic or solar thermal processes, or indirectly from the use of wind, biomass or small-scale water power.

SUNLIGHT.
Illumination provided directly or indirectly from the sun without supplementation from conventional lighting fixtures.

TASK LIGHTING.
Lighting provided to illuminate a specific task or task area. Task lighting is locally controlled. It often consists of portable lamp type lighting fixtures.

THERMOELECTRIC GENERATORS.
Thermoelectric generators convert heat energy directly into electricity by using the thermocouple principle. They may be fossil-fueled or radioisotope-fueled.

THERMIONIC GENERATOR.
An electrical current generator that derives power from the directed movements of thermionics. Thermionics are electrically charged particles emitted by an incandescent substance.

WIND ENERGY SYSTEMS.
Generation of limited amounts of power by utilizing wind power to drive a generator.

XERISCAPING.
Comprehensive water management approach to landscaping that is based on selecting, placing and maintaining plants that optimize water use.

4. REQUIREMENTS

4.1 General.

This handbook recommends design requirements prescribed by codes and industry standards and sets forth the framework for considering and evaluating other design requirements for energy management and conservation. The measures in this handbook are not necessarily imposed on the designs of all facilities. The applicability of this handbook is defined in the FAA engineering requirement, task order or NAS subsystem or project specification. All energy management and conservation measures should be cost effective; and designs, implementing these measures, should be in accordance with FAA-STD-032.

4.1.1 NAS mission impact.

The impact of an energy conservation measure on the NAS mission should be assessed. No energy management and conservation measure, regardless of its technical and economic merit, should degrade NAS mission objectives, safety and reliability; but, should enhance those objectives wherever possible.

4.1.2 Current proven technology.

All designs should be of current proven technology. Systems and equipment should be reliable, maintainable, and readily available in the market place.

4.1.3 Design objectives.

The energy related designs should meet the following objectives:

a. Reduce the life-cycle cost of energy consuming facilities, systems, and equipment;

b. Reduce the total cost of energy consumed;

c. Reduce the total energy consumption;

d. Promote the efficient use of energy through better control and increased use of more efficient equipment;

e. Promote switching from petroleum-based fuels and natural gas to sunlight, wind, and other renewable energy sources.

5. DETAILED REQUIREMENTS.

5.1 Energy sources

5.1.1 Non-renewable energy sources.

In the selection and analyses of non-renewable energy sources for any energy consuming system, the most accurate applicable current and projected prices and market availability of the various energy sources at the project site should be evaluated. The availability of the non-renewable energy, including the impact of disruptions due to foreseeable fuel shortages, should be considered for the duration of the useful life of the facility. Specific data may be obtained from the following sources:

a. Federal Register;
b. 10 CFR 436, Subpart A;
c. NBS Handbook 135;
d. Energy distribution utility companies in the area of the project.

5.1.2 Alternative/renewable energy sources.

Alternative/renewable energy sources should be evaluated, when they can be shown to be cost effective and when otherwise directed by the FAA.

5.1.2.1 Alternative/renewable electric power sources.

Alternative/renewable electric power sources should be utilized in accordance with FAA Order 6980.26. These sources include but are not limited to:

a. Solar energy;
b. Photovoltaic cells;
c. Wind energy system;
d. Thermoelectric generators;
e. Thermionic generators;
f. Bio-Mass.

5.1.2.2 Solar thermal energy systems.

Solar thermal energy system design should be utilized in accordance with ASHRAE Handbook, HVAC Systems and Equipment, and Applications Volumes and DOE/AD-0006-1, DOE/CS-0011 and SOLAR/0811-79/01. Solar panels should be vandal proof and should be installed where they will not be subjected to shade from trees, buildings, or other structures. Hydronic systems should be designed to prevent freezing of working fluids.

5.1.3 Thermal energy recovery.

Thermal energy (or heat) recovery should be evaluated for NAS facilities, whenever there can be shown an availability of excess or wasted energy and the simultaneous need for that energy. The energy savings potential and cost benefits depend primarily upon the number of hours per year that excess energy is available; and, can be utilized for purposes, that would otherwise require the use of additional purchased energy. Recovered energy may be used for conditioning of ventilation air, space heating and service water heating. Design of, and considerations for heat recovery systems should be in accordance with ASHRAE Handbook, HVAC Systems and Equipment Volume. Where the availability of excess energy and the need for that energy are not simultaneous, consideration should be given to storing excess energy, when available, and using it at a later time.

5.2 Climatic conditions and interior environments.

Climatic conditions and interior environments of national standard and site adapted designs should be in accordance with FAA-STD-032.

5.3 National codes and industry standards.

The design of all new facilities and equipment should, as a minimum, incorporate energy management and conservation measures as prescribed and recommended in nationally recognized codes and industry standards. Expansions of existing facilities should be considered as new facilities. Rehabilitation and modernization projects for existing facilities should also incorporate energy management and conservation measures prescribed by these codes and standards to the extent they are shown to be cost effective based on economic analysis. The following are nationally recognized energy codes and industry standards to be applied to FAA facilities:

a. ASHRAE/IES Standard 90.1;
b. ASHRAE Standard 90.2;
c. BOCA Basic/National Energy Conservation Code;
d. CABO Model Energy Code;
e. NEMA MG-10;
f. NEMA MG-11;
g. Public Law 102-486-Oct.24, 1992:
Energy Policy Act of 1992;
h. IEEE Recommended practice for sizing nickel cadmium batteries for stationary applications;
i. Executive Order 12902 - Energy Efficiency and Water Conservation at Federal Facilities;
j. 10 CFR 436 - Code of Federal Regulations, Federal Energy Management and Planning Programs.

5.4 Energy management and conservation measures.

The following list identifies energy management and conservation measures, that should be used in the design or evaluated as potential candidates for implementation into designs for NAS facilities, or expansions or modernizations to existing NAS facilities. This list is not intended to be comprehensive; nor exclude other energy management and conservation measures from evaluation.

5.4.1 Building.

Primary consideration should be given to non-energy consuming or passive energy components and devices.

a. All exterior doors should be equipped with automatic door closing devices.

b. Vestibules should be provided at moderately to heavily used exterior doors at attended facilities.

c. Vestibules should be provided at loading dock areas at attended facilities where doors open directly into a conditioned space.

d. The use of air curtain systems and transparent plastic curtain strips should be evaluated with the consideration of vestibules.

e. Thermal mass should be considered and should be in accordance with BIA Technical Notes in Brick Construction, 4 and 4A through 4H.

f. High maintenance dynamic exterior shading devices, such as solar tracking vertical louvers, should not be used.

g. Consideration should be given to placing insulation on building exteriors in predominantly southern or warm climate areas.

h. Double reflective roofs, with a ventilated space between roofs, should be evaluated to reduce solar gain in unattended facilities located predominantly in southern and southwestern regions.

i. Glass windows should be designed with either double glazed units or single glazed units with a storm sash. Depending on glass size and building orientation, glazing units should be designed with industry energy efficient features in mind, such as tinting, low E coating, and argon gas in hermetically-sealed insulating units. The overall window performance should be evaluated as part of the building envelope based on characteristics, such as, thermal conductance, shading coefficient and air leakage.

j. Purchase energy-efficient products, in accordance with established Office of Management and Budget (OMB) guidelines, whenever practicable, and whenever they meet specified performance requirements; and are cost-effective.

k. Purchase products, to the extent practicable and cost-effective, that are in the upper 25% of energy efficiency for all similar products, or products that are at least 10% more efficient than the minimum level that meet federal standards. This requirement should apply whenever such information is available, either through federal or industry approved testing and rating procedures.

5.4.2 Illumination.

5.4.2.1 Lamps.
Lamps should be the most efficient type suitable for the application. Consideration should also be given to the lamp's useful life and its rate of lumen depreciation, which affects overall lamp efficiency. All fluorescent lamps and light ballasts should be the new energy efficient types per E.O. 12902 and the Energy Act of 1992. Additionally, lamp selection should consider visual levels of comfort and other human factors. Consideration should be given to low mercury content fluorescent lamps, to reduce pollution and waste disposal costs. Types of lamps should include, but should not be limited to:

a. Incandescent;
b. Fluorescent;
c. Mercury vapor;
d. Metal halide;
e. High pressure sodium;
f. Low pressure sodium.

5.4.2.1.1 Safety and security considerations.
High efficiency lamps and ballasts should be utilized wherever feasible. Lighting levels should be determined by utilizing standard I.E.S. data for specific applications. In "light sensitive" areas, lighting levels should be determined with the assistance of the end users of the space. Consideration should be given to the color rendering of the proposed lamps and lighting system. Neither safety nor security should be compromised by any lamp type or lighting system.

5.4.2.1.2 Incandescent lamps.
The application of incandescent lighting should be restricted to areas of infrequent and short duration use, such as in janitor's closets and remote unattended facility toilet rooms. Incandescent lamps should only be used where clearly shown to be the most cost effective type of lighting for those areas.

5.4.2.2 Interior lighting.
The actual power used for interior lighting should be as low as practical and should not exceed 85% of the calculated lighting power budget.

5.4.2.2.1 Task lighting systems.

Task lighting systems should be utilized whenever workspaces are designed for specific functions. Task lighting should be on a separate circuit from the main lighting systems. Task lighting may be integrated in furniture or equipment.

5.4.2.2.2 Natural lighting.

Natural lighting should be utilized whenever feasible. Automatic dimming systems should be evaluated whenever natural lighting is available. Dimming devices should be of the energy saving types. Skylights should be evaluated as sources of natural lighting, along with passive daylighting systems that utilizes prismatic domes, reflective light and diffusing systems.

5.4.2.2.3 Fixtures.

Consideration should be given to mobile fixtures and to fixed fixtures with heat removal capability.

5.4.2.2.4 Controls.

Manual and automatic lighting controls should be provided to avoid unnecessary consumption of electrical energy for lighting. Controls should include, but should not be limited to, the following, as applicable to the specific project:

a. Multiple switching;
b. Dimming devices;
c. Key-activated switches;
d. Telephone signal-activated controls;
e. Three-way switches;
f. Ballast load switching systems;
g. Door activated controls;
h. Photocell controls;
i. Photocell/timeswitch combination controls;
j. Dimmer/photocell combination controls;
k. Dimmer/timeswitch combination controls;
l. Radio-controlled high pressure sodium ballast system;
m. Personnel detection controls, such as ultrasonic, passive infrared, active infrared, and acoustic;
n. Centralized programmable lighting control systems.

5.4.2.3 Exterior lighting.
Exterior lighting design should provide safe and secure access to and egress from NAS facilities. Calculations should include a cost-benefit analysis, which compares the higher energy-efficiency/lower first cost for larger fixtures to the higher operational-efficiency and controllability of a greater number of smaller fixtures.

5.4.2.3.1 Excluded areas.
Areas specifically excluded from consideration for exterior lighting include landscaping, general architectural lighting, or general site lighting.

5.4.2.3.2 Control.
The electrical design should incorporate sufficient system controls for exterior lighting to ensure energy-efficient operation of the system. System controls should be both ambient light dependent and time/time-of-day dependent. Exterior lighting circuits should be divided by lamp type and site vicinity in such a manner as to permit reductions in usable lighted parking zones and walk areas. The design should provide for conformity to seasonal, occupancy, and shift changes common to the operation of larger attended facilities. For unattended facilities, exterior lighting should be controlled by timed switches or photocells. Provisions should be made to allow an override of the timed switch or photocells whenever they are installed.

5.4.3 Electric power.

5.4.3.1 Electrical services
Electrical services should be obtained at the highest, most economically feasible voltage available. Consideration should be given to power company rate schedules, demand side management, service and transformer losses and service classifications.

5.4.3.2 Voltage drop and system losses.
Voltage drop should be limited to 3% for an individual branch circuit load, and a maximum of 5% for an individual branch circuit and feeder loads.

5.4.3.3 Voltage balance.
Voltage imbalance of the three phase power distribution system should be limited to a differential of 10% between any two phase legs.

5.4.3.4 Power factor correction.
Where poor power factor results in a penalty by the utility or where power factor is less than 85%, power factor correction devices should be evaluated. Economic analyses should be used to determine the relative cost effectiveness of installing the power factor correction devices at the service entrance or at the individual sources of poor power factor, which is the preferred location. Preference should be given to the use of synchronous motors or to the replacement of large motors with energy-efficient motors exhibiting higher power factors. When power factor correction is required, it should be increased to the most cost-effective level.

5.4.3.5 Transformers.

The minimum transformer efficiency should be 94%. The temperature rise, for a given transformer, should be the lowest available from the approved suppliers standard production stock for a unit that meets the design criteria. An economic analysis should be performed in accordance with IEEE Standard 141-1993, Section 14.4.9, Transformer Losses, to determine the cost effectiveness of high efficiency (98-99%) transformers.

5.4.3.6 Motors.

High efficiency motors should be used. Single-phase motors should be selected in accordance with NEMA MG-11. Polyphase motors should be selected in accordance with NEMA MG-10. Motors should be sized to handle design loads and designed for the particular environment encountered. Where the motor load varies significantly for extended duration, the use of multiple motors (i.e., a small and a medium size motor) rather than one large motor should be evaluated. Variable and multi-speed motors and motors with variable or multi-speed drives should be evaluated. Variable frequency motor drives or eddy current magnetic drives should be utilized to the greatest extent that is economically feasible.

5.4.3.7 Peak load demand shaving.

Peak load demand shaving should be provided, where economically feasible, to reduce the peak demand. Peak load demand shaving techniques should not adversely affect system reliability or maintainability. Peak load monitoring equipment should operate in the same time interval as the power company's demand meter and if possible, should utilize the power company's demand metering pulse.

5.4.3.7.1 Demand shaving techniques.

Demand shaving techniques should be considered, such as the transfer of specific loads from the normal power source to standby generator(s), where they are available. In addition, consideration should also be given to paralleling the generators with the utility power via paralleling switchgear and reducing the demand by carrying a specified portion of the load on the generators. A life-cycle cost analysis should be performed to determine the most economical engine generator system, gasoline, diesel, natural gas, or alternative fuels. Consideration should be given to the local availability of the various fuel types. Engine generator systems should be carefully chosen to obtain the most efficient combination possible for the particular size required. Engine and generator efficiencies should be reflected in the life-cycle cost analysis.

5.4.4 Heating, ventilating, and air conditioning (HVAC) systems.

5.4.4.1 General.

The requirements of this section represent minimum design criteria. It is recommended that the designer evaluate other energy conservation measures which may be applicable to the proposed facility.

5.4.4.2 Load calculations.

Heating and cooling system design loads, for the purpose of sizing systems and equipment, should be determined in accordance with the procedures described in the ASHRAE Handbook Fundamentals Volume.

5.4.4.2.1 Indoor design conditions.

Indoor design temperature and humidity conditions for FAA facilities should be as indicated in FAA-STD-032.

5.4.4.2.2 Outdoor design conditions.

Outdoor design conditions should be selected from the ASHRAE Handbook Fundamentals Volume or from data obtained from the National Climatic Center or similar recognized weather data source. For additional information, refer to FAA-STD-032.

5.4.4.3 Ventilation.

Ventilation systems should be designed to provide outdoor air ventilation rates in accordance with ASHRAE Standard 62.

5.4.4.4 Building envelope.

The building envelope heating and cooling loads should be based on envelope characteristics such as thermal conductance, shading coefficient, and air leakage.

5.4.4.5 Lighting loads.

Lighting loads should be based on actual design lighting levels or power budgets. Lighting loads may be ignored for the purposes of calculating design heating loads.

5.4.4.6 Other loads.

Other HVAC system loads, such as, those due to people and equipment, should be based on design data compiled from one or more of the following sources:

a. Actual information based on the intended use of the facility

b. Published data from manufacturer's technical publications.

c. Technical society publications such as the ASHRAE Handbook HVAC Applications Volume.

5.4.4.7 Air distribution systems.

Air distribution systems should be designed to minimize pressure losses due to friction and fitting losses.

5.4.4.7.1 Air distribution system friction rates.

Low pressure supply air distribution systems should be designed at a friction pressure loss rate of no more than 0.1 inches of water per 100 equivalent feet of duct. Low pressure return air distribution systems should be designed at a friction pressure loss rate of no more than 0.08 inches of water per 100 equivalent feet of duct. Medium pressure supply air distribution systems should be designed at a friction pressure loss rate of 0.3 inches of water per 100 equivalent feet of duct.

5.4.4.8 Minimum equipment efficiencies.

The HVAC equipment installed in FAA facilities should have a minimum efficiency at the specified rating conditions not less than those indicated in ASHRAE/IES Standard 90.1.

5.4.4.9 Filter efficiencies.

Air filtration efficiencies should be appropriate for the area served and should be in accordance with the recommendations contained in the ASHRAE Handbook HVAC Systems and Equipment Volume.

5.4.5 HVAC equipment.

The HVAC equipment installed in FAA facilities should comply with the requirements of ASHRAE/IES Standard 90.1.

5.4.5.1 Heating equipment.

Heating equipment should be evaluated on the basis of maximum efficiency over the operating range of the equipment when cost effective.

5.4.5.2 Air conditioning equipment and heat pumps.

Air conditioning equipment and heat pumps should be evaluated on the basis of the maximum coefficient of performance (COP) over the operating range of the equipment when cost effective.

5.4.5.2.1 Compressors.

Compressors, such as reciprocating and centrifugal, should be evaluated on the basis of full and partial load performance. The use of hot gas bypass should be avoided. Variable speed drives and capacity control by adjustable inlet vanes should be evaluated for partial load conditions.

5.4.5.2.2 Staging and arrangement.

The size and quantity of equipment should be determined from the operational profile of the facility. Equipment should be arranged in series or parallel and should be staged such that the minimum number of units are operating at, or near maximum efficiency to meet the load requirements.

5.4.5.3 Dehumidification equipment.

Dehumidification equipment should be evaluated on the basis of maximum pints of water, per hour, per input KW.

5.4.5.4 Humidification.

Steam humidification boilers and other humidification devices should be evaluated on the basis of maximum efficiency; and, should be controlled by the room sensor. The room sensor should shut down the boiler, or other humidification devices, when there is no demand for humidification.

5.4.6 Service (domestic) hot water systems.

5.4.6.1 Storage capacity and recovery rate.

The storage capacity and recovery rate should not exceed the design demand load requirements, except for energy demand control. Storage tank water temperature should be kept as low as practical, within code.
Storage tank water temperature should be a minimum of 140°F, because of Legionella Pneumophila disease, then, mixed at fixture for a temperature of 105°F maximum to prevent scalding. Storage tank and equipment should be insulated per state regulations.

5.4.6.2 Distribution.

Hot water distribution may be by direct discharge (non-recirculating) or recirculating. All piping should be insulated.

5.4.6.2.1 Recirculating pump.

The selection of the recirculating pump should be based upon optimization of minimum horsepower and maximum efficiency. Pump operation should be automatically controlled by timer or aquastat.

5.4.6.2.2 Recirculating versus hot water maintenance tape.

A trade-off study should be conducted to determine which system results in the minimum energy consumption, including pump energy and heat losses. Circuit of such equipment should be GFI type.

5.4.6.3 Dishwasher hot water supply.

Dishwasher hot water supply should be independent from the domestic hot water system, where practical. The water supply should be protected against backflow by an air gap or backflow preventer in accordance with code. Electric booster heaters should not be used. Where necessary, limiting controls should be evaluated to avoid excess peak electric power demand. Consideration should be given for dishwashers designed specifically for use with normal (105°F) domestic hot water temperature.

5.4.6.4 Energy demand control.

Consideration should be given to increased storage and reduced recovery rate of electric water heaters for electricity demand control, particularly where the service water heating energy requirements exceed 20 kW. Provide, in addition to the primary temperature controls, an over-temperature safety protection device constructed, listed, and installed in accordance with nationally recognized applicable standards for such devices. The same principle should apply to gas-fired water heaters, subject to penalties for gas consumption under interruptible service conditions.

5.4.6.5 Fixtures.

Fixtures should be water-saver type with flow restrictors and automatic shut-off features. Fixtures should not be a nuisance to the user which may result in overuse and defeat the purpose of its special design feature.

5.4.7 Process equipment.
Process equipment energy is that, which is consumed for purposes other than for comfort conditioning and illumination. In NAS facilities, this equipment is largely comprised of communication, surveillance, automation, and other electronic equipment. Energy management and conservation requirements, for this type equipment, are provided in facility development specifications for each subsystem or project. The process equipment, installed in FAA facilities, should comply with the requirements of ASHRAE/IES Standard 90.1.

5.4.7.1 Heat recovery.
Since process energy consumption normally results in additional energy requirements imposed on building environmental control systems, these systems must be examined for potential energy management and conservation measures. In particular, these systems should be evaluated for energy recovery for preheating ventilation air or heating adjacent spaces.

5.4.7.2 Equipment enclosures.
Equipment enclosures should be evaluated as energy management and conservation measures for electronic process equipment in unattended facilities. The enclosure would provide a means to condition the minimum volume necessary to house and access the equipment for maintenance. Work areas outside the enclosures would then be designed for broad, dead band temperatures.

5.4.8 Thermal energy recovery.
Thermal energy (heat) recovery should be evaluated for facility equipment and systems. In particular, consideration should be given to recovery of excess energy from power conditioning equipment for heating adjacent battery rooms, engine generator rooms, and other ancillary spaces.

5.4.9 Energy and load management.
Energy management and control systems, designed to reduce energy use or reduce energy costs, should be evaluated for use at NAS facilities. Energy management and control systems should be evaluated for: control throughout the facility, control of a group of systems or devices, or control of an individual device or system. All energy management and control systems should be evaluated for their ability to comply with ASHRAE Standard 62.

5.4.9.1 Localized energy management and control system.
Localized energy management and control systems provide independent, relatively low cost control for specified systems and equipment. Each local controller is independently controlling its specified system or equipment, without acting in conjunction with any other controlling device. Localized energy management and control systems include: time controls, automatic temperature setback/setup controls, economizer cycle controls, supply temperature reset controls, and dead band controls. Localized energy management systems can be pneumatic, electronic, direct digital, or a combination thereof.

5.4.9.1.1 Economizer cycle controls.

Economizer cycles utilize outdoor air to provide cooling to a space, whenever cooling is required and the outdoor air conditions are favorable. Dampers are positioned to select the most economical air stream (outside or return air) to provide the required cooling. The economizer cycle must maintain the ventilation air rate above the minimum required rate, as defined by federal, state and local codes. Consideration should be given to varying the minimum ventilation rate in accordance with ASHRAE Standard 62.

5.4.9.1.2 Dead band control system.

A dead band control system operates solely on the basis of room temperature. It establishes a relatively wide range (dead band), over which, no heating or cooling is provided. As the temperature falls below or rises above dead band settings, heating or cooling is gradually increased. A space demand reset control is provided, which uses space temperature to automatically readjust the temperature of the air being supplied to heat or cool the space. Dead band controls are applicable to HVAC systems, which provide heating and cooling in sequence; and can be used effectively even when these systems have economizer cycle controls; or, are interfaced with higher levels of energy management control systems.

5.4.9.1.3 Chiller energy management controller.

A chiller energy management controller uses programmed logic to load, unload, start, and stop centrifugal chillers. The controller also resets suction temperature automatically by sensing load requirements; remotely monitors and displays inlet vane position in percentage, as well as chiller operating hours; and starts the standby chiller automatically, when needed.

5.4.9.2 Remote limited and multifunction energy management control system.

Remote limited and multifunction energy management control system devices are typified by a limited function demand controller, which interfaces with numerous energy consuming devices and systems to limit electrical demand. Energy management control system devices are programmable through use of microprocessors and provide for multifunction capability in a common enclosure. Remote limited and multifunction energy management control system devices usually are most applicable when the functions to be performed are limited, and there are fewer than one hundred (100) points to be monitored and controlled.

5.4.9.2.1 Demand controller.

A demand controller prevents electrical demand from exceeding a predetermined maximum. Certain interruptible, non-critical, or secondary loads are connected to it. As usage approaches maximum during an interval, secondary loads are shed. When usage subsides, or when the demand interval ends, the secondary loads are restored. Demand controllers should be designed to contend with present utility rate structures and metering methods; and, to adjust to changes that might be imposed by utilities. Demand controllers should be designed not to interfere with essential facility operations.

5.4.9.3 Computer-based energy management control system.

A computer-based energy management control system is comprised of multiple microcomputer based control panels connected via a Local Area Network/Wide Area Network (LAN/WAN) low voltage power carrier to monitor and control various points. Man-machine interface devices can be connected to the system through the LAN wherever required. In some cases, the computer and support devices are remote with data generated in the building being transmitted to the computer via leased telephone lines. Computer-based systems usually are appropriate when:

a. Optimization functions are needed;

b. Control decisions are to be based on the number of parameters and conditions involved, and on the series of events which occur;

c. Control decisions are to be based on inputs from various other computer based systems such as fire alarm, security, or power monitoring systems;

d. There are 100 or more points; or

e. Multiple systems or facilities must be monitored and controlled from one location.

f. The performance of mission critical systems/equipment is to be enhanced.

5.4.9.3.1 Chiller optimization.

Chilled water optimization should be evaluated for chilled water plants with multiple chillers. The optimization program selects the chiller or chillers required to meet the load with minimum energy consumption. The system incorporates interlocks with chilled water pumps, condenser water pumps, and automatic valves for isolation of non-operating pumps and chillers.

5.4.9.3.2 Chilled water temperature reset.

Automatic chilled water temperature reset should be evaluated to reduce energy input per ton of refrigeration. Chiller discharge temperature is reset upward during non-peak periods to the maximum, which will satisfy space cooling and dehumidification requirements. The chilled water temperature is reset upward, until the required space temperature or humidity can no longer be maintained. This determination is made by monitoring positions of chilled water valves on various cooling systems; or, by monitoring space temperature and humidity conditions. Automatic chilled water temperature reset should not be used in plants utilizing multiple chillers, if the reset would cause the chiller optimization program to start additional chillers.

5.4.10 Water conservation.

Methods of water conservation should be evaluated for use at all NAS facilities. Provide systems in accordance with local codes and public utility requirements. Retrofit of existing systems should be accomplished, when such measures are shown to be cost effective based on economic analysis.

5.4.10.1 Plumbing fixtures.

Low water consumption fixtures should be specified in accordance with ASME/ANSI standards. When evaluating low water consumption fixtures, consideration should be given to size and slope of existing sanitary sewers to ensure proper scouring of piping.

5.4.10.2 HVAC equipment.

HVAC equipment should be selected and designed to conserve water. Closed loop water systems should be used, wherever feasible. When climate and utility rates suggest the use of evaporative cooling systems, water consumption should be included in the economic analysis. Selection of cooling tower water treatment systems should include an analysis of water consumption. Condensate should be returned to steam boilers, wherever feasible.

5.4.10.3 Landscape irrigation systems.

A xeriscaping approach should be used to maximize water savings in landscape design. Make use of zoning, timers and automatic control systems for irrigation distribution systems.

5.4.10.4 On-site wastewater recycling systems.

Feasibility of graywater systems should be evaluated. Design systems in accordance with local plumbing codes. Graywater systems may also be used in conjunction with vacuum toilet systems.

5.4.10.5 Other energy management and conservation measures.

Other energy management and conservation measures should be identified and evaluated to determine potential candidates for implementation into designs for new facilities, or expansions, or modernizations to existing facilities. The following referenced documents should be used for identifying potential energy management and conservation measures for evaluation. Only those measures applicable to NAS facilities should be considered.

DOE/CS-0132	Architects and Engineers Guide to Energy Conservation in Existing Buildings
DOE/CS-0133	Identifying Retrofit Projects for Buildings
GSA	Energy Conservation Guidelines for New Office Buildings
EEI	Energy Management Handbook
GSA	Energy Conservation Guidelines for Existing Office Buildings
Public Law/102-486	Energy Policy Act of 1992
10 CFR 436	Code of Federal Regulations, Federal Energy Management and Planning Programs
E. O. 12902	Energy Efficiency and Water Conservation at Federal Facilities

5.5 Energy consumption baseline and profile.

An annual energy consumption baseline, of all candidate energy sources under consideration, should be developed in accordance with ASHRAE/IES Standard 90.1. The annual energy consumption baseline should be provided for each new building or new energy consuming mechanical or electrical system, whichever represents the major design. All non-major design items should be incorporated within the overall major design for the purpose of developing the annual energy consumption baseline. Energy units and conversion factors should be as provided in 10 CFR 436, Subpart A. Preference should be given to the utilization of alternative/renewable energy sources. Energy consumption baselines and profiles should include process energy required to power electronic equipment. The analysis should clearly differentiate between the energy reduction attributed to the use of electronic equipment and the amount saved by energy management and conservation measures for the facilities.

5.5.1 National standard design.

Energy consumption baselines should be developed using the highest summer and lowest winter temperatures provided in the table of summer and winter climatic zones in FAA-STD-032, for each summer and winter climatic zone.

5.5.2 Site adapted design.

An hour-by-hour fuel and energy consumption profile, for each energy consuming system, should be developed for the hottest and coldest days and for a design summer (2.5 % column) and winter (97.5 % column) day for the location under consideration. Each profile should be for a 24-hour period, starting at midnight, and should include each candidate energy source under consideration and the overall sum total of these sources. When specified in an FAA engineering requirement, task order, or NAS subsystem or project specification, an hour-by-hour fuel and energy consumption profile should be developed in the manner cited above, for 8760 hours per year.

5.6 Economic analysis.

5.6.1 General.

Unless otherwise stated, energy management and conservation measures for design or retrofit should be analyzed for maximum cost-effectiveness. The type of economic analyses (simple payback or life-cycle cost) should be as provided in the FAA engineering requirement, task order or system or subsystem specification. Where implementation of energy management and conservation measures is made from selections based upon different types of economic analyses, life-cycle cost analysis (LCCA) should be performed on all such energy management and conservation measures. The economic life of facilities is provided in FAA-STD-032.

5.6.2 Exceptions.

For new facilities, economic analyses will not be required for energy management and conservation measures imposed by national codes and industry standards.

5.6.3 Standard.

Standard economic analyses should be in accordance with 10 CFR Part 436, Subpart A. The energy management and conservation measures under analysis should pass the presumption test under Section 436.13 of 10 CFR Part 436, prior to assessing cost effectiveness.

5.6.3.1 Economic feasibility.

5.6.3.1.1 Estimated simple payback time.

Except for alternative/renewable energy source conservation measures, an energy management and conservation measure should be considered economically feasible, if its estimated simple payback time is less than or equal to ten years.

5.6.3.1.2 Life-cycle cost analyses.

Except for alternative/renewable energy source conservation measures, an energy management and conservation measure should be considered economically feasible, if its savings-to-investment ratio (SIR) is greater than or equal to one.

5.6.3.1.3 Alternative/renewable energy sources.

The test for economic feasibility and other economic factors, for analyses of energy management and conservation measures involving use of alternate/renewable energy sources, will be provided by the FAA.

5.6.4 Analyses of multiple energy management and conservation measures.

The cumulative effect of implementing more than one energy management and conservation measure should be taken into account by using this or an equivalent procedure, subject to FAA approval:

a. Calculate the energy savings on all energy management and conservation measures.

b. Rank the energy management and conservation measures in order of decreasing SIRs or increasing estimated payback time, depending upon the type of economic analysis being used.

c. Starting with the most cost-effective energy management and conservation measure as ranked above, reduce the total energy use (BTU or KWH) by the amount of energy it conserves. This result, i.e., the reduced total energy use, becomes the basis for the calculation for the second ranked energy management and conservation measure.

d. Continue successively in the same manner with each energy management and conservation measure, until the calculations have been done for all ranked energy management and conservation measures.

e. Recompute the SIR or estimated simple paycheck times, based upon taking the cumulative effect into account by using the successively reduced calculated total energy use.

5.6.5 Computational requirements.

NBS Handbook 135 and Office of Management and Budget Circular A-94; which contains economic data, worksheets, computer programs, discount rates and methods should be used with 10 CFR 436, Subpart A.

5.7 Selection and implementation of energy management and conservation measures.

Unless otherwise directed by the FAA, all energy management and conservation measures should be implemented into the design in the following order of preference, within the constraints of construction time and budget:

a. Imposed national code and industry standard energy management conservation measures.

b. Ranked in order candidate energy management and conservative measures.

Whenever the estimated simple payback times, or the SIRs, of two energy management and conservation measures are within 10 %, preference should be given to the design feature exhibiting the greater energy savings, which exceeds by at least 5 % the energy saving of the energy management and conservation measures, with the lower estimated simple payback time or higher SIR, provided that reliability is not compromised by the more favorable energy-conscious selection.

5.8 Quality assurance requirements.

All design implementing energy management and conservation measures for new facilities and modifications to existing facilities should be in accordance with FAA-STD-032; and, should meet national and regional standards for construction, operation and maintenance and should be subject to the scrutiny of the Joint Acceptance Inspection. Tests should be conducted to ensure the validity of design or economic analysis techniques, which have not been proven by previous application.

6. NOTES.

6.1 Additional data required.

Attention of procurement request initiators is invited to the items listed below, which should be covered in the system/subsystem or engineering services specification or contract schedule.

6.1.1 General requirements.

Specifications should not categorically impose all requirements of this handbook. Only those requirements, which are applicable to the specific project should be imposed. Identify FAA system/subsystem or equipment to be served by the facility. Specify the deliverables. Specify those energy management and conservation measures that should not be considered or evaluated. Specify any deviations from this handbook (4.1).

6.1.2 Alternative/renewable energy sources.

Provide direction to A/E on the implementation or evaluation of alternative/renewable energy sources. Provide economic incentive factors (if any) and other relevant economic data for economic analysis. Provide direction for disposition of these energy management control systems, when alternative/renewable energy sources are determined not to be economically feasible (5.1.2 and 5.4).

6.1.3 Facility occupancy.

Specify facility human occupancy, i.e., number of persons, specific work areas, duration of work period, level of activity, etc. for A/E determination of environmental requirements and automatic controls (5.4).

6.1.4 Electric power demand control.

Specify interruptible non-critical and secondary loads that may be connected to the demand controller. Specify essential facility operations, which are not to be interfaced with (5.4.3).

6.1.5 Controls connected to the central control and monitoring system (CCMS) or remote maintenance monitoring system (RMMS).

Specify, whether or not, controls should be connected to the CCMS and RMMS; and, indicate compatibility sequences of these controls (5.4.3).

6.1.6 Process equipment.

Specify energy management and conservation requirements for process equipment (i.e., navigation, communication, surveillance, and other electronic and data processing equipment) (5.4.7).

6.1.7 Site adapted designs.

Specify when an hour-by-hour fuel and energy consumption profile should be developed for the entire 8760 hours in a year (5.5).

6.1.8 Economic analysis.

Specify the type of economic analyses, i.e., estimated simple payback period or life-cycle cost analysis. Specify any exceptions to the maximum payback period or minimum saving-to-investment ratios which are imposed herein (5.6).

6.1.9 Selection and implementation of energy management and conservation measures.

Specify deviations from handbook. Provide constraints including construction time and budget (5.7).

6.1.10 Suggested computer programs.

Computer program software may perform peak load calculations and the hour-by-hour calculations consistent with this handbook. Computer analyses may be used to aid the designer in calculating energy loads, energy consumption, highlighting energy end losses, selecting the best HVAC equipment, sizing equipment capacity for efficiency and economy, and testing effectiveness of differing building characteristics, orientation, and exterior environments as described in this handbook. Computer analyses and computer-aided design may be used whenever LCCA will be applied to the design options. Below is a list of suggested software. The list is by no means complete and the A/E is urged to use other programs subject to approval by the FAA.

a. **SOLAR.**

Name	Source
SOLCOST	Control Data's CYBERNET Services

b. **BUILDING FORM, EXTERIOR AND INTERIOR.**

Name	Source
ECUBE 75	Control Data's CYBERNET Services
SUNSET	Dubin - Mindell - Bloome Associates
Glass Comparison	Libbey-Owens-Ford
ARK-2	Perry, Dean & Stewart
B.O.P.	Skidmore, Ownings & Merrill
CCB/CALERDA	Control Data's CYBERNET Services

c. **HEATING, VENTILATING AND AIR CONDITIONING.**

Name	Source
E20-ii/HAP	Carrier Corporation
Trace 600	The Trane Company
System Analyzer	The Trane Company
DOE 2.1E	Lawrence Berkeley Labs
Elite CHVAC	Elite Software
Micro DOE 2 E Version	ERG/ACROSOFT International, Inc.

d. **DOMESTIC WATER PIPING DESIGN.**

Name	Source
KYPIPE 2	University of Kentucky Engineering
SPIPE	Elite Software Development, Inc.
Water	Research Engineers, Inc.

e. **LIGHTING.**

Name	Source
Lighting II	APEC
Lighting	Dalton, Dalton, Little & Newport
Analysis & Design	Giffels Associates, Inc.
Lighting Program	Isaac Goodbar
Lighting Program	Illumination Computing Service
Lighting Program	Ian Lewen
Lumen II	Smith, Hinchman & Grylls
Day Lighting	Libbey-Owens-Ford
Skypro	Natural Lighting Co. Inc.
PSAT	EDSA

f. **ELECTRICAL DEMAND.**

Name	Source
Electric Demand Load Study	Giffels Associates, Inc.

g. **ENERGY AUDIT AND BASELINE.**

Name	Source
Energy Program (EP)	Control Data's CYBERNET Services

h. **ENERGY AUDIT AND LIFE-CYCLE COST ANALYSES.**

Name	Source
Energy Analyst	American Energy Services, Inc.