01010

Scope of Work

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CONTENTS

A. Summary

This section contains general scope of work requirements owner-consultant architectural and engineering services agreements. The scope of work may vary according to the project requirements. See Section 01330: Designer Submittals, for detailed engineer submittals to Yale University.

1. Design/Enhanced Schematic Design

The engineering consultant must work with Yale University to define the best applicable systems based on performance, operation and ease of repairs, quality, first cost, operating cost, maintenance cost, and aesthetics. At the end of this phase, submit drawings, one-line diagrams, and a report to Yale University that address the following requirements. Include photographs and illustrations in the report, as necessary.

a. General

1. Survey and assess existing building systems.
2. Review applicable building codes, and identify requirements for the given building type and occupancy.
3. Identify energy sources and other utilities available or feasible at the site, and determine the most desirable sources that meet the needs of the project.

4. Identify or recommend the required degree of mechanical system flexibility to accommodate building expansion and changes in space usage or occupancy.
5. Identify special needs and/or Yale University requirements pertaining to mechanical systems, such as:
   - Special aesthetic treatment
   - Special safety or security requirements
   - Special acoustical requirements
   - Special temperature or humidity requirements, or control strategies
   - Indoor air quality levels
   - Special scheduling or sequencing of construction work
   - Special equipment
6. Propose recommended systems or equipment.
7. Provide information for the preparation of a detailed estimate of construction cost based on a preliminary system concept. Include a preliminary life-cycle cost analysis.
8. Determine the applicability of utility company or other energy conservation incentive programs.
9. Identify site conditions affecting construction.
10. Identify long lead-time items.
11. Provide the information necessary to develop a construction schedule.
12. Attend meetings, as requested, with Yale University, building committees, governmental agencies, and other groups.
13. Work with Yale University to determine energy management system requirements for all building systems.
14. Provide outline specifications in a system-type format.

b. Mechanical

1. Provide preliminary load calculations.
2. Select generic heating or cooling equipment.
3. Review or propose alternate types of systems and analyze them for first cost and life-cycle cost comparisons.
4. Review space requirements and service accessibility for all systems and equipment.
5. Provide flow diagrams for major systems.
6. Provide a one-line diagram showing major equipment and the proposed piping and ductwork layout.
7. Provide a systems description and sequence of operation.

c. Electrical

1. Provide one-line system diagrams.
2. Review or propose alternate types of systems and analyze them for first cost and life-cycle cost comparisons.
3. For renovation projects, submit copies of documentation generated during field investigations, including field notes, sketches, and photographs of all pertinent portions of the existing installation.
4. Provide preliminary load calculations based on loads shown in panelboard and switchboard schedules. Provide breakdowns of power consumption per square foot for lighting, air conditioning, and other major categories of utilization, together with total consumption.
5. Review space requirements, and service accessibility for all systems and equipment. Plan space requirements to meet the most demanding operations and maintenance required.
6. Provide a design intent document based on load requirements and design parameters.
7. Provide lighting calculations for each type of space in accordance with IES standards. Calculations must clearly indicate assumptions of reflectances, maintenance factors, and ballast factors. Present results in footcandles and in watts per square foot.

2. Design Development

Provide drawings and a report that addresses the following requirements:

a. General

1. Provide an updated estimate of construction cost indicating scope changes and including cost implications and updated life-cycle costing.
2. Provide lead-times for ordering equipment.
3. Attend agency reviews as requested by Yale University (for example, owner representatives, building inspector).
4. Identify demolition requirements.
5. Attend utility company reviews.
6. Identify bidding alternatives.
7. Provide an updated code analysis as a result of the design process.
8. Provide outline specifications in CSI format.

b. Mechanical

1. Provide preliminary detailed drawings showing equipment, piping and ductwork locations.
2. Determine space requirements for equipment, ductwork, and piping, including chases and mechanical rooms. Coordinate with structural members and other trades.
3. Define seismic requirements for mechanical systems.
4. Identify site utility locations.
5. Define equipment control strategies.
6. Update flow diagrams.

c. Electrical

1. Provide updated one-line diagrams.
2. Provide updated electrical load calculations.
3. Provide harmonics calculations in accordance with standard IEEE 519.
4. Provide short-circuit calculations showing contributions from each source, the characteristics of each circuit element, and the short-circuit energy available at each bus. Calculations must indicate the selection criteria for conductors, in addition to overcurrent devices.
5. Submit coordination analyses or all types of overcurrent devices in series.

3. Construction Documents

a. General

1. Provide final load calculations (mechanical and electrical).
2. Provide code compliance calculations.
3. Coordinate with other trades.
4. Provide a final estimate of construction cost.
5. Attend the final review and coordination meeting with Yale University representatives.
6. Formulate a submittals list along with a list of proprietary or non-University standard equipment.

b. Drawings

See Section 01330: Designer Submittals.

4. Bidding

a. General

1. Prepare or assist in the preparation of bid documents.
2. Review bid documents.
3. Assist in the selection of bidders.
4. Review bidder qualifications.
5. Attend pre-bid meetings with contractors.
6. Provide Yale University with a written analysis or comparison of submitted bids.
7. Review proposed substitutions or alternates.
8. Attend the bid opening meeting.

5. Construction

a. General

1. Assist with the preparation and filing of permits.
2. Attend the pre-construction meeting.
3. Review shop drawings.
4. Inspect installed work (roughing and finished work).
5. Attend job meetings as requested by Yale University.
6. Assist in the approval of payments to contractors.
7. Initiate requests for change orders, and/or review change orders.
8. Prepare punch lists.
9. Prepare record drawings (as-built).
10. Prepare or review system operation and maintenance manuals.
11. Assist with turnover and building commissioning.

b. Mechanical

1. Review testing or balancing reports.
2. Review emissions compliance studies.
3. Witness on-site tests of all mechanical systems. Provide a written report to Yale University.

c. Electrical

1. Review contractor submittals and shop drawings.
2. Witness on-site tests of all electrical systems. Provide a written report to Yale University.

6. Post Construction

- Verify system performance. (mechanical & electrical)
- Review as-built drawings.
- Review operation and maintenance manuals.
- Provide record drawings on Mylar® and diskettes.

a. Preparation and Reproduction Costs

Costs for preliminary, bidding, construction, and record documents and costs for bid, construction, and post-construction services include the following:

1. Presentation renderings and models.
2. Two or three sets of all other documents for Yale University. (The number of sets is determined for each project.)
3. Documents required for approval of the project by all outside agencies and/or organizations, including those involved with funding, codes, and ordinances.
4. Documents required for bidding and construction.

NOTE: In addition to furnishing the required quantities of documents to each general contractor, the local practice for bidding is to have the consultant make copies of the documents available to subcontractors on a refundable deposit when pre-filed bids are invited. Otherwise, the consultant will make copies of the documents available at the cost of reproduction.

5. Systems Designs.

   Do not allow contractors' shop drawings to in any way determine the design of systems or assemblies. Shop drawings are expected to reflect and respond to designs originated by the consultant.

6. Systems Descriptions.

   As described in Section 01330: Designer Submittals, the architect—through his consulting engineers—must provide maintenance and repair personnel with a written description of the mechanical and electrical systems and their operation, together with such one-line diagrams (or a reference to specific portions of the detailed drawings and specifications) as might be required. These descriptions are important to Yale University. Prepare them carefully and thoroughly. Systems descriptions and diagrams should be coordinated with, and cross-referenced to, contractor-furnished maintenance manuals. See Yale Specification, Section 01782: Operations and Maintenance Data. Yale University will retain a portion of the architect's fee until all documents are complete.

7. Archival Material.

   At the close of construction, or at any earlier stage at which they are no longer needed for the prosecution of work, the architect must collect and deliver to Yale University those developmental sketches, drawings, models or other materials that illustrate the evolution of the design and all presentation renderings and models prepared for any purpose relating to the building for which services were performed.

b. Fees for Special Consultants

1. In general, the nature of the project indicates, at project inception, whether any features will require professional competence or knowledge beyond that available to the architect’s office.

2. Unless the project inception agreement indicates otherwise, Yale University expects the architect's fee to cover any costs incurred in providing technical competence in all areas of design, including:
   - Structure, including soils engineering, de-watering, and underpinning
   - Mechanical features
   - Electrical features, including lighting
   - Vibration isolation and/or damping
   - Kitchen facilities
   - Hospital facilities
   - Laboratory facilities
   - Acoustics, including special design for acoustically significant areas or assemblies, and normal design for sound absorption and travel
   - Interior decoration involving building surfaces

c. Costs and/or Fees for Time Spent in Coordination with Yale University

1. If the nature of the project indicates the need for coordination with Yale University , the architect's normal non-reimbursable services must include consultation with other University consultants in the fields of source, provision, and use of all utilities; architectural master planning; architectural landscape planning; exterior lighting; and occupational and environmental health.

2. The degree of such consultation is fixed during design development in discussion between the architect and Yale University's project administrators. The degree of such consultation is usually not excessive and is what an architect would expect to provide for an owner with an existing "campus."

End of Section

01040
Coordination

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CONTENTS

Please contact the Yale University Department of Facilities Contract Administrator about coordination requirements.

01060

General Regulatory and Directive Standards

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CONTENTS

A. Summary

1. This section identifies general plumbing, fire protection, HVAC, and electrical design regulatory and directive standards, codes, and references. It also contains general project documentation and occupational and environmental health guidelines, and identifies the desired quality, type, and characteristics of certain materials and facilities and the regulations and standards to be followed for the design of building systems.

2. The items contained in this section should be discussed during the development of each project. Use of this section and the other relevant sections listed in the following paragraph is intended to save time and help produce high-quality construction documents and buildings that provide a safe and healthy environment, are accessible to handicapped persons, are efficient to operate, and are compatible with existing operating and maintenance procedures.

B. Project Documentation Requirements

1. Specifications

Comply with the following specification requirements. Deviation from these requirements is not permitted without formal notice and Yale University's written approval.

a. Format

Arrange project specifications per the Construction Specifications Institute (CSI) MasterFormat,™ which arranges subjects in numbered sections within 16 established divisions. Precede these specifications with the general documents containing bidding documents and general conditions. Use of the CSI MasterFormat™ saves all users time and effort. This feature is important to an institutional owner. Therefore, the arrangement of specifications on Yale University projects by CSI division is mandatory, unless there is a valid reason for not doing so and that reason is approved by the University.

b. Practice

Unless policy is dictated by a funding agency, Yale University favors the following practices.

(1) Submit performance specifications, or specify acceptable manufacturers (usually a minimum of three) and omit the term “or equal.”

(2) Insert specific product approval standards under General Requirements, covering the following items:

(a) Where performance specifications are used, the Contractor is obligated, on request of the architect, to present an affidavit from the manufacturer certifying compliance prior to incorporation in the project.

(b) For approval of products other than those specified, a bidding contractor must submit a request in writing at least 10 calendar days prior to the bid date. Such requests must be accompanied by all of the data necessary to completely describe the item for conformance. The architect's approval, after consultation with Yale University, must be in the form of a specification addendum to all prime contract bidders of record.

(c) The substitution of products will be approved after bids are opened only for such reasons as unavailability beyond the control of the contractor. Requests must be in writing, and substitutions must be accompanied by all of the data necessary to completely describe the item for conformance and by added cost or credit data. The architect's approval, after consultation with Yale University, must be in writing.

(d) Except in the instance of items beyond the control of the contractor, the contractor is be responsible for the space and fit requirements of approved substitutions.

(e) Comments leading to revisions should be routed to the Office of Facilities Planning. The Office of Facilities Planning will record the names of all persons or firms to whom issue is made and will attempt to inform the recipients about changes. Users, however, should check periodically to be sure they have all revisions.

c. Language and Technology

When reviewing specifications, Yale University uses the CSI Manual of Practice and Specification Series. As an owner concerned with avoiding the defense of contingent liability lawsuits, the University expects the architect to pay particular attention to the language used in, and technology described by, the specifications.

d. Reproduction

Make single-sided reproductions of specifications to allow use of the blank side for attaching addenda and bulletin items and for annotations by users.

e. Shop Drawings and Samples

Each specification section should state if shop drawings and samples are required. If required, state the required quantities if not spelled out in the general documents.

2. As-Built Drawings and Documentation

As-built drawings and documentation required of the mechanical engineer or contractor must be reviewed by the engineer.

a. Revise as-built drawings and documentation to reflect modifications made to any part of the facility or mechanical systems.

b. Carefully monitor and document any change in usage, installed equipment, loads, or occupancy.

c. Drawings must be compatible with the CADD platform specified in *CADD Requirements for Outside Consultants*. Each mechanical drawing must contain all layers listed therein, whether or not actually used.

d. Operation and maintenance manuals should include a copy of the Testing and Balancing Report.

3. Working Drawings

All persons using the drawings are sensibly interested in using them easily and with the least waste of time and effort. Obviously, good drafting and lettering are a requisite quality, but the arrangement of information is just as important. Some desired arrangement features that should be incorporated in the drawings are described in the following paragraphs.

a. Size and Scale

Sheets should not be larger than 30" H x 42" L. The preferred scale for all overall plans and sections, except where very limited work is shown, is 1/4" - l'-0". To avoid a conflict in these requirements for larger buildings, use multiple sheets with suitable match lines.

b. *Numbering*

An attempt should be made to have drawing numbers, such as SB, B, 1, 2, 3, 4, 5, show plans for sub-basement, basement, lst, 2nd, 3rd, 4th, and 5th floors. A logical extension of this scheme involves P, M, and E prefixes to these numbers for the appropriate mechanical and electrical floor plans. Drawing numbers should be located in the lower right-hand corner of a title block appearing in the lower right hand corner of each drawing.

c. *Room Designation*

Rooms should be designated on plans by name, as well as room number, per Yale University Standards and Guidelines, Central Campus Room Numbering Standards. Room numbers are important. They should be approved before the design development phase and remain unchanged.

d. *Room Finish and Painting Schedules*

Locate individual floor schedules on the same sheet as the associated floor plan.

e. *Drawing Index*

In addition to the complete face sheet index, repeat a partial index on other drawings. For example, on plan drawings the local index should refer to sheet locations for items most wanted when looking at the plans.

Example:

Item	Dwg. No.
Equipment schedules	10
Plumbing details	14
Lab. equipment details	35

f. *Standard Abbreviations List*

The face sheet should include a list of all standard abbreviations.

4. Project Document Inclusions

a. Place the following note in bold type on each MEP sheet:

All control boxes, valves, control valves (of every type, shape, and function), and DDC control boxes must be installed in such a manner as to be fully and reasonably accessible and free from insulation or other construction components. Fully and reasonably accessible is defined as capable of being accessible for repair or replacement by an average-size individual, on a ladder if necessary, and capable of being removed without removing other components of the work.

b. Statements similar to the following should be included on drawings or in a specification section on special requirements for mechanical and electrical work:

(1) Mechanical and electrical drawings show pipe, duct, and conduit runs, and the locations of equipment, valves, panels, and other components. Dimensions not shown must be obtained from the architect, and not scaled from the drawings. Lay out routing and locations to meet field conditions, to provide easy access for service and maintenance, and to avoid conflict between the work of all trades. Submit proposed routings and locations to the architect for approval, and modified or relocate them within reasonable limits, as directed, without extra cost.

(2) Provide equipment and apparatus complete with all the usual and necessary fittings and accessories not normally shown or specified, but which are required for proper installation and operation. Place gauges, thermostats, thermometers, and other accessories, not specifically located on the drawings, where directed by the architect.

(3) Provide written operating and maintenance instructions for all equipment and systems, in approved form, to the architect before final acceptance of the work.

c. The architect is expected to design spaces housing equipment so that the actual layout, when complete, will allow Yale University to service the equipment. Include a statement similar to the following so the contractor is cautioned about this feature:

Locate all equipment and accessories to provide easy access for proper service and maintenance. Install equipment and accessories to enable the removal of any part without the need to remove other components.

C. Occupational and Environmental Health

The Division of Occupational and Environmental Health of the Yale University Health Service has responsibility for all occupational health and safety provisions in and around Yale University buildings. Through the Office of Facilities Planning, make arrangements for conferences and consultation with the Division Director and such section directors as indicated by the nature, contents, and occupancy of the particular project.

1. General

The Division of Occupational and Environmental Health Services (DOEHS) of the Yale University Health Service is responsible for the formulation of safety guidelines and conduct of other such activities as to promote the general health and well-being of the University community. The Division is concerned with matters pertaining to exposures to potentially hazardous biological, chemical or radiological agents; to the establishment of a relatively safe work environment; and to provide health services for conditions arising as a result of employment.

2. Consultation Services

The DOEHS provides consultation services through its several sections for specific questions or problems dealing with health and safety issues. These consultations, considered essential components of any construction project, should be requested and completed at the schematic design stage of the project. The nature of the project should lead to the forwarding of consultation requests to one of the following DOEHS sections:

a. *Biological Safety*

Review new construction, renovations, or alterations involving any facilities in the areas listed below with the Director, Office of Biological Safety, University Health Services. Before designing Class P3 or DCD3 laboratories, review the Yale University checklist for design of these areas. This checklist may be obtained from the Department of Architectural and Engineering Services.

- Medical School
- Kline Biology Tower
- Any other area where work with infectious agents is conducted
- Any area where animal experiments are conducted

b. *Environmental Health*

The following principal areas impact environmental health and sanitation. Projects that include these areas should be reviewed by the Environmental Health Office.

- Food service, storage and/or processing facilities
- Swimming pools
- Potable water systems
- Solid waste handling (garbage and rubbish)
- Dormitory facilities
- Sewage disposal at off-campus sites

c. Occupational Safety

The Safety Department is concerned with the establishment and maintenance of a safe work environment, and is responsible for ensuring compliance with OSHA regulations The following list of areas of interest is not all-inclusive, but serves as an example of the areas covered by OSHA for which construction plans should be reviewed. Questions concerning other areas not on this list that might also be covered by OSHA should be directed to the department's Occupational Safety section.

- All laboratory facilities
- Walking and working surfaces
- Ventilation systems
- Fume hood systems
- Stairways
- Shop facilities
- Storage facilities
- Electrical services
- Plumbing services

d. Radiation Safety

New construction or renovations to any of the following facilities, systems, or components should be reviewed to ensure incorporation, during the early design stages, of sufficient engineering controls for radiation protection purposes. The list is not all-inclusive, but serves as an example of the types of plans that might need review.

- Research laboratories
- Clinical laboratories
- Patient care facilities (including radiation services)
- X-ray facilities
- Accelerator laboratories
- Laser facilities
- Microwave facilities
- Ventilation systems
- Drainage systems
- Shielding
- Shielded facilities

D. Stairs, Steps, and Ramps

In addition to conformance with the State of Connecticut Building Code or other code requirements, consider the following:

- Facilities for the handicapped
- Adequate exterior lighting, as well as interior features
- Barriers at changes in levels (exterior and interior) where persons, including children, can fall from one level to another

E. Exterior Lighting

In addition to lighting at exterior stairs and steps, consider the amount and type of other exterior lighting. Discuss with Yale University the need to coordinate design with the University master plan for lighting of exterior spaces.

F. Design, Construction, and Alteration for the Handicapped

1. Under Section 504 of the Rehabilitation Act of 1973 all new construction must be barrier free and, in the case of additions and/or alterations, the renovated or added areas must be made accessible "to the maximum extent feasible."
2. Design, construction, and alteration must meet the guidelines in ANSI A117.1, Specifications for Making Buildings and Facilities Accessible to, and Usable by, Physically Handicapped People, published by the American National Standards Institute, unless other methods clearly provide equivalent access.
3. In addition, Article 21 of the State of Connecticut Building Code makes mandatory certain provisions for the handicapped that are more stringent than the guidelines of ANSI A117.1. The provisions of Article 21 are mandatory for all new construction. For alteration projects, the provisions are mandatory by code where the costs of construction exceed 50 percent of the current replacement value of the building and might be made mandatory in cases where the costs exceed only 25 percent of the replacement value.

G. Submittals

1. Contract documents are often produced at the last minute. If the contract award is based on competitive bidding, document review and coordination often occurs during the bidding period, which generates numerous bidding period addenda and costly errors. This last-minute document review and coordination results from a document completion target date that is usually the out-to-bid or bid-due date. To avoid these problems, Yale University has adopted a policy of creating an earlier target date. An advance printing of all contract documents is expected one month earlier than the:
    - Out-to-bid date, if the award is based on bidding
    - Contract signing date, if the award is based on negotiation

2. Yale University realizes that the size of the proposed building might not justify the one-month advance date, and that in award-by-negotiation situations, such an advance date might not be feasible. However, the advanced target date will hold unless a departure agreement becomes a matter of record. See the Yale University Guidebook for New or Remodeled Building Construction: General Conditions, Division 1, General Requirements regarding the early submission of proposed General Conditions, Supplementary General Conditions, and General Requirements.

H. Project Document Inclusions

1. Include under General Requirements in the specifications, such statements as the following:

   a. *Until construction is complete, protect all equipment from water, dirt, and physical damage.*

   b. *Cover pumps, fans and similar equipment with tarpaulins or heavy plastic to protect bearings, motors, couplings, and other such components from weather and dust.*

   c. *Do not use mechanical equipment as scaffolding or working platforms for other trades (painters, plasterers).*

   d. *Upon completion of construction, chipped or scratched factory-finished equipment must be "touch-up" painted by the painting contractor at mechanical contractor's expense.*

2. Place the following note in bold type on each MEP sheet:

   All control boxes, valves, control valves (of every type, shape, and function), and DDC control boxes must be installed in such a manner as to be fully and reasonably accessible and free from insulation or other construction components. Fully and reasonably accessible is defined as capable of being accessible for repair or replacement by an average-size individual, on a ladder if necessary, and capable of being removed without removing other components of the work.

End of Section

01061
Plumbing Regulatory and Directive Standards

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CONTENTS

A. Summary

This section identifies applicable plumbing design standards, codes, references, and project document inclusions, and describes broad system concepts that address a number of sub-systems. These sub-systems are generally described here, but might be further described and specified in a separate section of the Yale University Design Standards. This and all other applicable sections should be read carefully and understood before designing or specifying any system or piece of equipment.

B. System Design and Performance Requirements

1. Design the HVAC system for longevity, durability and flexibility. Include redundant equipment in the design to provide Yale University with the capability to maintain the plumbing system without disturbing normal building operation.
2. Several options are available when selecting systems and equipment for a given type of building. To best serve Yale University's facility management strategies and for ease of maintenance, use proven central-type systems. For example, use central storage or instantaneous domestic hot water heaters, instead of local hot water heaters on each floor.
3. See the Division 15 sections of these standards, as well as Section 00703: General Plumbing Design Conditions, for further detailed design requirements.

4. The design team is responsible for coordinating the construction drawings to ensure that adequate space is available in the general location of each component. The general contractor or construction manager is responsible for coordinating the construction to ensure compliance with this space requirement. Any corrective work is at the expense of the general contractor or construction manager.

C. Submittals

See Section 01330: Designer Submittals and the Division 15 mechanical sections of these standards for submittals requirements.

End of Section

01062

Fire Protection Regulatory and Directive Standards

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CONTENTS

A. Summary

This section identifies applicable fire protection design standards, codes, and references, and describes broad system concepts that address a number of sub-systems. These sub-systems are generally described here, but might be further described and specified in a separate section of the Yale University Design Standards. This and all other applicable sections should be read carefully and understood before designing or specifying any system or piece of equipment.

B. System Design and Performance Requirements

1. The insurers will review an early printing of the contract documents. Arrange for a conference, through the Yale University Facilities group, with the University Fire Marshal and with the Municipal Fire Marshal having jurisdiction.
2. The design team is responsible for coordinating the construction drawings to ensure that adequate space is available in the general location of each component. The general contractor or construction manager is responsible for coordinating the construction to ensure compliance with this space requirement. Any corrective work is at the expense of the general contractor or construction manager.
3. See Section 00704: General Fire Protection Design Conditions and Section 13915: Fire Suppression and for further, detailed design requirements.

C. Project Document Inclusions

1. Include under General Requirements in the specifications, such statements as the following:

   a. *Until construction is complete, protect all equipment from water, dirt, and physical damage.*

   b. *Cover pumps, fans and similar equipment with tarpaulins or heavy plastic to protect bearings, motors, couplings, and other such components from weather and dust.*

   c. *Do not use mechanical equipment as scaffolding or working platforms for other trades (painters, plasterers).*

   d. *Upon completion of construction, chipped or scratched factory-finished equipment must be "touch-up" painted by the painting contractor at mechanical contractor's expense.*

2. Place the following note in bold type on each MEP sheet:

   All control boxes, control valves (of every type, shape, and function), and DDC control boxes must be installed in such a manner as to be fully and reasonably accessible and free from insulation or other construction components. Fully and reasonably accessible is defined as capable of being accessible for repair or replacement by an average-size individual, on a ladder if necessary, and capable of being removed without removing other components of the work.

D. Submittals

See Section 01330: Designer Submittals and Section 13915: Fire Suppression for submittals requirements.

End of Section

01063

HVAC Regulatory and Directive Standards

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CONTENTS

A. Summary

This section identifies applicable HVAC design standards, codes, and references, and describes broad system concepts that address a number of sub-systems. These sub-systems are generally described here, but might be further described and specified in a separate section of the Yale University Design Standards. This and all other applicable sections should be read carefully and understood before designing or specifying any system or piece of equipment.

B. System Design and Performance Requirements

Design the HVAC system for longevity, durability and flexibility. Include redundant equipment in the design to provide Yale University with the capability to maintain the HVAC system without disturbing normal building operation. See Section 00705: General HVAC Design Conditions and the Division 15 mechanical sections of these standards for further, detailed design requirements.

The design team is responsible for coordinating the construction drawings to ensure that adequate space is available in the general location of each component. The general contractor or construction manager is responsible for coordinating the construction to ensure compliance with this space requirement. Any corrective work is at the expense of the general contractor or construction manager.

C. Project Document Inclusions

1. Include under General Requirements in the specifications, such statements as the following:

   a. *Until construction is complete, protect all equipment from water, dirt, and physical damage.*

   b. *Cover pumps, fans and similar equipment with tarpaulins or heavy plastic to protect bearings, motors, couplings, and other such components from weather and dust.*

   c. *Do not use mechanical equipment as scaffolding or working platforms for other trades (painters, plasterers).*

   d. *Upon completion of construction, chipped or scratched factory-finished equipment must be "touch-up" painted by the painting contractor at mechanical contractor's expense.*

2. Place the following note in bold type on each MEP sheet:

   All control boxes, control valves (of every type, shape, and function), and DDC control boxes must be installed in such a manner as to be fully and reasonably accessible and free from insulation or other construction components. Fully and reasonably accessible is defined as capable of being accessible for repair or replacement by an average-size individual, on a ladder if necessary, and capable of being removed without removing other components of the work.

D. Memos

Include any memos issued that affect changes and updates to the design standards.

E. Submittals

See Section 01330: Designer Submittals and the Division 15 mechanical sections of these standards for submittals requirements.

End of Section

01064
Electrical Regulatory and Directive Standards

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CONTENTS

A. Summary

This section lists general electrical standards, codes, and guidelines.

B. Yale University Electrical Design Standards and Schedules

1. 1600-1: Electrical Plans Standard Symbols
2. 1600-2: Electrical Diagrams Standard Symbols
3. 1600-3: Electrical Abbreviations
4. 16123-1: Feeder Schedule
5. 16500-1: Lighting Fixture Schedule
6. 16530: Walkway Lighting Details

End of Section

01330

Designer Submittals

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CONTENTS

A. Summary

This section contains detailed mechanical and electrical submission requirements applicable to engineers performing design services under Divisions 15000 and 16000.

B. Submittals

Table 1 identifies the submittal requirements for mechanical and electrical engineers.

Table 1. Submittal Requirements for Mechanical and Electrical Engineers

Item	PD*	CD*	CA* & Closeout
Title Sheet	X	X	
Demolition Plans(if necessary)	X	X	
Site Plan	X	X	
Utility Plans	X	X	
Engineer Floor Plans	X	X	
Details and Schedules	X	X	
MEP Design Progress Report	X		
MEP Plans	X	X	
MEP Schedules	X	X	
MEP Riser Diagrams	X	X	
Mechanical Flow Diagrams	X	X	
Equipment Sequence of Operation	X	X	
Electrical One-Line Diagrams	X	X	
Outline Specifications (systems format)	X	X	
Component Specifications (16-division CSI format)	X	X	
Project Manual		X	
Construction Cost Estimate	X	X	
Life-Cycle Cost Analysis	X		
Code Review or Analysis	X		
Code Compliance Calculations		X	
Block Heating & Cooling Loads	X		
Mechanical Load Calculations	X	X	
Control Points List	X	X	
Controls Location Plan	X	X	
Electrical Load Calculations	X	X	
Submittal List		X	
List of Proprietary or Non-University Standard Items	X	X	
Archive Documents		X	X

* PD = Preliminary/Enhanced Schematic Design
* CD = Construction Documents
* CA & Closeout = Construction Administration and Closeout

Table 1. Submittal Requirements for Mechanical and Electrical Engineers – Continued

Item	PD*	CD*	CA* & Closeout
Record Product Data and Samples			X
Operations and Maintenance Data			X
Warrantees and Bonds			X
Spare Parts/Maintenance Materials			X
Progress Photographs			X
As-Built Documents (if required)			X

* PD = Preliminary/Enhanced Schematic Design
* CD = Construction Documents
* CA & Closeout = Construction Administration and Closeout

C. Information Requirements

1. Drawings

a. General

(1) Ensure that all drawings are neat, clear, and of appropriate scale and completeness to easily determine the intended work.

(2) Draw floor plans on 24" x 36" sheets at a minimum scale of 1/4" = 1'0". Draw site plans on 24" x 36" sheets at an appropriate scale.

(3) Show demolition on separate drawings.

(4) Drawings must be compatible with the CADD platform specified in *CADD Requirements for Outside Consultants*. Each drawing must contain all layers listed in the CADD requirements document, whether or not they are actually used.

(5) Where ductwork, piping, conduit, and bus bars interface with the systems or equipment of other divisions, make a clear distinction between division 15 and 16 work and the work of other divisions. Do not make references by subcontractor or trade.

(6) Show the key plan, North arrow, and room locations.

(7) Provide separate floor plans for removals and demolition. Show all existing equipment, piping, ductwork, and electrical components within the area of work. Clearly identify all of the equipment, piping, ductwork, and electrical components that will remain or be removed.

(8) Provide floor plans for new work.

(9) All new systems should clearly show connections to the existing systems (ductwork, piping, reused equipment electrical parts, and portions of mechanical and electrical rooms). Remove piping, ductwork, and electrical wiring and conduit back to the first "live" branch or main. Cap off mechanical components with a valve and live cap electrical conductors. If the complete circuit is removed, lock and tag the circuit breaker.

(10) Equipment locations must show work access spaces, filter removal areas, coil pull areas, clearance in front of switchgear, motor control centers, and code required work space.

(11) For renovation projects, coordinate the new equipment numbers and operation with the existing equipment. Use Yale University acronyms for all equipment shown on the drawings.

(12) Provide record drawings in Mylar® and on diskettes upon completion of construction.

(13) Ensure that symbols and abbreviations used on drawings are in accordance with the latest Yale University standards for symbols and abbreviations.

b. Mechanical

(1) Draw ductwork double-lined, and clearly indicate the direction of air flow. Show supply, return, and exhaust ductwork with a different intensity of shading. Clearly indicate all rises and drops. If ductwork is not shown in section, indicate the height of the bottom of the duct.

(2) Draw all piping larger than 2-1/2" double lined, and clearly indicate the direction of flow and use. When piping of different usage is shown on the same drawing, show each group of piping with a different intensity of shading. Clearly indicate all rises and drops. If piping is not shown in section, indicate the height of the bottom of the pipe. Show floor plans, building sections, isometric diagrams, and details. Plumbing and fire protection may be included on the same drawings unless they are extensive enough to warrant separate floor plans.

(3) Draw all equipment to scale. Clearly indicate service and pull spaces. Use shading to distinguish new equipment from existing equipment. Identify equipment according to the designation on the drawing schedule. Duct work and equipment may be included on the same drawing with HVAC piping unless they are extensive enough to warrant separate floor plans. Ductwork and equipment drawings should include the proper designation for all air handling equipment and show all local exhaust, general exhaust, fume hoods, VAV boxes, VVE boxes, and other similar equipment.

(4) Controls drawings must contain control and wiring diagrams, point lists, and a written sequence of operation. Associated electrical work must be shown clearly on electrical drawings and referenced on mechanical and/or controls drawings. Engineering consultants must work with Yale University and controls vendors selected by the University to define control systems and strategies.

(5) Riser diagrams must include air flow, gpm, cfm, and direction of flow arrows. Provide riser diagrams for such systems as:

- Cold and hot water piping supply and return
- DI water piping
- Watering systems for animals
- Sanitary or waste drainage, including pumps
- Vent piping
- Acid waste piping
- Storm drainage, including pumps
- Process piping: natural gas, vacuum, nitrogen, $C0_2$, compressed air, and oxygen
- Fire suppression systems: wet and dry sprinkler piping systems
- Special systems
- HVAC air flow for HVAC systems, including fume hood and general exhaust
- Toilet exhaust
- Animal room exhaust
- Radioactive exhaust with HEPA filters
- Chilled water flow for HVAC systems
- Hot water flow for HVAC systems, including heat exchangers
- High, medium, and low-pressure steam
- High, medium, and low-pressure condensate
- PRV stations, condensate pumps, and condensate receivers
- Refrigerant piping

(6) Provide block or one-line diagrams for HVAC control diagrams. Show all interlock equipment, such as fans, VAV boxes, and motorized dampers. Show all interlocks for fume hood exhaust VVE boxes, general exhaust VVE boxes, and supply air VAV boxes. State how room pressurization is maintained as the fume hood sash is opened, and show how air locks are used.

(7) Provide sections or elevations for:
- Air handling units
- Cooling towers
- Main mechanical rooms
- Floor plans for main distribution

c. Electrical

Where wiring interfaces with equipment or systems of other divisions, clear distinction shall be made between work of division 16 and work of other divisions; Do not make references by subcontractor or trade.

(1) Provide separate floor plans or removals and demolition, and for power, lighting, and fire alarm systems.

(a) Equipment locations for other systems, such as intrusion detection and telecommunications systems, may be included on power plans, unless the other systems are extensive enough to warrant separate floor plans.

(b) Include relevant building information, such as ceiling heights and slopes, exposed joists, beam and girder locations, and fan CFMs, on fire alarm system floor plans.

(2) Provide one-line diagrams for power distribution systems.

(a) Indicate on the diagram the short-circuit energy available at each bus or tabulate it on the drawing.

(b) Indicate grounding methods and locations for all separately-derived systems. Where extensive or complex grounding arrangements are required (including ground-fault protection systems), provide separate grounding diagrams.

(3) Provide riser diagrams for such systems as fire alarm, intrusion detection, and telecommunications. Include the locations of vertical chases.

(4) Equipment schedules for feeders, switchboards, panelboards, and lighting fixtures must be in accordance with standard details shown in the relevant standards.

(5) Calculate demands for the following loads:

- Loads operating at 120 volts
- Lighting loads
- All other normal loads
- Emergency loads, excluding fire pumps (include itemized list)
- Fire pump, with horsepower rating
- Standby loads (include itemized list)
- Maximum coincident demand expected on the normal source and the alternate source

(6) Where multiple buildings are fed from a load center, list the following information for each building:

- The expected power factor prior to power factor improvement measures
- Duty cycles for each category of equipment
- Sizing calculations for switches over 100 amperes
- Calculations for selection and sizing of all transformers, including connected load, future loads, harmonics, and temperature considerations
- Calculations for sizing bus ducts
- Lighting fixtures catalog cuts
- Lighting calculations or isofootcandle layouts demonstrating that required illumination levels will be achieved throughout all egress routes

2. Specifications

Write specifications in accordance with current CSI guidelines for section titles and numbering, section format, and page format.

3. Cost Estimates

a. Arrange cost estimates according to major project divisions. Present costs within each major division according to the CSI broad-scope section number. Life-cycle cost is the basis of system evaluation. The standard life-cycle cost is based on system service life (or 20 years minimum) and use a 7.5-percent discount rate, unless the Yale University Project Manager provides a different rate.

b. Design for new and replacement mechanical systems and equipment must include a life-cycle cost analysis that includes the initial cost, cost of capital, inflation rate, energy cost, maintenance cost, salvage value, and space cost. The life-cycle cost must include all replacement costs for the full system service life. Consult with the Yale University Project Manager to obtain the applicable rates for use at Yale University.

4. Supporting Information

Provide Yale University with supporting information that clearly shows the basis for the design of each part of the project. Where applicable, supporting information must include the following, and may include additional information described elsewhere in these standards or requested by Yale University when individual equipment or installation conditions require special attention.

a. When calculations are performed by computer, include input values in the submittal, and indicate program title and version number. Calculations must highlight all assumptions made.

b. For renovation projects, submit copies of documentation generated during field investigations. Such documentation includes field notes, sketches, and photographs of all pertinent portions of the existing installation. Develop a list of all existing equipment to coordinate the new equipment numbers.

c. Provide heating and cooling load calculations based on Yale University design standards and the latest codes. Compare the results with the applicable energy requirements of the State Building Code.

d. Provide hydraulic calculations for fire protection piping.

e. Submit load calculations based on loads shown in panelboard and switchboard schedules. Provide breakdowns of power consumption per square foot for lighting, air conditioning, and other major categories of utilization, together with total consumption. Separate analyses may be required for various building areas. Compare the results with the applicable energy requirements of the State Building Code.

f. Submit harmonics calculations in accordance with standard IEEE 519. The calculations must indicate the basis for neutral conductor sizing and selection of transformer k rating.

g. Submit short-circuit calculations showing contributions from each source, the characteristics of each circuit element, and the short-circuit energy available at each bus. The calculations must indicate the selection criteria for conductors in addition to overcurrent devices.

h. Submit coordination analyses for all types of overcurrent devices in series. The equipment manufacturer will complete a short-circuit and coordination study.

i. Submit lighting calculations for each type of space in accordance with IES standards and based on the zonal cavity method for interior lighting and on manufacturers' isofootcandle curves for exterior lighting. The calculations must clearly indicate assumptions of reflectances, maintenance factors, and ballast factors and present the results in footcandles and in watts per square foot.

5. Design Intent

a. Basic commissioning includes the design intent documentation, one-line diagrams, and operating descriptions for full and part-load conditions to help communicate design intentions to current and future building operators. The description of the mechanical system and its intended operation and performance must include the following information, which must also be included on the drawings:

- Design intent
- Assumptions
- Noise criteria
- Facility occupation and utilization
- Basic system type
- Major components
- Interrelationship of components
- Capacity and sizing criteria
- Equipment selection and redundancy criteria
- Control strategies (The intended operation under all loads, changeover procedures, part-load operational strategies, design setpoints with permissible adjustments, operation of system components in life-safety modes, energy conservation procedures, and any other engineered operational mode of each system.)

b. Submit a design intent document for indoor air quality that includes:
   - Method of ventilation, occupancy times, and number of people
   - Method and equipment for fume hood exhaust systems
   - Chemicals proposed in tabs for use in fume hoods
   - Expected noise level in occupied spaces
   - Design temperature in the space
   - Design relative humidity (summer and winter)
   - Type of HVAC system and selection criteria
   - Kitchen hood exhaust methods
   - Air distribution zoning
   - Filter types and efficiency
   - Method of room pressurization for labs

c. Submit a design intent document for energy conservation methods that includes:
   - Methods of free cooling using outside an air economizer and condenser water economizer
   - Methods of heat recovery using runaround coils, Zduct, heat wheel, or other similar equipment.
   - Energy-saving methods for semester break in December and January

d. Submit a design intent document for heating of spaces using:
   - Perimeter radiation
   - Warm air
   - Panel units
   - Unit heaters

e. Submit a design intent document for equipment sizing criteria and calculations for chillers, boilers, VAV boxes, VVE boxes, VFDs, mixing boxes for existing dual duct systems, and other similar equipment.

f. Submit a design intent document for specific spaces, such as animal rooms, and for kitchen hood exhaust methods.

g. Submit a design intent document for air distribution zoning.

h. Submit a design intent document for motion sensors to prove occupancy.

i. Submit a design intent document for pump selections. Provide Yale University with the following documentation:
   - Total GPM complete with GPM by equipment type, such as air handlers, unit heaters, fan coil units, all coils, and fin tube radiation.
   - Certified pump curves to indicate that pumps are non-overloading in parallel or individual operation, and operate within 25 percent of the mid-point of the published maximum efficiency curve. Plot the pump and system operating point. Include the NPSH curve when applicable.
   - Electrical data: voltage, required horsepower, full-load amps, electric phases used.

6. Sequence of Operation

a. Submit a sequence of operation of the DDC system for all controlled equipment, including:
   - The position of failed equipment, including provisions for freeze protection, normally closed, and normally open
   - The method of maintaining minimum ventilation by code, for occupied spaces
   - The anticipated close off pressures for both supply and return, including differential pressure, for chilled water systems

b. Provide a separate sequence of operations for the occupied, unoccupied, and warm-up cycle for each season of the year.

c. Describe the life safety operating modes for:
   - Atrium systems
   - Smoke pressurization systems
   - Fire pumps
   - Smoke detectors and automatic shut-off of supply and return air fans
   - Smoke dampers and automatic shut-off of supply and return air fans

d. Provide a plan to integrate control of existing HVAC systems with new HVAC systems.

e. State whether pre-heat coils for 100% air make-up units are to be steam or glycol hot water.

f. Describe humidification methods and show psychometric calculations.

7. Control Points List

Important! Provide a points list with Yale university acronyms. Coordinate new numbers with existing equipment. Obtain approval for acronyms before starting drawings.

D. Mechanical Design Requirements

Design criteria and assumptions should include the following design conditions for each space:

- Indoor dry bulb temperature
- Indoor relative humidity
- Outdoor dry bulb temperature
- Outdoor wet bulb temperature
- Occupancy, hours, and degree of activity
- Lighting and miscellaneous power
- Ventilation – recirculation and outside air
- Internal loads
- Special loads
- R-values for roof, wall, glass, and other insulating materials
- Percentage of glass – fenestration
- Type of glass, including coatings and solar coefficient
- Building pressurization and infiltration
- Zone control
- Air changes
- Smoke control
- Air movement
- Control responses of the ATS
- Freeze protection of steam, hot water, and chilled water coils
- IAQ
- Noise

E. Electrical Design Requirements

Where wiring interfaces with equipment or systems of other divisions, clear distinction shall be made between work of division 16 and work of other divisions; Do not make references by subcontractor or trade.

1. Provide separate floor plans or removals and demolition, and for power, lighting, and fire alarm systems.
   a. Equipment locations for other systems, such as intrusion detection and telecommunications systems, may be included on power plans, unless the other systems are extensive enough to warrant separate floor plans.
   b. Include relevant building information, such as ceiling heights and slopes, exposed joists, beam and girder locations, and fan CFMs, on fire alarm system floor plans.
2. Provide one-line diagrams for power distribution systems.
   a. Indicate on the diagram the short-circuit energy available at each bus or tabulate it on the drawing.
   b. Indicate grounding methods and locations for all separately-derived systems. Where extensive or complex grounding arrangements are required (including ground-fault protection systems), provide separate grounding diagrams.
3. Provide riser diagrams for such systems as fire alarm, intrusion detection, and telecommunications. Include the locations of vertical chases.
4. Equipment schedules for feeders, switchboards, panelboards, and lighting fixtures must be in accordance with standard details shown in the relevant standards.
5. Provide design and engineering criteria, as well as space and ambient conditions. Specify the system under the designed intent to perform.

6. Calculate demands for the following loads:
   - Loads operating at 120 volts
   - Lighting loads
   - All other normal loads
   - Emergency loads, excluding fire pumps (include itemized list)
   - Fire pump, with horsepower rating
   - Standby loads (include itemized list)
   - Maximum coincident demand expected on the normal source and the alternate source
7. Where multiple buildings are fed from a load center, list the following information for each building:
   - The expected power factor prior to power factor improvement measures
   - Duty cycles for each category of equipment
   - Sizing calculations for switches over 100 amperes
   - Calculations for selection and sizing of all transformers, including connected load, future loads, harmonics, and temperature considerations
   - Calculations for sizing bus ducts
   - Lighting fixtures catalog cuts
   - Lighting calculations or isofootcandle layouts demonstrating that required illumination levels will be achieved throughout all egress routes

8. The building electrical service and distribution should be based on following criteria or conditions:
   - Service entrance configuration
   - Connected load estimate: receptacles, lighting, motors, special loads
   - Demand load estimate
   - Provision for future load growth
   - Level of redundancy or reliability requirement
   - Basis for equipment sizing: connected or demand load, load factor, non-linear load, future load growth, overload criteria
   - Automatic scheme and interlock
   - Over-current protection criteria and degree of selectivity at each voltage level
   - Required metering and accuracy
   - Provision for testing and maintenance
   - Grounding system requirement: safety, instrumentation, lightning protection
   - Special protection requirement: transient voltage surge suppression, under-voltage or loss of phase protection, EMI or RFI
9. The emergency power system should be based on following criteria or conditions:
   - Connected load estimate: receptacles, lighting, motors, special loads
   - Demand load estimate
   - Provision for future load growth
   - Motor starting capability
   - Non-linear loads
   - Transient performance, block load, and unload criteria
   - Generator auxiliary systems: starting, fuel supply and storage, cooling, combustion air supply, exhaust, sound attenuation, fire protection
   - Configuration and mode of operation
   - Required metering and accuracy
   - Provision for testing and maintenance
   - Over-current protection criteria and degree of selectivity
   - Provision for monitoring, supervisory and alarm
   - Interaction with other systems: fire protection, elevator, energy management, security, lighting control

10. The fire alarm system should be based on following criteria or conditions:
    - System configuration and equipment
    - Type of detection and signaling to be provided in each space
    - Type of system, initiating device circuit, and signaling circuit per NFPA 72
    - Standby power supply
    - Interaction with other systems: fire protection, elevator, HVAC, security, fire door and fire curtain, lighting control and egress lighting
    - Provision for signaling, monitoring, supervisory and alarm annunciation
11. The communication and paging system should be based on following criteria or conditions:
    - System configuration and equipment
    - Zone listing
    - Audibility criteria
    - Instrument type and functionality
    - Reliability and redundancy
    - Interaction with other systems: fire alarm, security
    - Power supply: UPS, emergency power, DC battery

End of Section

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Special Project Procedures

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

CONTENTS

A. Summary

This section includes design criteria for equipment location and installation, working in confined spaces, emergency power, and central building utility metering systems.

B. Designing Safe Mechanical and Support Spaces

1. General

The purpose of these design guidelines is to aid the design, consulting, and contracting community working on Yale University projects to design and build mechanical and support spaces that are inherently safe for construction, operation, and maintenance. By designing safe mechanical and support spaces, the designer can eliminate or minimize confined spaces or design confined spaces that are more easily and safely accessed. These guidelines focus on the design of safe mechanical and support spaces by avoiding the hazards associated with such spaces. Such hazards include:

- Inadequate dimensions, entries, and exits
- Toxic atmosphere or oxygen deficiency
- Moving parts
- Electrical shock hazard
- Heat and chemical hazards
- Structural hazards that can cause injury

- Combustible dust
- Irritant or corrosive agents
- Moisture or water
- Noise and vibration
- Surface residues making the floor unsafe for walking

2. Design Guidelines

a. Allocate sufficient space within the building footprint for utilities and for mechanical, electrical, telecommunications, and other equipment, including mechanical rooms, rather than designing such features as vaults, hatches, and tunnels outside of buildings.

b. Design mechanical rooms large enough for the intended equipment, with:
   - sufficient distances and clearances for each piece of equipment,
   - sufficient work area around the equipment,
   - sufficient space for removal of equipment components for repair and replacement, and
   - sufficient space for removal of the entire unit for replacement.

c. Design access doors, corridors, ventilation, lighting, and other mechanical room components to meet applicable code requirements while also designing safe working conditions. Requirements for safe working conditions must apply to both normal and emergency operating conditions.

d. Design entries, exits, ventilation, and other mechanical room components with consideration for the conditions inside the room, as well as conditions inside adjacent spaces.

e. Design mechanical rooms with the proper penetrations and seals for cable and piping entries to prevent the penetration of such things as water, moisture, fumes, gases, and heat.

f. Design appropriate doors, rather than hatches, for mechanical rooms and support spaces.

g. Lay out equipment in the mechanical rooms and support spaces for safe service and repair under normal and emergency operating conditions. Ensure that there are sufficient distances and clearances for each piece of equipment, sufficient work area around the equipment, space for removal of equipment components for repair and replacement, and removal of the entire unit for replacement.

h. Design mechanical rooms and support spaces with adequate lighting, ventilation, insulation, noise attenuation, drainage, flood alarms, means of communication, and other safety measures to ensure safe working conditions under normal and emergency operating conditions.

i. Locate cable splicing and other items that require periodic inspection and service within the building, rather than outside of the building in a confined space.

j. Locate utilities distribution systems equipment that require periodic inspection and service within the building rather than outside of the building in a confined space.

k. Provide adequate spacing of equipment, piping, and cables and a safe working environment for their installation, inspection, and service under normal and emergency working conditions. Provide coordination drawings in the design documentation; the coordination and layout of equipment in mechanical rooms and support spaces should not be left to the construction manager.

C. Designing Confined Spaces

1. General

a. Confined spaces can pose serious health and safety hazards to persons performing inspection, service, maintenance, or related activities. Use the following information about confined spaces in the building design, construction, and renovation process to eliminate such spaces or, where not feasible, to design confined spaces that are more easily and safely accessed. Also, follow OSHA standards.

b. OSHA's standard on confined spaces (29 CFR Part 1910.146) defines a confined space as one that meets all of the following criteria:
   - Large enough and so configured that it can be entered to perform work
   - Has a limited or restricted means of entry or exit
   - Is not designed for continuous employee occupancy

c. Some common examples of confined spaces include below ground electrical vaults that are accessed by ladder, various tanks and pits, boiler interiors, and crawlspaces. For more information, refer to applicable OSHA publications and the OSHA web site: http://www.osha-slc.gov/SLTC/confinedspaces/.

2. Types of Confined Spaces and Basic Design Options

The following paragraphs describe the major types of confined spaces, including the type of space, typical hazards, and the means for minimizing or eliminating the hazards. One of the most frequent safety issues associated with confined spaces involves entry and exit (access). Additionally, the materials introduced into confined spaces and the operations performed with them can create unsafe conditions by releasing toxic materials (for example, welding, cleaning, painting) or reducing oxygen levels below safe levels. Such hazards are possible within any confined space, as is the nearly ever-present danger of an oxygen-deficient environment.

a. Telecommunication or Electrical Distribution Vaults

(1) Telecommunication and electrical distribution vaults typically consist of a below-ground, poured-concrete vault, accessible by a grade-level access hatch. Depending upon inner depth, portable ladders or a fixed rung ladder are used to reach the base.

(2) Although telecommunication and electrical distribution vaults rarely contain hazardous processes (provided the electrical cabling is sheathed or is enclosed in conduits), their physical location below-grade carries the risk of oxygen deficiency, falls during entry or exiting, and water accumulation. Operations performed in, and materials introduced into, these spaces can also create unsafe conditions by releasing toxic materials (for example, welding, cleaning, painting) or by reducing the oxygen level below a safe level.

(3) Basic safety design options include:

- Incorporating new vaults as part of a building basement, providing a full-size door to eliminate the confined space (preferred).
- Ensuring an access or hatchway diameter of no less than 30" (36" or larger is preferred for equipment and materials transfer).
- Providing an OSHA-compliant fixed stairway or ladder with an extendable grab bar or rail.
- Grading the floor and including a small sump pit to collect any water seepage that accumulates within the space and permit easier pump-down before entry. The sump pit should be located away from the ladder base.

b. Electrical Transformer Vaults

(1) Electrical Transformer Vaults are very similar in structure to telecommunications or electrical distribution vaults, but with the added potential hazard from electricity during periodic manual interactions with switches.

(2) Basic safety design options include all those for telecommunications or electrical distribution vaults, plus:

- A minimum clearance of 36" from all breakers, switches, and other components
- Passive ventilation of space to avoid accumulations of ozone or an oxygen-deficient atmosphere
- Providing vaults with frequent need for access with permanent, moisture-protected lighting
- Placing transformers and switch gear away from access doors or hatches

c. *Steam Distribution Systems*

(1) Steam distribution systems include large horizontal and vertical pipe chases (some are tunnel sized), valve access vaults, and condensate return pits.

(2) The hazards associated with these steam distribution system components include all those for telecommunications or electrical distribution vaults, plus exposure to very high levels of heat and humidity and the potential for exposure to steam leaks and possible steam explosions.

(3) Basic safety design options include all those for telecommunications or electrical distribution vaults, plus:

- Maximizing clearances from all steam pipes and other obstructions, both to provide greater distance from hot surfaces and to reduce head and face injuries.
- Ventilating the space to reduce heat and humidity loads. For vaults, the preferred method is the use of a dual-pipe or duct system to induce convective airflows. For tunnels, provide outdoor access grilles or panels at regular tunnel intervals to enhance natural airflows through individual tunnel sections.
- Ensuring that all pipes that must be stepped over in order to reach a confined area have metal guards around the insulation, and/or steps and platforms.

d. *Power Plants*

(1) Power plants contain a large number and wide variety of confined spaces due to their complex and interconnected operational systems. Some examples of confined spaces in the power plants include:

- Boilers
- Turbines or generators
- Liquid storage and other types of tanks
- Water and cooling towers
- Numerous pits and recessed floor or grade channel ways
- Large ventilation system components (for example, ductwork, filter houses, plenums)

(2) The hazards in specific power plant confined spaces vary by system. However, access in many power plant spaces is difficult due to elevated heights and narrow entry or exit ways, and should be designed with ease of access and safe maintenance in mind.

e. Elevator Systems

(1) Building elevator systems consist of a vertical elevator shaft, a motor or service room, and a pit at the bottom of the elevator shaft.

(2) Hazards associated with elevator systems include:

- Elevator shaft: access hazards, physical hazards from moving cables and counterweights, fall hazards.
- Motor or service room (those located in rooftop penthouses or other locations without an ordinary door entry): physical hazards from the cable winding, potentially exposed mechanical components on the motor and gear shafting, and electricity, including an accumulation of ozone in poorly ventilated rooms.
- Pit: access hazards, oxygen deficiency, falling objects, and possible drowning from engulfment in accumulated water.

(3) Basic safety design options include:

- The installation of a lockable door, rather than a hatch to both the shaft and pit
- Fall protection attachment points for shaft work
- Passive or active ventilation of the motor or service room
- Fixed permanent lighting for the motor or service room
- Machine and equipment guarding where possible on exposed moving motor and gear or winding parts

f. Sump Pump and Sewage Ejector Pits

(1) Although the liquid materials to be pumped vary, sump pump and sewage ejector pits share many common features. Both consist of concrete or lined pits, often with a liquid holding tank and pump (either submersible or remote). These pits are generally located below-grade in a basement area or outdoors inside a vault. Access is typically made by either a metal grating cover, solid hatch, or manhole cover. Some of these systems possess a fixed ladder.

(2) Hazards include oxygen deficiency, the potential for accumulation of toxic vapors (including those from materials discharged to domestic waste lines), falls during entry or exit, and possible drowning from engulfment in liquid.

(3) Basic safety design options include:

- The installation of remote pumps, or pumps that can be easily retrieved without requiring pit entry (also requires means for pump retrieval or attachment of retrieval means)
- The installation of permanent fixed ladders
- A means of valving-off and locking-out water or wastewater inputs into the pit during entry
- Lockable access to prevent unauthorized entry

g. HVAC Systems

(1) Many larger HVAC systems contain remote supply air plenums, larger diameter ductwork, filter and coil “houses,” mechanical rooms, and related components that qualify as confined spaces. These remote areas are often elevated in height with restrictive means of access.

(2) The most common hazards of HVAC confined spaces are restricted access, vertical shafts and plenums or ducts, and mechanical and electrical energy sources.

(3) Basic safety design options include:

- Providing fall protection for elevated walkways (preferably railings)
- Guarding exposed mechanical elements (for example, belts and drive shafts)
- Installing adequately-sized drains for condensate collection pans and basins
- Providing adequate clearance around all moving parts, electrical transformers, high voltage switches, and other similarly hazardous systems
- Providing adequate access space and clearance space for repairs and movement of new or replacement equipment
- Providing fixed ladders or stairs (preferred) for air supply intake plenums and related building “moats”
- Providing filter rooms and mechanical rooms with permanent, moisture-protected lighting
- Installing true doors rather than hatches, where possible
- Lockable access to prevent unauthorized entry

h. Crawlspaces and Chases

(1) Although not generally identified as confined spaces, a variety of crawlspaces, pipe chases, ceiling plenums, and related areas require periodic entry for inspection and repair. Difficult access to these spaces, coupled with their general layout, can create significant confined space hazards.

(2) The majority of hazards associated with crawlspaces and chases pertain to restricted access, entrapment, and head and face injuries from obstructions and falls, either directly to the individuals entering these areas or indirectly by dropping tools or other objects. In certain cases (for example, some pipe chases), high-pressure steam can also be a hazard if piping is leaking or a valve is damaged.

(3) Basic safety design options include:

- Eliminating crawlspaces wherever possible. Where crawlspaces are necessary, maximize their cross-sectional area and minimize obstructions.
- Installing floor gratings in large vertical pipe chases at each entry point or grade.
- Installing permanent, fixed ladders in large building-wide pipe chases.
- Providing designated access hatches for above-ceiling MEP system components that will likely require regular service (for example, VAV mixing boxes).

i. Tanks and Vessels

(1) A wide variety of tanks and vessels are used for storage, collection, and distribution, including fuel tanks, boiler vessels, and wastewater neutralization tanks, as well as tanks used for the temporary retention of domestic water, chilled or cooling water, and those used in research applications (for example, liquid nitrogen bulk storage and the van de Graff accelerator at WNSL). The confined nature of these kinds of spaces is generally well understood by service and maintenance staff. Those tanks that are located below-ground (for example, many fuel tanks) have limited or no direct means of entry, except after partial excavation.

(2) The hazards associated with tanks and vessels include their material contents or residue, atmospheric hazards (oxygen deficiency, toxicity, flammable or explosive) and access (including falls upon entry or exit).

(3) Basic safety design options include:

- Boltable or lockable access to prevent unauthorized entry
- A means of removing the contents prior to entry
- Fixed ladder and railing access systems for elevated tanks requiring regular entry or inspection
- A means for remote assessment of contents level
- A means for valving-off and locking-out inputs into the tank or vessel during entry

j. Miscellaneous Areas

Several other areas and locations present access problems that can create confined space and related hazards, including tunnels, platforms, and some attic areas where fall hazards can exist because of inadequate or non-existent railings, the absence of a fixed ladder or stairway, or very low clearance within the space. These kinds of issues are best addressed by providing standard means of access (preferably stairs), incorporating hand and toe rail protections, and installing larger entry ways or doors instead of hatches.

3. Basic Design Guidance

a. The most effective means of reducing the hazards associated with a confined space (as well as the long-term operational and procedural requirements associated with these spaces) is to eliminate the confined space from the start. Depending upon the space, this can be accomplished by several means, including:

- incorporating the space as an element of a building,
- providing a true full-size door instead of a hatch or manhole for access, and
- installing a stair rather than a ladder.

b. Where these steps are not feasible, the following is a brief listing of good design practices that can significantly reduce the hazards associated with most confined spaces.

(1) Provide as-built drawings of all confined spaces, showing all penetrations and systems contained within them.

(2) Ensure space is sufficiently large to provide adequate clearances.

(3) Design the space to be linear in configuration, with a clear line of sight.

(4) Minimize obstructions and penetrations to provide clear and safe paths of travel.

(5) Adopt a standardized hinged and counterweighted cover in lieu of ordinary manhole covers or large grates.

(6) Ensure that access ways are sufficiently large to accommodate anticipated supplies and equipment transfers into and out of the space.

(7) Provide a means of fall protection, preferably through the use of railings and gratings.

(8) Provide a safe and easy means for collecting and removing accumulated water in below-grade vaults, using sloped flooring and small sump pits away from the ladder landing.

(9) Where possible, provide quality fixed ladders. Follow OSHA guidelines.

(10) Install moisture- or weather-protected fixed lighting in frequently-accessed spaces.

(11) Provide a means for passive or active ventilation for especially hot or humid locations and all other locations with anticipated atmospheric hazards.

(12) Provide an easily accessible means for locking or tagging out power supplies and liquid inputs to the space to prevent accidental engulfment, electrocution, or physical injury during entry.

4. Design Document Review and Approval

a. Yale University departments assigned to project reviews review all phases of the design documentation, giving special attention to safe design and the elimination of confined spaces.

b. If a confined space is unavoidable, the project manager must obtain approval of the design from the managers of the departments servicing the confined space —Yale University Facilities group and/or Telecommunications.

c. Submit the final design documentation to Yale University's Office of Environmental Health and Safety for review and approval to ensure the design of safe mechanical, support, and confined spaces.

D. Emergency Power

1. Usual Essential Plumbing System Power Requirements

a. Storm water pumping systems.

b. Sewage ejectors.

c. Laboratory waste lift station.

d. Booster water pumping systems.

2. Usual Essential Fire Protection System Power Requirements

a. Fire and jockey pumps and control panel.

b. Sprinkler system controls.

c. Smoke evacuation system.

3. Usual Essential HVAC System Power Requirements

a. Energy Management and Control System, each field cabinet (stand-alone control panel), the control air compressor and dryer, and any electric controls for systems on emergency power.

b. Laboratory hood exhaust fans and fume hood controllers.

c. Air handling supply and exhaust fans, and chilled water circulating pump and controls for servicing specialized HVAC equipment and systems.

d. Emergency power required to prevent crystallization in absorption water chillers during a power failure.

e. Central system heating equipment.

f. Ventilation equipment and controls for emergency generator rooms.

g. Refrigeration system and controls for food storage freezers.

4. Usual Essential Electrical System Power Requirements

a. Emergency lighting.

b. Fire alarm system.

c. Circuits for health care services and critical equipment support.

d. Security and emergency paging system.

e. Critical communication services.

5. System Design Considerations

a. Because of the odor take generator exhaust to the roof whenever possible.

b. Locate louvers to provide unobstructed air intake and exhaust. Size them per the manufacturer's recommendations.

c. Verify code and facility fuel requirements for an extended run time.

E. Equipment Installation

1. The contractor is responsible for notifying all sections or individuals identified by the project manager at least three days before the disruption of utilities.
2. The contractor must provide the Yale University Physical Plant Control Center with a 24-hour emergency telephone number.
3. During installation, the contractor must have personnel who are available for immediate response in case of emergency (for example, broken pipes or interrupted electricity).

F. Central Building Utilities Metering System

1. The Central Co-Generation Plant provides electricity, steam or condensate, and chilled water to the Yale University buildings. The Sterling Power Plant generates steam and chilled water for the Yale University School of Medicine and New Haven Hospital. Electricity is purchased from the local utility company, United Illuminating. The Yale University Facilities group manages the respective generation and distribution systems.
2. The objective of the Central Building Utilities Metering System (CBUMS) is to provide real-time monitoring, alarm reporting, on-line diagnostics, and report generation for billing, energy management, and engineering relevant to the utilities systems. CBUMS is an integral part of the Yale University real-time facilities network called Maxnet.
3. The CBUMS meters installed throughout the buildings communicate with their servers via serial communication and industry-standard communication drivers. The servers reside on the Campus Ethernet backbone, sharing information with other servers connected to Maxnet.

4. Engineers and managers within the Yale University Facilities group have direct access to all information residing on the Maxnet. Clients within or outside of the University can access the data available on the Maxnet by Netscape browser. Interested parties can look up the information via the internet.
5. For CBUMS utility metering connections, contact Yale University. See the Yale University website for the appropriate department.

End of Section

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Special Procedures for Historic Treatment

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

CONTENTS

A. Summary

This section contains general design guidelines associated with the treatment of historic buildings.

B. General Design Guidelines

1. The architect must review each project with Yale University for specific project conditions. Specific treatment is dependant on many factors, including building age, historic value, types of existing materials, and desired outcome.
2. Generally, the architect should refer to the National Park Service guidelines for preserving, rehabilitating, restoring and reconstructing historic buildings, which can be found at:

   http://www2.cr.nps.gov/tps/standguide/index.htm
3. The National Park Service guidelines seek to minimize the impact of updates made to historic buildings. The publication contains guidelines for exterior and interior treatment of historic buildings, including such elements as stone, masonry, windows, and interior finishes. These guidelines also provide helpful definitions for preservation, rehabilitation, restoration, and reconstruction.

End of Section

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Sustainable Design Requirements

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Change History

Date	Description of Change	Pages / Sections Modified	Change Approver Initials
3/11/11	Modified 4th bullet point to indicate all projects shall incorporate metered building energy consumption and diagnostic tools to evaluate system operations.	68 – Section 01352, #4a (Special Requirements), LEED NC	GC
3/11/11	Added 6th bullet point to indicate all projects shall incorporate metered project area energy consumption and diagnostic tools to evaluate system operations.	70 – Section 01352, #4a (Special Requirements), LEED CI	GC
5/12/11	Added "Small Scope Sustainability Checklist" section (#3).	77 – Section 01352 (Small Scope Projects)	GC
9/6/11	Modified formatting of the following spreadsheet: "Small Scope Projects Product List"	76 – Section 01352 (Small Scope Projects)	GC
9/09/11	Modified two spreadsheets: "Sustainable Design Matrix" and "Small Scope Sustainability Checklist"	75 – Section 01352 (Limited Scope Projects, #5) 77 – Section 01352 (Small Scope Projects, #3)	GC
2/1/12	Modified entire section, modified Life Cycle Cost spreadsheet link, and added new link of "Yale Weightings of Desirable Sustainable Attributes"	71 – Section 01352, #7 (Life Cycle Cost and Life Cycle Assessment)	GC
2/1/12	Modified entire section	72 – Section 01352, #8 (Sustainability Workshops)	GC
3/28/12	Added items 5 and 6 – Salvageable Building Components and Salvageable Furniture and Equipment	76 – Section 01352	GC
3/28/12	Added items 3 and 4 – Salvageable Building Components and Salvageable Furniture and Equipment	78 – Section 01352	GC
3/28/12	Sustainable Products Lists and instructions replaced with 2012 versions	77 – Section 01352, D	GC
12/4/12	Added links to Life Cycle Cost calculators for Central/Medical and West Campuses.	71 – Section 01352, #7 (Life Cycle Cost and Life Cycle Assessment)	GC
12/4/12	Added link to Yale weightings of desired sustainable attributes	71 – Section 01352, #7 (Life Cycle Cost)	GC
6/7/13	Added "Archive Sustainability Documents" as part of Comprehensive Scope Projects	73 – Section 01352, #10	GC
6/7/13	Added "Archive Sustainability Documents" as part of Limited Scope Projects	77 – Section 01352, #10	GC
6/7/13	Added "Archive Sustainability Documents" as part of Small Scope Projects	79 – Section 01352, #6	GC
1/21/14	Added reference to "Yale University, A Framework for Campus Planning, Sustainability Supplement"	68 – Section 01352, Summary 78 – Section 01352, Sustainable Design Matrix 80 – Section 01352, Small Scope Sustainability Checklist	GC
1/21/14	Added LEED NC credit requirements – Storm Water Design, Quality Control and Water Efficient Landscaping	69 – Section 01352, Special Requirements	GC

A. Summary

Sustainable design seeks a balance between the environment, economics, occupant comfort and human health considerations. Sustainably-designed buildings aim to lessen their impact on our environment by using energy and environmental resources efficiently while providing for the present and future needs of Yale University. Yale University is committed to the incorporation of sustainable design practices in the design of construction of all size projects on campus. This section describes the goals, strategy and procedures for providing and meeting sustainable design requirements for projects designated by Yale Facilities as **Comprehensive, Limited or Small Scope** projects. Note: Each project regardless of scope classification shall follow the required reference document "Yale University, A Framework for Campus Planning, Sustainability Supplement".

B. Comprehensive Scope Projects

1. System Design and Performance Requirements

a. Yale University has adopted the Leadership in Energy and Environmental Design (LEED-NC or LEED-CI) rating system, administered by the US Green Building Council (USGBC) as the method to help achieve a commitment to sustainable design.

b. All comprehensive new construction and renovation project designs must meet LEED "Gold" status or higher. Registration with USGBC may occur at any time in the design process, but must be transitioned to the version in effect at the end of the CD phase.

c. Yale University has outlined several "points," listed under **Special Requirements**, below as mandatory areas of compliance.

2. Submittals

Submit the LEED checklist in the pre-design phase, DD phase and 50% CD phase with those points proposed for project inclusion. Score all designs at each design phase for Yale University's information.

3. Materials & Product Standards

Designers shall provide product and materials specifications that preferentially select resource, energy saving and health building materials and design features.

4. Special Requirements

All sustainable design alternatives shall be presented to the University for their consideration with analyses as described herein. Designers are encouraged to reduce the energy loads, apply the most efficient systems, and look for synergies wherein all systems, building construction and components will work together to produce overall functionality and environmental performance.

a. Special Requirements

(1) Required Credits (Note: This currently references credits in LEED-NC v3 and LEED-CI v3. These references will be updated as new versions are published and adopted by Yale).

The following LEED NC and LEED CI points are required credits:

(a) Sustainable Sites

LEED NC: Must incorporate SS Credit 6.1, Storm Water Management. (LEED CI: Not Applicable)

LEED NC: Must incorporate SS Credit 6.2, Storm Water Design – Quality Control (LEED CI: Not Applicable)

(b) Water Efficiency

LEED NC: Must incorporate WE Credit 1: Water Efficient Landscaping.

(c) Energy and Atmosphere

LEED NC: Must incorporate EA Credit 1, Optimize Energy Performance, using detailed energy modeling.

- Lab building or other building with 100% OA requirements: 12 pts (34% new, 30% existing)
- All other building types: 7pts (24% new, 20% existing)
- Must incorporate EA Credit 3, Enhanced Commissioning.

- Although EA Credit 5 Measurement & Verification is not required, all projects shall incorporate metered building energy consumption and diagnostic tools to evaluate system operations. Yale Utilities & Engineering shall indicate criteria for Measurement & Verification for each project.

LEED CI:

- Must incorporate EA Credit 1.1 Lighting Power (3 pts). Reduce installed lighting power density to 25% below ANSI/ASHRAE/IESNA Standard 90.1-2007 as a minimum.
- Must incorporate EA Credit 1.2 Lighting Controls (2 pts). Provide daylight controls for regularly occupied day lit spaces within 15 feet of windows and under skylights. Install daylight controls for at least 50% of the connected lighting load –or- install occupancy sensors for at least 75% of the connected lighting load.
- Must incorporate EA c1.3 Option 1Appropriate Zoning/Controls (5 pts) and EAc1.3 Option 2 Performance Modeling (5 pts). For Option 1, zone each solar exposure and interior spaces separately, and provide active controls capable of sensing space use and modulating the HVAC systems in response to space demands of private offices and special occupancies. For Option 2, demonstrate that HVAC system performance criteria used for tenant space are 15% better than a system that is in minimum compliance with ANSI/ASHRAE/IESNA Standard 90.1-2007 using a whole building energy simulation. Note: Chilled water and steam shall be held cost neutral in energy simulations in accordance with the "Required Treatment of District Thermal Energy in LEED NC v2.2."

In the case where a project does not have dedicated base building infrastructure, must incorporate EAc1.3 Option 1 Appropriate Zoning/Controls (5 pts) and EAc1.3 Option 1 Equipment Efficiency (5 pts). Zone each solar exposure and interior spaces separately, and provide active controls capable of sensing space use and modulating the HVAC systems in response to space demands of private offices and special occupancies, and also demonstrate that HVAC systems comply with the efficiency requirements outlined in the Advanced Buildings Core Performance Guide Sections, 1.4, 2.9, and 3.10 as applicable to project scope.

- Must incorporate EA Credit 1.4 (4 pts) Equipment & Appliances 90% (by rated power) of ENERGY STAR eligible equipment and appliances shall be qualified by EPA’s ENERGY STAR program.
- Must incorporate EA Credit 2 Enhanced Commissioning (5 pts).
- Although EA Credit 3 Measurement & Verification is not required, all projects shall incorporate metered project area energy consumption and diagnostic tools to evaluate system operations. Yale Utilities & Engineering shall specify criteria for Measurement & Verification for each project.

(d) Materials and Resources

LEED-NC and LEED-CI

- Must incorporate MR Credit 2, Construction Waste Management; divert a minimum 90% of construction waste from landfills.

5. Salvageable Building Components

Design Consultant, with review by Facilities Project Manager and Planning Office to identify salvageable building components and determine their reuse by Yale or qualified salvage vendor.

6. Salvageable Furniture and Equipment

Facilities Project Manager and TR&S to evaluate existing furniture and equipment for potential storage and re-use on other projects

7. Life-Cycle Cost and Life Cycle Assessment

a. Life Cycle Cost (LCC) evaluates the total lifetime cost of alternative building systems or construction options. Instead of focusing on the first cost, it incorporates the potential savings in energy and water, as well as ongoing costs of maintenance and service. It also recognizes that future dollars are not equivalent to present dollars, and converts future cash flows to present value for comparison.

(1) For all major sustainable design alternatives that have quantifiable economic impact over time (e.g. reduced cost for maintenance, energy or water use). Use Yale Life Cycle Cost calculator (found here for Central and Medical campuses, and here for West Campus). The spreadsheet incorporates:

(a) A GHG analysis that enumerates emission reducing measures with quantified MTCO2 avoidance and cost, and

(b) An analysis that calculates total life-cycle costs, including design, construction, capital, operational, commissioning costs.

b. Life Cycle Assessment (LCA) is a method of evaluating sustainable attributes and environmental impacts of construction materials over the lifetime of the building. Published LCA reports should be referenced for alternative products, assemblies and systems to assist in selections. Sustainable attributes of specific interest to Yale should be emphasized in these selections, and the referenced LCAs submitted to Yale. Yale weightings of desired sustainable attributes can be found here.

8. Sustainability Workshops

a. Eco- Charrette occurs in the first weeks after a project's kick off meeting with update meetings every phase thereafter, incorporating full team participation including:

(1) Yale representatives from multiple groups including Planning and/or Project Management, Utilities & Engineering, Facilities Operations, Office of Sustainability, Waste Management/Recycling, Custodial, Buildings and Grounds Maintenance
(2) Consultants including the Architect, Sustainability Engineer, MEP Engineer, Civil Engineer, Geotechnical Engineer, Landscape Architect, Structural Engineer, Lighting Consultants, Waste Management Consultant, Cost Estimator, Construction Manager

b. Topics to include but not limited to:

(1) A Framework for Campus Planning, Sustainability Supplement: Project team shall review "A Framework for Campus Planning, Sustainability Supplement" and consider all applicable recommendations for integration into proposed project.
(2) Life Cycle Cost (LCC) and Life Cycle Assessment (LCA): for each of the topics addressed, determine a preliminary list of design alternatives that might require Life Cycle Cost and /or a Life Cycle Assessment.
(3) Site (utilities, building massing, landscape, hydrology)
(4) Water (opportunities for reuse, water conserving landscape design, storm water runoff mitigation using green and/or grey infrastructure)
(5) Energy (interaction with central plant, building facades, building systems, LEED performance requirements)
(6) Materials (opportunities for reuse of existing materials for building and landscape, demolition waste management)

(7) Indoor Environment (daylight views, operable windows, environmentally preferable materials, HVAC systems options)

9. Sustainability Resource Group

The Sustainability Resource Group (SRG) will serve as an advisory body for Comprehensive Scope Projects providing input and guidance as needed on projects' sustainable design attributes. Project team (or Yale Planner) will meet with the Sustainability Resource Group after the first Eco Charrette to present proposed sustainable design strategies including the team's response to the recommendations in "A Framework for Campus Planning, Sustainability Supplement". The integration of recommendations into each project will be tracked on the Sustainability Supplement Recommendations Checklist, which can be found here. The checklist is a tool to assess the depth and range of sustainable attributes that are being integrated into each project.

10. Archive Sustainability Documents

After LEED certification has been awarded, provide a compilation of all LEED documentation that was submitted to USGBC on-line plus all supporting analyses in the form of a bookmarked PDF file. Provide the following:

a. LEED Submittal File: The full LEED documentation that was submitted to the USGBC for the project.

b. LEED Final Report: The final report from USGBC that states each credit and describes what was earned and the final rating achieved with commentary from the USGBC reviewer regarding the design team responses.

c. Energy Modeling Reports: Energy Modeling Reports that were prepared to analyze energy strategies for the project.

d. Additional Supplements: Additional information, reports, studies etc. that provide insight into why decisions were made.

C. Limited Scope Projects

No LEED certification is required but the following sustainable attributes are required if the category is applicable. In addition, and depending on the type of project, life cycle costing must be used for comparative analysis for all measures. (Note: This currently references credits in LEED-NC v3 and LEED-CI v3. These references will be updated as new versions are adopted by Yale.

1. Energy and Atmosphere

Optimize energy performance (e.g. –and not limited to- use of occupancy sensors, light fixture and lamp selections, controllability systems, HVAC system zoned and controlled for low energy consumption, use of energy star equipment, day lighting, thermal comfort, building insulation and reduced heat island effect roofing, etc.)

a. Lighting:

(1) LEED CI EA Credit 1.1: Optimize Energy Performance, Lighting, reduce lighting power density to 25% below the standard)

(2) LEED CI EA Credit 1.2: Optimize Energy Performance; lighting controls

b. HVAC:

(1) LEED CI EA Credit 1.3: Optimize Energy Performance, HVAC

(2) LEED CI EA Credit 2: Enhanced Commissioning (only if totally replacing HVAC system)

(3) LEED NC EA Credit 4, Enhanced Refrigerant Management, if replacing or installing a chiller

(4) Include Metering to enable monitoring of systems performance (where possible connecting to existing DDC)

c. Plug Load:

(1) LEED CI EA Credit 1.4: Optimize Energy Performance, Equipment and Appliances (use energy star rated appliance)

d. Building Envelope:

(1) LEED NC SS Credit 7.2 Heat Island Effect: Roof

2. Materials and Resources

Specify high recycled content, low emitting materials, high content of rapidly renewable materials, use of regional materials (e.g. when specifying carpet, floor tiles, ceiling tiles, casework etc.).

a. Material Specifications:

(1) LEED CI MR Credit 4: Recycled content, 10%

(2) LEED CI MR Credit 5: Regional Materials, 20% Manufactured Regionally

(3) LEED CI MR Credit 6: Rapidly Renewable Materials

(4) LEED CI MR Credit 7: Certified Wood

(5) LEED CI IEQ Credit 4.1: Low Emitting Materials, Adhesives & Sealants

(6) LEED CI IEQ Credit 4.2: Low Emitting Materials, Paints and Coatings

(7) LEED CI IEQ Credit 4.3 Low Emitting Materials, Flooring Systems

(8) LEED CI IEQ Credit 4.4 Low Emitting Materials, Composite Wood and Agrifiber Products

(9) LEED CI MR Prerequisite 1: Storage and Collection of Recyclables

3. Water Use Reduction

Use e.g. dual flush toilets, water saver faucets, low flow lavatories, and where applicable reduce storm water runoff, reduce heat islands, and limit potable water irrigation.

a. Plumbing Fixtures:

(1) LEED CI WE Credit 1 Water Use Reduction, 30%

b. Landscape and Storm Water:

(1) LEED NC SS Credit 6.1 Storm Water Design Quantity Control

(2) LEED NC SS Credit 6.2 Storm Water Design Quality Control

(3) LEED NC SS Credit 7.1 Heat Island Effect, Non Roof

(4) LEED NC WE Credit 1 Water Efficient Landscaping, Reduce by 50%

4. Construction Methods

The following construction methods must be followed where applicable:

a. Construction and Demolition Debris:

(1) LEED CI MR Credit 2: Divert 75% of construction waste from landfill

b. Salvageable Building Components:

(1) Design Consultant, with review by Facilities Project Manager and Planning Office to identify salvageable building components and determine their reuse by Yale or qualified salvage vendor.

c. Salvageable Furniture and Equipment:

(1) Facilities Project Manager and TR&S to evaluate existing Furniture and Equipment for potential storage and reuse on other projects.

d. Air Quality:

(1) LEED CI IEQ Credit 3.1 Construction IAQ Management Plan, during Construction

(2) LEED CI IEQ Credit 3.2 Construction IAQ Management Plan, before Occupancy

e. Construction Activity Pollution Prevention

(1) LEED NC SS Prerequisite 1: Construction Activity Pollution Prevention

5. Salvageable Building Components

Design Consultant, with review by Facilities Project Manager and Planning Office to identify salvageable building components and determine their reuse by Yale or qualified salvage vendor.

6. Salvageable Furniture and Equipment

Facilities Project Manager and TR&S to evaluate existing furniture and equipment for potential storage and re-use on other projects.

7. Sustainable Design Matrix

Sustainable goals will be considered throughout the design process and will be tracked on the Sustainable Design Matrix (a modified LEED scorecard) which can be found here. The matrix is the means to measure the level of compliance with the Limited Scope Project Standard. If a project is out of compliance, an explanation is required in the Remarks column of the Matrix with attachments submitted as backup as needed. The Design Team will submit the Sustainable Design Matrix at the mid-point of Schematic Design and at the end of all design phases, to the Yale Project Manager for review and signoff. Sustainable Design Matrix shall reflect the applicable recommendations considered by the Design Team from "A Framework for Campus Planning, Sustainability Supplement".

8. Sustainability Resource Group

The Sustainability Resource Group (SRG) will serve as an advisory body for Limited Scope Projects. The SRG will provide input and guidance as needed on projects' sustainable design attributes. The Project Manager will use the Sustainable Design Matrix to communicate the sustainable features of the project to the SRG at the intervals noted above. The SRG will respond with comments, questions or suggestions. The SRG may also request a meeting with the project team for clarification.

9. Verification

Constructor is required to sign project Sustainability Matrix attesting that the provisions in the matrix have been provided as per the Contract Documents.

10. Archive Sustainability Documents

After project is complete, submit a copy of the updated and final Sustainable Design Matrix which was used throughout the design and construction process to track sustainable attributes of the project, (see C. 7 above).

D. Small Scope Projects

No LEED certification is required. Sustainable products and construction methods must be followed as per the Yale Sustainable Products List and the Construction Methods listed below. Substitutions may be made if approved by Yale Project Manager with products or methods that achieve the same or greater sustainable attributes. The Sustainable Products List with instructions on how to use it can be found here. A simple listing of products for easy reference can be found here.

1. Yale Sustainable Products List

The Yale Sustainable Products List provides information on approved products typically used on small scope projects. The Yale Sustainable Products List will be updated regularly.

2. Construction Methods

The following construction methods must be followed where applicable:

a. Construction and Demolition Debris:

(1) LEED CI MR Credit 2: Divert 75% of construction waste from landfill

b. Salvageable Building Components, Furniture and Equipment:

(1) Per project requirements if needed, similar to requirements for Limited Scope Projects

c. Air Quality

(1) LEED CI IEQ Credit 3.1 Construction IAQ Management Plan during Construction

(2) LEED CI IEQ Credit 3.2 Construction IAQ Management Plan, before Occupancy

d. Construction Activity Pollution Prevention:

(1) LEED NC SS Prerequisite 1: Construction Activity Pollution Prevention

3. Salvageable Building Components

Design Consultant, with review by Facilities Project Manager and Planning Office to identify salvageable building components and determine their reuse by Yale or qualified salvage vendor.

4. Salvageable Furniture and Equipment

Facilities Project Manager and TR&S to evaluate existing furniture and equipment for potential storage and re-use on other projects

5. Small Scope Sustainability Checklist

Sustainable design and construction goals will be considered throughout the design process and be tracked on the Small Scope Sustainability Checklist which can be found here. Design Team shall submit the Checklist to the Yale Project Manager at the end of the CD Phase indicating the products, systems and material specified that contribute to a sustainable project outcome. The Construction Manger shall submit the Checklist at construction completion with close out documents verifying the installation of specified products, systems and materials and use of required construction methods. The Sustainability Checklist shall reflect the applicable recommendations considered by the Design Team from "A Framework for Campus Planning, Sustainability Supplement". As needed and indicated by Directors, Project Managers and Planners will review the Small Scope Sustainability Checklist with the Sustainability Resource Group for input and guidance.

6. Archive Sustainability Documents

After project is complete, submit a copy of the updated and final Small Scope Sustainability Check List which was used throughout the design and construction process to track sustainable attributes of the project, (see D. 5 above).

End of Section

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References (Non-Regulatory)

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CONTENTS

A. Information Available to Designers

1. Central Campus Floor Numbering Standards
2. Central Campus Room Numbering Standards
3. Request for Extension of Utilities
4. Yale Accessibility Guidelines
5. Yale CAD Standards
6. Yale Security Standards
7. Yale University Electrical Acronyms
8. Yale Standard Detail 16000-1, Electrical Plans Standard Symbols
9. Yale Standard Detail 16000-2, Electrical Diagrams Standard Symbols
10. Yale Electrical Distribution Master Plan
11. Yale University Exterior Lighting Manual
12. Yale University Plant Engineering Department website: http://www.facilities.yale.edu/Work/Work.asp

B. General Regulatory and Directive Standards

1. Accessible Design Handbook (1991)
2. ADA Compliance Guide (1991) (Contains Minimum Guidelines and Requirements for Accessible Design, 1982, from Federal Register)
3. American Society of Mechanical Engineers (ASME)
4. ANSI/ASHRAE/IESNA, Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings
5. American National Standards Institute (ANSI)
6. American Society for Testing and Materials (ASTM)
7. Environmental Protection Agency (EPA)
8. Factory Mutual (FM)
9. National Electric Manufacturers Association (NEMA)
10. National Fire Protection Association (NFPA)
11. NFPA, Life Safety Code 101 with Connecticut Supplement
12. Occupational Safety and Health Administration (OSHA)
13. Practical Guide to Seismic Restraint (ASHRAE)
14. Underwriters Laboratories (UL)

C. Site Construction

1. Water Distribution

a. ANSI A21.4

b. ANSI A21.10

c. ANSI A21.11

d. ANSI A21.51

e. ASTM D1556

f. AWWA C-205

g. AWWA C-600

2. Chilled Water Distribution

a. ASME

b. AWWA

c. ASTM A53

d. ASTM D1556

3. Steam Distribution

a. ANSI B31.1

b. ASME Section IX

c. ASTM A53 or A106

d. ASME B16.5

e. ASTM D1556

4. Storm Sewerage Systems

a. AASHTO M294

b. ASTM A48

c. ASTM C76

d. ASTM D1556

e. ASTM D3034

5. Sanitary Sewerage Systems

a. ASTM A48

b. ASTM D3034

c. ASTM D1556

D. Architectural Regulatory and Directive Standards

1. Masonry

a. ASTM C67—Methods of Sampling and Testing Brick and Structural Clay Tile

b. ASTM A82—Cold-Drawn Steel Wire for Concrete Reinforcement

c. ASTM A153—Zinc Coating (Hot-Dip) on Iron and Steel Hardware

d. ASTM C90—Hollow Load-Bearing Concrete Masonry Units

e. ASTM C144—Aggregate for Masonry Mortar

f. ASTM C150—Portland Cement

g. ASTM C207—Hydrated Lime for Masonry Purposes

h. ASTM C216—Facing Brick

i. ASTM C270—Mortar for Unit Masonry

j. ASTM C476—Grout for Reinforced and Non-Reinforced Masonry

k. ASTM C744—Prefaced Concrete and Calcium Silicate Masonry Units

l. ASTM E119—Fire Tests of Building Construction and Materials

2. Woods and Plastics

a. AWI—Architectural Woodwork Institute Quality Standards and Guide Specifications

b. NWMA—National Wood Manufacturers Association

c. PS 20—American Softwood Lumber Standard

d. ANSI A156.9—American National Standard for Cabinet Hardware

e. NEMA LD3—High Pressure Decorative Laminates

3. Thermal and Moisture Protection

a. ASTM C516—Vermiculite Loose Fill Insulation

b. ASTM C578—Preformed, Cellular Polystyrene Thermal Insulation

c. ASTM E84—Surface Burning Characteristics of Building Materials

d. ASTM C764—Mineral Fiber Loose Fill Insulation

e. FS HH-558—Insulation, Board, Blanket, Felt, Sleeving (Pipe and Tube Coverings) and Pipe Cover Insulation

f. ASTM E605—Test Method for Thickness and Density of Sprayed Fire-Resistive Materials Applied to Structural Members

g. ASTM E736—Test Method for Cohesion/Adhesion of Sprayed Fire-Resistive Materials Applied to Structural Members

h. ASTM E759—Test Method for Effect of Deflection on Sprayed Fire-Resistive Materials Applied to Structural Members

i. ASTM E760—Test Method for Effect of Impact on Bonding of Sprayed Fire-Resistive Material Applied to Structural Members

j. ASTM E859—Test Method for Air Erosion of Sprayed Fire-Resistive Materials Applied To Structural Members

k. ASTM E937—Test Method for Corrosion of Steel by Sprayed Fire Resistive Material Applied to Structural Members

l. ASTM E119—Method for Fire Tests of Building Construction and Materials

m. ASTM E 814—Fire Tests of Through-Penetration Fire Stops

n. UL 723—Test for Surface Burning Characteristics of Building Materials

o. UL 1479—Fire Tests of Through-Penetration Firestops

p. ASTM A361—Sheet Steel, Zinc-Coated (Galvanized) by the Hot-Dip Process for Roofing and Siding

q. ASTM D225—Asphalt Shingles Surfaced with Mineral Granules

r. ASTM D226—Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing

s. ASTM D2822—Asphalt Roof Cement

t. ASTM D3018—Class A Asphalt Shingles Surfaced with Mineral Granules

v. ASTM D3462—Asphalt Shingles Made From Glass Felt and Surfaced with Mineral Granules

w. ASTM D4586—Asphalt Roof Cement, Asbestos-Free

x. ASTM C728—Perlite Thermal Insulation Board

y. ASTM D41—Asphalt Primer Used in Roofing, Dampproofing, and Waterproofing

z. ASTM D312—Asphalt Used in Roofing

aa. ASTM D1863—Mineral Aggregate Used on Built-Up Roofs

ab. ASTM D2178—Asphalt Glass Felt Used in Roofing and Waterproofing

ac. ASTM D2626—Asphalt Saturated & Coated Organic Felt Base Sheet used in Roofing

ad. FS-HH-I-529—Insulation Board, Thermal (Mineral Aggregate)

ae. FS-HH-I-1972—Insulation Board, Thermal-Faced, Polyurethane or Polyisocyanurate

af. NRCA—The NRCA Roofing and Waterproofing Manual

ag. PIMA—Technical Bulletin 281-1, Conditioning Procedures

ah. ASTM D412—Rubber Properties in Tension

ai. ASTM D4637—Vulcanized Rubber Sheet used in Single Ply Roof Membrane

aj. ASTM D746—Brittleness Temperature of Plastics and Elastomers by Impact

ak. FM Approval Guide—Equipment, Materials, Services for Conservation of Property

al. FM Loss Prevention Data 1-28—Insulated Steel Deck

am. FM Loss Prevention Data 1-49—Perimeter Flashing

an. ASTM D746—Brittleness Temperatures of Plastics and Elastomers by Impact

ao. FM Approval Guide—Equipment, Materials, Services for Conservation of Property ap. ASTM C177—Test Method for Steady-State Thermal Transmission Properties by Means of the Guarded Hot Plate

aq. ASTM A526-90—Spec for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, Commercial Quality

ar. ASTM D226-89—Spec for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing

as. SMACNA—Architectural Sheet Metal Manual

at. ASTM B32—Solder Metal

au. ASTM A653-96—Spec for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

av. ASTM B209-93—Spec for Aluminum and Aluminum: Alloy Sheet and Plate

aw. ASTM B209-93—Spec for Aluminum and Aluminum: Alloy Sheet and Plate

ax. ASTM C790—Recommended Practices for Use of Latex Sealing Compounds

ay. ASTM C804—Recommended Practice for Use of Solvent-Release Type Sealants

az. ASTM C834—Latex Sealing Compounds

ba. ASTM C920—Elastomeric Sealants

bb. ASTM C1193—Standard Guide for Use of Joint Sealants

4. Doors and Windows

a. ANSI A224.1—Test Procedure and Acceptance Procedure for Prime Painted Steel Surfaces

b. ASTM A366—Steel Carbon, Cold-Rolled Sheet, Commercial Quality

c. ASTM A653—Spec for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

d. ASTM E152—Methods of Fire Tests of Door Assemblies

e. DHI (Door Hardware Institute)—The Installation of Commercial Steel Doors and Steel Frames, Insulated Steel Doors in Wood Frames and Builder's Hardware

f. SDI-100—Standard Steel Doors and Frames

g. SDI-105—Recommended Erection Instructions for Steel Frames

h. UBC 702 (1997)—Standard Methods of Testing Positive Pressure Fire Door Assemblies

i. UL 10B—Standard for Safety for Fire Tests of Door Assemblies

j. UL 10C—Standard for Positive Pressure Fire Tests of Door Assemblies

k. AWI—Quality Standards of Architectural Woodwork Institute

l. ITS (Warnock Hersey) —Certification Listings for Fire Doors

m. NFPA 80—Fire Doors and Windows

n. NFPA 252—Standard Methods of Fire Tests for Door Assemblies

o. FSC—Forest Stewardship Council guidelines for environmentally certified wood doors

p. ANSI A115 Series—American National Standards Institute: Door and Frame Preparation

q. ANSI A156 Series—American National Standards Institute: Specific hardware items

r. BHMA—Builder's Hardware Manufacturer's Association: Recommended Locations for Builder's Hardware

s. NFPA 80—National Fire Protection Association; Standard for Fire Doors and Windows

t. ANSI Z97.1—Safety Performance Specifications and Methods of Test for Safety Glazing Material Used in Buildings

u. ASTM C1036—Specification for Flat Glass

v. ASTM C1048—Specification for Heat Treated Flat Glass-Kind HS, Kind FT Coated and Uncoated Glass

w. ASTM E773—Test Method for Seal Durability of Sealed Insulating Glass Units

x. ASTM E774—Specification for Sealed Insulating Glass Units

y. CPSC 16CFR-1201—Consumer Product Safety Commission, Safety Standard for Architectural Glazing Materials

z. FS DD-M-411—Mirrors, Plate Glass, Framed and Unframed

aa. Flat Glass Marketing Association (FGMA) Glazing Manual

ab. Insulated Glass Certification Council (IGCC)

5. Finishes

a. ASTM D2047—Static Coefficient of Friction of Polish-Coated Floor Surfaces

b. ASTM D16—Definitions of Terms Relating to Paint, Varnish, Lacquer, and Related Products

c. ASTM D4442—Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Base Materials

d. PDCA—Architectural Specifications Manual; Painting and Decorating Contractors of America

e. SSPC—Steel Structures Painting Manual; Steel Structures Painting Council

6. Specialties (Toilet Accessories, Toilet Partitions)

a. ASTM A167—Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

7. Equipment

a. ASTM A240—Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

b. ASTM A366—Steel, Sheet, Carbon, Cold-Rolled, Commercial Quality

c. ASTM A167—Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

d. ASTM E84—Test Method for Surface Burning Characteristics of Building Materials

8. Furnishings—None

9. Special Systems—None

10. Conveying Systems

a. ANSI/ASME A17.1—Elevators, Escalators, and Moving Walks

b. NSI/ANSI/ASME A17.2—Inspectors' Manual for Elevators and Escalators

c. AASME A17.3—Safety Code for Existing Elevators and Escalators

d. ANSI A117.1—Specifications for Making Buildings and Facilities Accessible to and Usable by Physically Handicapped People

e. ADAAG—Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities

E. Mechanical Regulatory and Directive Standards

1. General Design References

a. AABC National Standards

b. Air Conditioning and Refrigeration Institute (ARI) standards

c. American Gas Association (AGA)

d. American Society of Heating, Ventilating and Air Conditioning Engineers (ASHRAE) Handbook:

- Applications
- Equipment
- Fundamentals
- Systems and Equipment

e. ASHRAE—A Practical Guide to Noise and Vibration Control for HVAC Systems, Schaffer, Mark E.

f. ASHRAE Green Guide

g. ASHRAE Humidification and Dehumidification Controls Strategies

h. ASHRAE Humidity Control Design Guide for Commercial and Institutional Buildings

i. ASHRAE HVAC Design Manual for Hospital and Clinics

j. ASHRAE Standard 15, Safety Code for Mechanical Refrigeration

k. ASHRAE Standard 62, Ventilation for Acceptable Indoor Air Quality

l. ASHRAE—Thermal Guidelines for Data Processing Environments

m. ASHRAE—The HVAC Commissioning Process

n. American Water Works Association (AWWA)

o. American Conference of Governmental Industrial Hygienists, latest edition of the Industrial Ventilation Guide

p. American Society of Plumbing Engineers (ASPE), Data Books

q. American Society of Sanitary Engineers (ASSE)

r. ASTM-E84—Fire Hazard Classifications

s. Cameron Hydraulic Data

t. Carrier Design Manual

u. “The Commissioning Design Intent Narrative,” Ronald J. Wilkinson, P.E.

v. Corrosion Control Handbook

w. CSA standards

x. Guidelines for Planning and Design of Biomedical Research Laboratories (published by ASHRAE)

y. Hydraulic Institute standards

z. Hydronic System Design and Operation, Erwin G. Hansen, New York: McGraw-Hill (1985)

aa. Manufacturer's Standardization Society (MSS) of the Valve & Fittings Industry

ab. MCAA(MSS) —Guideline for Quality Piping Installation

ac. MSS SP 58(MSS)—Pipe Hangers and Supports Materials, Design and Manufacture

ad. MSS SP 69—Pipe Hangers and Supports Selection and Application National Association of Plumbing/Heating/Cooling Contractors (PHCC) ae. National Environmental Balancing Bureau (NEBB)

af. National Fire Protection Association (NFPA):

- 72—National Fire Alarm Code
- 90A—Installation of Air Conditioning and Ventilating Systems
- 90B—Installation of Warm Air Heating & Air-Conditioning Systems
- 92A—Recommended Practice for Smoke Control Systems
- 92B—Guide for Smoke Management Systems in Malls, Atria, and Large Areas
- 96—Ventilation Control and Fire Protection of Commercial Cooking Operations

ag. NCPWB, Welding Procedure Specifications

ah. Plumbing and Drainage Institute

ai. Roadmap for Integrating Sustainable Design into Site-Level Operations, US Department of Energy (March 2000)

aj. Sheet Metal and Air Conditioning Contractors National Association (SMACNA) design guides

ak. Seismic Restraint Manual Guidelines for Mechanical Systems, 2nd edition SMACNA

al. Thermal Insulation Manufacturers Association (TIMA)

am. Trane Company:

- Air-to-Air Energy Recovery Manual
- Air Conditioning Manual
- Rooftop/VAV System Design Applications Manual
- Systems Design Manual
- Variable Air Volume Duct Design

an. "Understanding Owner Project Requirements Documentation (Design Intent)," Karl Stum, P.E., National Conference on Building Commissioning (2001)

ao. US Green Building Council, Leadership in Energy & Environmental Design

2. Basic Materials and Methods

a. ANSI Piping and Equipment Labeling Requirements

b. ANSI/UL 674—Electric Motors and Generators for Use in Division I Hazardous (Classified)

c. ASHRAE Standard C680—Standard Practice for Determining Heat Gain or Loss

d. ASME PTC 8.2 and 9

e. ASTM Standards for Thermal Insulation

f. ASTM C930—Classification of Potential Health and Safety Concerns Associated With Thermal Insulation Materials and Accessories

g. ASTM C1094—Standard Guide for Flexible, Removable Insulation Covers

h. ASTM E413—Classification for Rating Sound Insulation

i. CSA C22.2 No. 100-95—Motors and Generators

j. IEEE Standard 112 Method B

k. NEMA MG 10-2001—Energy Management Guide for Selection and Use of Fixed-Frequency Medium AC Squirrel-Cage Polyphase Industrial Motors

l. NEMA MG 11-1977—Energy Management Guide for Selection and Use of Single-Phase Motors

m. NEMA MG 1—Motors and Generators

n. NEMA Standard MG-1-12.53a

o. UL 1004—Electric Motors

p. Yale Specification Section 15930—Insulation Jackets

3. Fire Protection Design References

a. ANSI Elevator Code A17.1

b. ANSI B31.1—B31.9

c. NFPA Fire Prevention Handbook

d. NFPA 10—Portable Fire Extinguishers

e. NFPA 13—Installation of Sprinkler Systems

f. NFPA 14—Installation of Standpipe

g. NFPA 20—Installation of Centrifugal Fire Pumps

h. NFPA 24—Installation of Private Service Mains and Their Appurtenances

i. NFPA 25—Inspection, Testing and Maintenance of Water-Based Fire Protection Systems

j. NFPA 30—Flammable and Combustible Liquids Code

k. NFPA 45—Fire Protection for Laboratories Using Chemicals

l. NFPA 70—National Electric Code

m. NFPA 72D—Protective Signaling Systems

n. NFPA 72E—Automatic Fire Detectors

o. NFPA 75—Protection of Electronic Computer/Data Processing Equipment

p. NFPA 92A—Recommended Practice for Smoke Control Systems

q. NFPA 92B—Guide for Smoke Management Systems in Malls, Atria, and Large Areas

r. NFPA 96—Ventilation Control and Fire Protection of Commercial Cooking Operations

s. Yale Specification Section 15310—Fire Protection

4. Piping

a. ABMA, Boiler Water Limits and Steam Purity Recommendations for Water Tube Boilers

b. ACGIH Threshold Limit Values for Chemical Substances

c. ANSI/ASME B16.1—Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800

d. ANSI/ASME B16.24—Cast Copper Alloy Pipe Flanges and Flanged Fittings

e. ANSI/ASME B16.34—Valves-Flanged, Threaded, and Welding Ends

f. ANSI/ASME PTC 25—Pressure Relief Devices

g. ANSI/ASHRAE 41.2—Standard Methods for Laboratory Airflow Measurement

h. ANSI/ASHRAE 41.3—Standard Method for Pressure Measurement

i. ANSI/ASHRAE 41.1—Standard Method for Temperature Measurement

j. ANSI/ASHRAE 41.8—Standard Methods of Measurement of Flow of Liquids in Pipes Using Orifice Flowmeters

k. ANSI/Hydraulic Institute 8.1–8.5

l. API 6D—Specification for Pipeline Valves (Gate, Plug, Ball and Check)

m. API 598—Valve Inspection and Testing

n. ASHRAE—Legionellosis Position Paper (1998)

o. ASME PTC 19.5—Application of Fluid Meters

p. ASME MFC-10M—Method for Establishing Installation effects on Flowmeters

q. ASME Boiler and Pressure Code, Section VIII

r. ASME—Consensus on Operating Practices for the Control of Feedwater and Boiler Water Chemistry in Modern Industrial Boilers (1994)

s. ASME B31.1—Power Piping

t. ASME B31.5—Refrigeration Piping and Heat Transfer Components

u. ASME B31.9—Building Services Piping

v. ASSE/ASTM 6030

w. “The Analytical Control of Anticorrosion Water Treatment,” W.F. Langelier, 1936

x. DOE—Non-Chemical Technologies for Scale and Hardness Control (1998)

y. Ingersoll-Rand Compressed Air and Gas Data Book

z. ISO 4126-1—Safety Valves, Part 1: General Requirements

aa. NFPA 99—Health Care Facilities

ab. Plumbing and Drainage Institute

5. Plumbing Fixtures and Equipment

a. ANSI/ASHRAE 18—Methods of Testing for Rating Drinking Water Coolers with Self Contained Mechanical Refrigeration Systems

b. ASME PTC 8.2 and 9

c. ANSI Z-358.1

d. ANSI/ASHRAE 118.1

e. ANSI/UL 399—Drinking Water Coolers

f. ARI-1010—Self Contained, Mechanically Refrigerated Drinking Water Coolers

g. American Society of Sanitary Engineers

h. ASSE 1016

i. ASSE 1017

j. CAN/CSA-C22.2 No. 110-94

k. NSF/ANSI 5

l. NSF/ANSI 61—Drinking Water System Components Health Effects

m. UL Motor-Operated Water Pumps Standard

n. UL 795

o. UL 1453

6. Heat Generation Equipment

a. ABMA—Packaged Boiler Engineering Manual

b. ABMA—Boiler Water Limits and Achievable Steam Purity for Watertube Boilers

c. ABMA—Boiler Water Requirements and Associated Steam Purity—Commercial Boilers

d. ABMA—Operation and Maintenance Safety Manual

e. ABMA— (Selected) Codes and Standards of the Boiler Industry

f. ABMA—Combustion Control Guidelines

g. ABMA—Utility and Boiler Terms and Phrases

h. ACCA Manual CS—Commercial Applications Systems and Equipment, 1st ed.

i. ASME—Boiler and Pressure Vessel Code

j. ASME CSD-1—Control and Safety Devices for Automatically Fired Boilers

k. ANSI/UL 343—Pumps for Oil-Burning Appliances

l. ANSI Z21.13/CSA 4.9—Gas-Fired, Low-Pressure Steam and Hot Water Boilers

m. ANSI/NFPA 8501—Single Burner Boiler Operations

n. ANSI/NFPA 8502—Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers

o. ANSI/UL 834—Heating, Water Supply, and Power Boilers—Electric

p. CSA ANSI Z83.3—Gas Utilization Equipment in Large Boilers

q. CSA CAN 1-3—Industrial and Commercial Gas-Fired Package Boilers

r. CSA B-51—Boiler, Pressure Vessel, and Pressure Piping Code

s. CSA B 140.7.2—Oil-Fired Steam and Hot-Water Boilers for Commercial and Industrial Use

t. Hydronics Institute IBR—Testing and Rating Standard for Heating Boilers

u. UL 726—Oil-Fired Boiler Assemblies (1995)

v. UL 795—Commercial/Industrial Gas Heating Equipment (1999)

7. Refrigeration Equipment

a. AABC National Standards—Cooling Tower Testing

b. ACGIH—Bioaerosols: Assessment and Control

c. ACGIH—Threshold Limit Values for Chemical Substances

d. ACCA Manual CS—Commercial Applications, Systems, and Equipment, 1st ed.

e. ANSI/AHAM DH-1—Dehumidifiers

f. ANSI/ASHRAE 15—Safety Standard for Refrigeration Systems

g. ANSI/ASHRAE 30—Method of Testing Liquid-Chilling Packages

h. ANSI/ASHRAE 34—Designation and Safety Classification of Refrigerants

i. ANSI/UL 474—Dehumidifiers

j. CSA C22.2 No 92-1971—Dehumidifiers

k. ARI 365-94—Commercial and Industrial Unitary Air-Conditioning Condensing Units

l. ARI 410—Forced Circulation Air Cooling and Air Heating Coils

m. ARI-440—Room Fan Coils and Unit Ventilators

n. ARI 450—Water-Cooled Refrigerant Condensers, Remote Type

o. ARI 460—Remote Mechanical-Draft, Air-Cooled Refrigerant Condensers

p. ARI 560—Absorption Water-Chilling and Water-Heating Packages

q. ARI 550—Centrifugal and Rotary Screw Water-Chilling Packages

r. ARI 590—Positive-Displacement Compressor Water-Chilling Packages

s. ASHRAE Guideline 3—Reducing Emission of Halogenated Refrigerants in Refrigeration and Air Conditioning Equipment and Systems

t. ASME PTC 23—Atmospheric Water Cooling Equipment

u. CSA C743—Performance Standard for Rating Packaged Water Chillers

v. CTI ATC-128—Code for Measurement of Sound from Water Cooling Towers

w. CTI PFM-143—Recommended Practice for Airflow Testing of Cooling Towers

x. CTI STD-201—Certification Standard for Commercial Water Cooling Towers

y. ISO 6718—Bursting Discs and Bursting Disc Devices

z. NFPA 214—Water-Cooling Towers

aa. UL 1995/C22.2 No. 236-95—Heating and Cooling Equipment

ab. UL 2182—Refrigerants

8. HVAC Equipment

a. ACCA Manual CS—Commercial Applications Systems and Equipment, 1st ed.

b. ACCA Manual RS—Comfort, Air Quality, and Efficiency by Design

c. ANSI/ASHRAE 62—Ventilation for Acceptable Indoor Air Quality

d. ACCA Manual CS—Commercial Applications, Systems and Equipment, 1st ed.

e. ACGIH—Bioaerosols: Assessment and Control

f. ACGIH—Threshold Limit Values for Chemical Substances

g. ANSI/ARI 430—Central Station Air Handling Units

h. ASHRAE—A Practical Guide to Noise and Vibration Control for HVAC Systems," Schaffer, Mark E. (1992)

i. ANSI/ARI 640—Commercial and Industrial Humidifiers

j. ANSI/ASHRAE 127-2001—Method of Rating Computer and Data Processing Room Unitary Air Conditioners

k. ASME BPVC-2001—Boiler and Pressure Code, Section VIII, Division 1: Pressure Vessels

l. ARI Compliance for Units with Capacities Less Than 135,000 Btuh (39.6 kW): ARI 210/240, Commercial and Industrial Unitary Air-Conditioning and Air-Source Heat Pump Equipment

m. ARI Guideline B for Rooftop Unit Mounting

n. ARI 410—Forced Circulation Air Cooling and Air Heating Coils

o. CAN/CSA-C273.3-M91—Performance Standard for Split System Central Air Conditioners and Heat Pumps

p. Hydronic Institute IBR—Testing and Rating Standard for Baseboard Radiation, 6th ed.

q. Hydronic Institute IBR—Testing and Rating Standard for Finned-Tube (Commercial) Radiation

r. NRCA Low-Slope Membrane Roofing Construction Details Manual, Illustration—Raised Curb Detail for Rooftop Air Handling Units and Ducts

s. Sound Power Level Ratings: Comply with ARI 270, Sound Rating of Outdoor Unitary Equipment

t. TEMA—Standards of Tubular Exchanger Manufacturers Association, 8th ed. (1999)

u. UL/CSA 998/C22.2 No. 104—Humidifiers (2001)

v. UL/CSA 1995/C22.2 No. 236—Heating and Cooling Equipment

9. Air Distribution

a. ACCA Manual Q—Commercial Low Pressure, Low Velocity Duct System Design, 1st ed.

b. ACCA Manual Q—Pressure, Low Velocity Duct System Design, 1st ed.

c. ACGIH—Industrial Ventilation: A Manual of Recommended Practice, 24th ed.

d. ACGIH—Selection of Air Filtration Equipment

e. ADC-91—Flexible Duct Performance and Installation Standards, 3rd ed.

f. AMCA 99—Standards Handbook

g. AMCA 201—Fans and Systems

h. AMCA 211—Certified Ratings Program: Air Performance

i. AMCA-410—Recommended Safety Practices for Users and Installers of Industrial and Commercial Fans

j. AMCA-2404—Drive Arrangements for Centrifugal Fans

k. AMCA-2407—Motor Positions for Belt or Chain Drive Centrifugal Fans

l. AMCA-2406—Designation of Rotation and Discharge of Centrifugal Fans

m. AMCA-2410—Drive Arrangements for Tubular Centrifugal Fans

n. ANSI S12.11—Methods for the Measurement of Noise Emitted by Small Air-Moving Devices

o. ANSI/AMCA 210

p. ANSI/AMCA 330

q. ANSI/ASHRAE 51—Laboratory Methods of Testing Fans for Aerodynamic Performance Rating
r. ANSI/ASHRAE 52.1—Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
s. ANSI/ASHRAE 52.2—Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
t. ANSI/ASHRAE 68—Laboratory Method of Testing to Determine the Sound Power in a Duct
u. ANSI/ASHRAE 70—Method of Testing for Rating the Performance of Air Outlets and Inlets
v. ANSI/ASHRAE 113—Method of Testing for Room Air Diffusion
w. ANSI/ASHRAE 120—Method of Testing to Determine Flow Resistance in HVAC Ducts and Fittings
x. ANSI/AWS D9.1-2000—Sheet Metal Welding Code
y. ANSI/UL 705—Power Ventilators
z. ANSI/UL 900—Air Filter Units
aa. ARI 670—Fans and Blowers
ab. ARI 850-93—Commercial and Industrial Air Filter Equipment
ac. ARI 880—Air Terminals
ad. ARI-885—Procedure for Estimating Occupied Sound Levels in the Application of Air Terminals and Air Outlets
ae. ASC-A-7001A—Adhesives Standard for Duct Liner Adhesive & Sealant
af. ASHRAE—A Practical Guide to Noise and Vibration Control for HVAC Systems, Schaffer, Mark E.
ag. ASHRAE Standard 129 Schaffer Measuring Air Change Effectiveness
ah. ASME PTC 11 Schaffer Fans
ai. ASHRAE 51-1999 Schaffer Laboratory Methods of Testing Fans for Aerodynamic Performance Rating

aj. ASHRAE 52-1999 Schaffer Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ak. ASTM F1471 Schaffer Test Method for Air-Cleaning Performance of a High-Efficiency Particulate Air Filter System

al. CSA C22.2 No. 113-M Schaffer Fans and Ventilators

am. Industrial Ventilation: A Manual of Recommended Practice, 24th ed. (2001)

an. SMACNA 2002—Accepted Industry Practices for Sheet Metal Lagging, 1st ed.

ao. SMACNA—HVAC Air Duct Leakage Test Manual

ap. SMACNA—HVAC Duct Construction Standards, Metal and Flexible

aq. SMACNA—Rectangular Industrial Duct Construction Standards

ar. SMACNA—Duct Design

as. SMACNA—Round Industrial Duct Construction Standards

at. SMACNA—Duct Liner Applications

au. SMACNA—Mechanical Fasteners Standard

av. SMACNA—HVAC Air Duct Leakage Test Manual, 1st ed.

aw. SMACNA—HVAC Duct Systems Inspection Guide, 2nd ed.

ax. SMACNA—Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems, 5th ed.

ay. UL 181—Factory-Made Air Ducts and Air Connectors

az. UL 181A—Closure Systems for Use with Rigid Air Ducts and Air Connectors

ba. UL 181B—Closure Systems for Use with Flexible Air Ducts and Air Connectors

bb. UL 507—Electric Fans (1999)

bc. UL 555C—Ceiling Dampers

bd. UL 555S—Smoke Dampers

be. UL 585—High-Efficiency, Particulate, Air Filter Units

bf. UL 710—Exhaust Hoods for Commercial Cooking Equipment

bg. UL1046—Grease Filters for Exhaust Ducts

10. HVAC Instrumentation and Controls

a. AABC National Standards, Chapter 12—Temperature Control Systems

b. AMBA—Guideline for the Integration of Boilers and Automated Control Systems in Heating Applications

c. ANSI/ASHRAE 111—Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems

d. ANSI/ASHRAE 114-1986—Energy Management Control Systems Instrumentation

e. ANSI/Hydraulic Institute 1.6—Centrifugal Pump Test

f. ARI Guideline G—Mechanical Balance of Fans and Blowers

g. Buildings Controls Group of the UK—Control Sensor Installation website

h. Central Building Utilities Metering System (CBUMS) website: http://www.facilities.yale.edu/Work/Work.asp

i. Hydraulic Institute 9.1-9.6—Pumps: General Guidelines (including Measurement of Airborne Sound)

j. Johnson Controls—Metasys Design Manual

k. NEBB—Procedural Standards for Certified Testing of Cleanrooms, 2nd ed.

l. NEBB—Procedural Standards for Testing, Adjusting, Balancing of Environmental Systems, 6th ed.

m. NEBB—Procedural Standards for Building Systems Commissioning, 1st ed. (1993)

n. SMACNA—HVAC Systems Testing, Adjusting and Balancing, 3rd ed.

F. Electrical Regulatory and Directive Standards

1. General Design References

a. ASHRAE 90.1—Energy-Efficient Design of New Buildings Except Low-Rise Residential Buildings

b. ANSI/IEEE C2-1993—National Electrical Safety Code

c. ANSI/IEEE 141-1986—Electric Power Distribution for Industrial Plants (Red Book)

d. ANSI/IEEE 142-1991—Grounding of Industrial and Commercial Power Systems (Green Book)

e. ANSI/IEEE 241-1990—Electric Power Systems in Commercial Buildings (Gray Book)

f. ANSI/IEEE 242-1986—Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)

g. ANSI/IEEE 399-1990—Industrial and Commercial Power Systems Analysis (Brown Book)

h. ANSI/IEEE 493-1990—Design of Reliable Industrial and Commercial Power Systems (Gold Book)

i. ANSI/IEEE 602-1986—Electric Systems in Health Care Facilities (White Book)

j. ANSI/IEEE 739-1984—Energy Conservation and Cost-Effective Planning in Industrial Facilities (Bronze Book)

k. ANSI 117.1—Providing Accessibility and Usability for Physically Handicapped People

l. ANSI Z117.1—Safety Requirements for Confined Spaces

m. ANSI/IEEE 100-1988—Standard Dictionary of Electrical and Electronics Terms

n. ANSI/IEEE 519-1992—Harmonic Control in Electrical Systems

o. ANSI/IEEE 693-1984—Seismic Design of Substations

p. ANSI/IEEE 946-1992—DC Auxiliary Power Systems for Generating Stations

q. ANSI/IEEE 979-1984—Substation Fire Protection

r. ANSI/IEEE 980-1987—Containment and Control of Oil Spills in Substations

s. ANSI/IEEE 1001-1988—Interfacing Dispersed Storage and Generation Facilities with Electric Utility Systems

t. ARI Guideline G—Mechanical Balance of Fans and Blowers

u. ETL Directory (1987)

v. IEEE 666-1991—Electric Power Service Systems for Generating Stations

w. IEEE 1109-1990—Interconnection of User-Owned Substations to Electric Utilities

x. IEEE 1127-1990—Design, Construction, and Operation of Safe and Reliable Substations for Environmental Acceptance

y. Lineman's and Cableman's Handbook, 5th ed. (Bradley)

z. National Electrical Safety Code Handbook

aa. Switchgear and Control Handbook (Bradley)

ab. UL Directories:
- Electrical Appliance and Utilization Equipment (1990)
- Electrical Construction Materials (1990)
- Fire Protection Equipment (1990)
- Hazardous Location Equipment (1990)

ac. United Illuminating Company:
- Company Energy Blueprint Program
- Company Energy Opportunities Program
- Electric Service Guidelines
- Engineering and Construction Standards
- Electric Service Guidelines (1992)

2. Power and Distribution

a. Johnson Controls—Metasys Design Manual

b. Robert Shaw Controls—Electronics Products Master Catalog

c. ICEA S-19-81—Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

d. ICEA S-61-402—Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

e. NEMA OS1—Sheet-Steel Outlet Boxes, Device Boxes, Covers and Box Supports

f. NEMA RN1—Polyvinyl-Chloride Externally Coated Galvanized Rigid Steel Conduit and Electrical Metallic Tubing

g. NEMA TC2—Electrical Plastic Tubing (EPT) and Conduit (EPC-40 and EPC-80)

h. NEMA TC3—PVC Fittings for Use with Rigid PVC Conduit and Tubing

i. NEMA WD1—General-Purpose Wiring Devices

j. NEMA WD2—Semiconductor Dimmers for Incandescent Lamps

k. NEMA WD5—Specific-Purpose Wiring Devices

l. Underwriters Laboratories (UL):
   - 1—Flexible Metal Electrical Conduit
   - 5—Surface Metal Electrical Raceways and Fittings
   - 6—Rigid Metal Electrical Conduit
   - 20—General-Use Snap Switches
   - 50—Electrical Cabinets and Boxes
   - 62—Flexible Cord and Fixture Wire
   - 83—Thermoplastic-Insulated Wires and Cables
   - 310—Electric Quick-Connect Terminals
   - 360—Liquid-Tight Flexible Steel Conduit, Electrical
   - 486A—Wire Connectors and Soldering Lugs for Use with Copper Conductors

- 486C—Splicing Wire Connectors
- 486E—Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors
- 498—Electrical Attachment Plugs and Receptacles
- 508—Electric Industrial Control Equipment
- 510—Insulating Tape
- 514A—Metallic Outlet Boxes, Electrical
- 514B—Fittings for Conduit and Outlet Boxes
- 651—Schedule 40 and 80 Rigid PVC Conduit
- 651A—Type EB and A Rigid PVC Conduit and HDPE Conduit
- 773A—Non-Industrial Photoelectric Switches for Lighting Control
- 797—Electrical Metallic Tubing
- 870—Electrical Wireways, Auxiliary Gutters, and Associated Fittings
- 886—Outlet Boxes and Fittings for Use in Hazardous (Classified) Locations
- 943—Ground-Fault Circuit Interrupters
- 1059—Electrical Terminal Blocks
- 1242—Intermediate Metal Conduit
- 1449—Transient Voltage Surge Suppressors

3. Transmission and Distribution

a. ANSI C84.1—Voltage Ratings for Electric Power Systems and Equipment

b. IEEE 739—Energy Conservation and Cost-Effective Planning in Industrial Facilities (Bronze Book)

c. IEEE 980—Containment and Control of Oil Spills in Substations

d. IEEE S-135—Power Cable Ampacities

e. NEMA TC3 and TC6—PVC Conduit and Tubing

f. ANSI/NEMA 70—National Electric Code

g. ICEA/NEMA S-61-402/WC 5, S-66-524/WC, and S-68-516/WC 8—600 Volt or Less Conductors

h. UL 44 and 83—600 Volt or Less Conductors

i. ANSI/NEMA FB1—Cast Metal Boxes and Conduit Bodies for Conduit and Cable Assemblies

j. NFPA 70—National Electrical Code

k. NECA 5055—Standard of Installation

4. Low-Voltage Distribution

a. IEEE 446—Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)

b. NEMA:

- AB1—Molded Case Circuit Breakers
- BU1—Busways
- FU1—Low-Voltage Cartridge Fuses
- ICS 1—General Standards for Industrial Control and Systems
- ICS 2—Industrial Control Devices, Controllers, and Assemblies
- ICS 3—Industrial Systems
- KS1—Enclosed Switches
- PB1—Panelboards
- SG3—Low-Voltage Power Circuit Breakers
- ST20—Dry-Type Transformers, for General Applications
- TR27—Commercial, Institutional, and Industrial Dry-Type Transformers

c. Underwriters Laboratories (UL):

- 50—Electrical Cabinets and Boxes
- 67—Electric Panelboards
- 98—Enclosed Switches
- 198C—High-Interrupting-Capacity Fuses, Current-Limiting Types
- 198E—Class R Fuses
- 489—Molded-Case Circuit Breakers and Circuit-Breaker Enclosures
- 506—Specialty Transformers
- 508—Electric Industrial Control Equipment
- 845—Electric Motor Control Centers

- 857—Busways and Associated Fittings
- 943—Ground-Fault Circuit Interrupters
- 1008—Automatic Transfer Switches
- 1561—Large General Purpose Transformers

5. Lighting

a. IES Lighting Handbook

b. ANSI C78.1 (with supplements)—Dimensional and Electrical Characteristics of Fluorescent Lamps, Rapid Start Types

c. ANSI C78.2 (with supplements)—Dimensional and Electrical Characteristics of Fluorescent Lamps, Preheat Start Types

d. ANSI C78.20—Characteristics of Incandescent Lamps of A, G, PS, and Similar Shapes with E26 Medium Screw Bases

e. ANSI C78.21—Characteristics of Incandescent Lamps of PAR and R Shapes

f. ANSI C78.1350 through C78.1359—High-Pressure Sodium Lamps

g. ANSI C78.1375 through C78.1381—Metal Halide Lamps

h. ANSI C82.1—Specifications for Fluorescent Lamp Ballasts

i. ANSI C82.2—Methods of Measurement of Fluorescent Lamp Ballasts

j. ANSI C82.3, Specifications for Fluorescent Lamp Reference Ballasts

k. ANSI C82.4 (with supplement) —Specifications for High-Intensity-Discharge and Low-Pressure Sodium Lamp Ballasts (Multiple-Supply Type)

l. ANSI C82.5 (with supplement)—Specification for High-Intensity Discharge Lamp Reference Ballasts

m. ANSI C82.6 (with supplement)—Methods of Measurement of High-Intensity Discharge Lamp Ballasts

n. NEMA FA1—Outdoor Floodlighting Equipment

o. NEMA LE1—Fluorescent Luminaires

p. UL 924—Emergency Lighting and Power Equipment

q. UL 935—Fluorescent-Lamp Ballasts

r. UL 1029—High-Intensity-Discharge-Lamp Ballasts

s. UL 1570—Fluorescent Lighting Fixtures

t. UL 1571—Incandescent Lighting Fixtures

u. UL 1572—High Intensity Discharge Lighting Fixtures

End of Section

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Project Execution and Closeout

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

CONTENTS

Please contact the Yale University Department of Facilities Contract Administrator about project execution and closeout requirements.

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Warranties

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CONTENTS

Please contact the Yale University Department of Facilities Contract Administrator about warranty requirements.

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Operation and Maintenance Data

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

CONTENTS

A. Summary

This section includes administrative and procedural requirements for preparing and submitting operation and maintenance manuals.

B. Definitions

1. System—an organized collection of parts, equipment, or subsystems united by regular interaction.
2. Subsystem—a portion of a system with characteristics similar to a system.

C. Submittals

Submit operation and maintenance documentation in accordance with the following requirements.

1. Submittal Schedule

Submit three copies of each O&M manual in final form at least 15 days before final inspection. O&M documentation is required before occupation of the building by Yale University.

2. Coordination

Where operation and maintenance documentation includes information on installations by more than one factory-authorized service representative, assemble and coordinate information furnished by the representatives, and prepare the manuals.

3. Binding

a. Bind each manual in a loose-leaf, three-ring binder of the following size and quality:
   - Ring size (thickness): as necessary to accommodate the contents
   - Dimensions: 8-1/2" x 11"
   - Covering: vinyl
   - Quality: heavy-duty, commercial-quality

b. The binder must include pockets inside the front and back covers to hold folded sheets.

c. The binder must include clear plastic sleeves on the front cover and spine to hold a cover sheet and label containing the following information:
   - Title: Operation and Maintenance Manual
   - Project name
   - System, subsystem, or equipment name
   - Volume number (as appropriate)

d. If necessary, separate the contents of the manual into two or more volumes to accommodate the data. Group the information in each volume by subsystem and related components. Provide appropriate cross-references to information contained in other volumes.

e. Provide heavy, paper dividers with plastic-covered tabs for each section of the manual. Mark each tab to indicate its contents. Include a description of the section contents on the front of each divider.

f. Use the manufacturer's standard printed material. If unavailable, print the required content on 8-1/2" x 11", 20 lb/sq ft, white bond paper.

g. Attach reinforced, punched binder tabs on drawings and bind them with the text. Fold oversize drawings to the same size as the text pages for use as fold-outs. If a drawing is too large for a fold-out, fold it neatly and place it in the front or back pocket of the binder. Insert a page at the appropriate place in the manual containing the drawing title, a description of the drawing, and its location (front or back pocket).

h. Place diagnostic software CDs for computerized electronic equipment inside protective, transparent, plastic sleeves.

D. Operation and Maintenance Documentation Directory

Provide an operation and maintenance documentation directory that includes the following elements.

1. Organization

Include a section in the directory for each of the following:

- List of documents
- List of systems
- List of equipment
- Table of contents

2. List of Systems and Subsystems

List systems alphabetically. Include references to O&M manuals that contain information about each system.

3. List of Equipment

List equipment for each system, organized alphabetically by system. List pieces of equipment not part of a system alphabetically in separate list.

4. Tables of Contents

Include a table of contents for each O&M manual.

5. Identification

In the documentation directory and in each operation and maintenance manual, identify each system, subsystem, and piece of equipment with the same designation used in the contract documents. If no designation exists, assign a designation according to ASHRAE Guideline 4, "Preparation of Operating and Maintenance Documentation for Building Systems."

E. O&M Manual Organization

Organize each manual into separate sections for each piece of related equipment. As a minimum, each manual must contain a title page; a table of contents; copies of product data supplemented by drawings and written text; and copies of each warranty, bond, and service contract issued.

1. Title Page

Provide a title page in a transparent, plastic envelope as the first sheet of each manual. The title sheet must contain the following information.

- Subject matter covered in the manual
- Name and address of the project
- Date of submittal
- Name, address, and telephone number of the contractor
- Name and address of the architect/engineer

2. Contractor List

Provide contact information for the following project personnel:

- General Contractor
- Sub-contractors
- Primary Vendors
- Primary Suppliers

The contact information should include the following information.

- Company name
- Address
- Phone number
- Name and phone number for main contact person for project
- Company web address/URL

3. Table of Contents

Provide a table of contents for each volume, after the title page.

4. General Information

Provide a general information section immediately following the table of contents. List each product included in the manual, identified by product name. Under each product, list the name, address, and telephone number of the subcontractor or installer and the maintenance contractor. Clearly delineate the extent of their responsibility for the product. Include a local source for replacement parts and equipment.

5. Product Data/Systems and Equipment

Where the manuals include the manufacturer's standard printed data, include only sheets that are pertinent to the part or product installed. Mark each sheet to identify each part or product included in the installation. Where the project includes more than one item in a tabular format, identify each item, using appropriate references from the contract documents. Identify data that is applicable to the installation, and delete references to information that is not applicable. Provide the following information for each piece of equipment, each building operating system, and each electric or electronic system.

a. Description

Provide a complete description of each unit and related component parts, including:

- Name of manufacturer, model number, serial number, and equipment tag number
- General description of system or equipment function and its purpose
- Operating characteristics
- Limiting conditions
- Performance curves
- Engineering data and tests
- Complete nomenclature and number of replacement parts
- Design factors and assumptions

b. Manufacturers' Information

Provide the following information for each manufacturer of a component part or piece of equipment.

- Printed operation and maintenance instructions
- Assembly drawings, wiring diagrams, and diagrams required for maintenance
- List of items recommended to be stocked as spare parts
- Shop drawings, engineering data, and product data
- Warranty data and copies of warranties

c. Maintenance Procedures

Provide essential maintenance procedures, including:

- Routine operating procedures
- Troubleshooting procedures
- Calibration procedures
- Disassembly, repair, and reassembly procedures
- Alignment, adjusting, and checking procedures
- Inspection and testing procedures

d. Operating Procedures

Provide equipment and system operating procedures, including:

- Testing procedures
- Startup procedures
- Equipment or system break-in procedures
- Routine and normal operating procedures
- Regulation and control procedures
- Stopping procedures
- Shutdown and emergency procedures
- Summer and winter operating procedures
- Special operating procedures
- Required sequences for electric or electronic systems
- Precautions against improper use

e. Servicing Schedule

Provide a schedule of routine preventative maintenance and lubrication requirements, including a list of required lubricants for equipment with moving parts.

f. Controls

Provide a description of the sequence of operation and as-installed control diagrams by the control manufacturer for systems requiring controls. Refer to the requirements in specification section 15950, Energy Management and Controls System, and section 15960, Laboratory Airflow Control System.

g. Coordination Drawings

Provide each contractor's coordination drawings.

(1) Provide as-installed, color-coded, piping diagrams, where required for identification.

(2) Provide charts of valve-tag numbers, with the location and function of each valve.

h. Circuit Directories

(1) Provide complete panel-board circuit directories for electric and electronic systems, including:

- Electric service
- Controls
- Communication

(2) Refer to the requirements in specification section 15950, Energy Management and Controls System, and section 15960, Laboratory Airflow Control System.

F. Special Control System O&M Manuals

See the content requirement in specification section 15950, Energy Management and Controls System, and section 15960, Laboratory Airflow Control System.

G. Product Safety/Data Manual

Provide three copies of a manual containing product safety/data sheets for all project products, arranged in accordance with CSI MasterFormat®

End of Section

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General Commissioning

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

CONTENTS

A. Summary

1. When required by Yale University, follow the commissioning procedures contained in this section. For limited project scope, commissioning may be selectively applied by the University.

2. This section contains general requirements for commissioning building systems, subsystems, and equipment to ensure reliable, safe, and secure operation. The commissioning process verifies that systems are complete and functioning properly upon project completion and that the Yale University staff has received appropriate system documentation and training.

3. As part of the commissioning process, Yale University may choose to follow the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Program requirements, which require fundamental building systems commissioning, as well as additional commissioning. For further information related to Yale University's sustainable design guidelines, see Section 01352: Sustainable Design Requirements

B. System Design and Performance Requirements

1. Commissioning is a quality-focused process for enhancing the delivery of a project.[1] Commissioning helps the project team to understand project goals and take logical steps along the way to ensure and document that those goals are met.
2. Yale University commissioning is a quality-focused process that targets:
   - Documentation
   - Testing
   - Training
3. Through documentation, commissioning ensures acceptance that all building or facility systems perform interactively. This interactive performance must be in accordance with Yale University's design intent, the designer's documentation, and Yale University's operational needs for documentation and operating personnel training.
4. Commissioning may be performed by the design engineer, Yale University personnel, or a third-party commissioning consultant. For complex projects, Yale University prefers a third-party consultant contracted directly to the University.

[1] ASHRAE Guideline 0-200X, "The Commissioning Process"

C. Extent of Commissioning

1. Ideally, commissioning activities begin during the design phase of the project and proceed through the warranty period. The four phases of commissioning at Yale University are design, construction, acceptance, and warranty.

2. Each project requires a customized approach. The Yale University project team develops a project-specific list of systems to be commissioned. Building systems that affect life safety, energy consumption, water usage, and indoor environmental quality should generally be commissioned. Table 1 lists general, mechanical, and electrical systems that are representative of systems that may be commissioned to verify full conformance with Yale University's project requirements and design intent.

Table 1. Representative Systems, Subsystems, and Equipment

General Systems Commissioning
• Mechanical room floor over critical spaces • Building thermal and moisture envelope [2] • Equipment • Doors and windows • Life safety and personnel egress systems • Conveying systems (functional testing oversight by Yale University fire marshal and elevator consultant) • Telecommunications systems

[2] Tseng, Paul C. "LEED, the Building Envelope, and Commissioning"

Table 1. Representative Systems, Subsystems, and Equipment—Continued

Mechanical Systems Commissioning

- Chilled and condenser water systems
- Process chilled water system
- Utility metering (chilled water and condensate)
- Air handling units, including glycol preheat/heat recovery systems
- Humidification system
- Exhaust air handling units
- Fans—exhaust, return, and transfer
- Terminal units, including VAV boxes, CV boxes, reheat coils, unit heaters, FCUs, baseboard radiation, and radiant panels
- Heating hot water system
- Steam system, including PRVs and condensate system
- Building automation system
- Laboratory air control sequences, including fume hood controls
- Room pressurization
- Plumbing system
- RO/DI system
- Vacuum systems
- Lab neutralization system
- Lab waste duplex lift station
- Compressed air system
- Domestic hot water heaters and pumps
- Grey water system
- Sanitary lift station
- Backflow preventers
- Fire protection/fire pumps

Table 1. Representative Systems, Subsystems, and Equipment—Continued

Electrical Systems Commissioning

- Building main electrical service switchgear, switchboard, or substation
- Major switchboard with breakers rated 400 A or higher
- Normal power double-ended substations
- Outdoor, liquid type, pad-mounted transformers
- Alternate power switchgear
- Lighting control systems
- Automatic transfer switches
- Major switchboards or panelboards following ATS
- Emergency power system MCC
- Normal power outage simulation tests
- Emergency switchgear or switchboard
- Emergency panels, including emergency power outlets
- Emergency lighting, exit sign and lighting control (testing oversight by the Yale University fire marshal)
- Fire alarm system (tests are performed by Yale University personnel)
- Security system (tests are performed by Yale University personnel)

D. General Commissioning Activities

The rest of this section provides supplementary information about the four phases of commissioning (design, construction, acceptance, and warranty) shown on the Yale University Commissioning Process flow chart. The general commissioning activities described in this paragraph apply to two or more phases of the Yale University commissioning process. These activities are not described again in the subsequent paragraphs associated with commissioning activities specific to each phase. The Yale University project manager determines which commissioning activities are required on a project-by-project basis.

1. Commissioning Scheduling Activities and Regular Reviews

(See design phase activity D11, construction phase activities C3 and C4, and acceptance phase activity T9 on the Yale University Commissioning Process Flow Chart.)

a. Immediately following the commissioning kickoff meeting, the commissioning authority, in concert with the Yale University project manager, establishes regularly scheduled commissioning coordination meetings. The purpose of these meetings, in coordination with construction meetings, is to establish lines of communication, determine the routing of submittals and documents, facilitate maintenance of the schedule, and provide a forum for discussion of action items. Regular reviews are conducted throughout the project during construction team status meetings or commissioning coordination meetings.

b. The commissioning authority lends their expertise with respect to timing and duration of the various commissioning tasks and works with the construction manager to incorporate commissioning into the master schedule. The commissioning authority reviews the schedule periodically for information regarding progress for upcoming activities, submissions, and any issues that might impact the successful and timely completion of commissioning.

2. Commissioning Action Item List

(See design phase activity D12, construction activity C15, and acceptance phase activity T19 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority tracks scheduled commissioning-related issues and functional performance testing. The commissioning authority also develops and maintains an action item list and submits it to the commissioning team on a regular basis for information and appropriate responses.

3. Change Order Reviews and other Construction Phase Documentation

(See construction phase activity C13 and acceptance phase activity T7 on the Yale University Commissioning Process Flow Chart.)

During the construction and acceptance periods, the commissioning authority reviews change orders, requests for information, supplemental instructions, and meeting minutes for equipment and/or systems that are to be commissioned. The commissioning authority reviews the documents for issues or directives that could impact a system's ability to comply with the design intent. In addition, the commissioning authority reviews maintainability issues and incorporates designer-approved changes into the system readiness checklists and final functional test procedures.

4. Construction Team Status Meetings

(See construction phase activity C14 and acceptance phase activity T8 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority attends the construction team status meetings periodically to obtain information on construction progress. These meetings are typically facilitated by the construction manager.

b. The commissioning authority and Yale University determine the number of meetings to be conducted and attended.

5. Design Intent Document Update

(See Design Phase activity D9, Construction Phase Activity C17, and Acceptance Phase Activity T13 on the Yale University Commissioning Process Flow Chart.)

Due to the evolving nature of all design and construction projects, the design intent document is modified during the design process if budgeting and scheduling decisions necessitate a change in expected system performance. At that time, Yale University and the designers discuss and document an owner-approved change to the design intent document.

6. Commissioning Record Book Maintenance

(See Design Phase activity D13, Construction Phase Activity C18, and Acceptance Phase Activity T14 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority maintains a record of commissioning activities throughout the design, construction, and acceptance testing and training periods. Recorded information and issues aid in creating and tracking the documentation to be included in the commissioning report.

E. Design Phase Commissioning

1. Discovery Phase

(See design phase activity D1 on the Yale University Commissioning Process Flow Chart.)

Design phase commissioning involves completing a project-specific commissioning plan. Questions that must be asked of Yale University include:

- As a cost-saving measure, can the facility's operations and maintenance staff undertake some of the process management tasks, training oversight, or other activities, with the commissioning authority acting as a "coach"?
- Will the systems testing strategy be to test all systems or conduct random sampling?
- Will contractors be penalized for failed tests?
- What are the final deliverables?

2. Commissioning Plan

(See design phase activity D2 on the Yale University Commissioning Process Flow Chart.)

1. The commissioning plan defines the commissioning process and identifies the commissioning activities for a specific project. Among other things, the plan outlines the organization's structure, the allocation of resources, and the documentation requirements of the commissioning process. The plan also identifies the project phases and lists the commissioning team members, their commissioning-related responsibilities during each phase, and the expected deliverables from each team member.
2. The commissioning authority prepares the plan at the beginning of their involvement in the project—ideally during conceptual or schematic design—and develops it in greater detail as the project progresses through its various phases. The plan is strictly a process-roadmap for commissioning activities and does not include such items as detailed checklists, test procedures, and forms, which are identified and developed during the commissioning activities defined in the plan.
3. See the sample Commissioning Plan.

3. Design Phase Commissioning Kickoff Meeting

(See design phase activity D3 on the Yale University Commissioning Process Flow Chart.)

The design phase commissioning kickoff meeting is an opportunity for the commissioning authority and Yale University to present the commissioning plan to the entire design phase project team (Yale University project manager, designers, O&M staff, construction manager, and other special consultants). During the meeting, project team members are given an overview of the commissioning process and informed of their roles and responsibilities, the purpose of the design intent document, future maintenance provisions, and design review protocols. Although the project team continues to learn about commissioning throughout the entire project, the overview serves to broaden their perspective and explains the benefits of participating in the commissioning process.

4. Design Intent Document

(See design phase activity D4, construction phase activity C17, and acceptance phase activity T13 on the Yale University Commissioning Process Flow Chart.)

a. The design intent document describes Yale University's project requirements and identifies system performance goals in quantitative and verifiable terms. In addition, the document includes the university's vision for the facility, the facility's functional requirements, and the university's expectations regarding the facility's design, use, and operation.

b. The purpose of the design intent document is to focus all project activities on achieving the desired outcome. It also serves as the reference for evaluating success and quality in all phases of the project and becomes the benchmark for system maintenance and repair/replacement decisions. In addition, the design intent document serves as the basis for preparing system design narratives and design documents that contain the calculations, rationale, and assumptions necessary to achieve the design intent.

c. The Yale University project manager requests the design intent document from the design professional. The designer—in consultation with Yale University, and with input from facility users and operators—prepares the design intent document, based on an understanding of the project requirements. The commissioning authority reviews and approves the document.

d. The design intent document is updated periodically during the design and construction phases of the project to reflect changes in project requirements. A final update occurs during the acceptance phase. Yale University reviews and approves all changes, and the commissioning authority documents them.

e. Items to consider for inclusion in the design intent document are listed in the example Design Areas and Owner Project Requirement (Design Intent) Categories table. See also the sample Design Intent Document—Space Conditions form used for recording space conditions.

5. Design Reviews

(See design phase activity D6 on the Yale University Commissioning Process Flow Chart.)

a. Design documents are reviewed by other Yale University and regulatory agency representatives at various project milestones, such as schematic design, design development and construction documents. Yale University determines the number of reviews, which depends on project type and scope.

b. The commissioning authority reviews the design documents to answer to the following questions.
   - If constructed as designed, will the systems meet the design intent?
   - Are the systems (as designed) "commissionable"? Have the designers included the features necessary to verify that the systems will meet the design intent at the end of construction?
   - Are the system components accessible and maintainable? Are the specified O&M documentation requirements adequate? Are the specified operator training requirements adequate?
   - Are the design documents unambiguous? Do the drawings and specifications clearly detail requirements, or do they leave a lot up to the imagination and creativity of the contractor?

c. The design engineers review the commissioning authority's comments and submit their responses, through the construction manager, to the commissioning authority and Yale University.

d. See the sample Design Review form used for design reviews.

6. Technical Design Review

(See design phase activity D6b on the Yale University Commissioning Process Flow Chart.)

a. Technical design reviews are conducted at several stages in a project. The number and type of reviews are based on project scope, and reviews may not be required on some projects. An electrical load flow analysis review (described in the following paragraph) is one type of technical design review that may be conducted, as well as reviews for other engineering disciplines.

b. Under normal conditions, a load flow analysis determines real and reactive power flow in power system circuits. It also determines bus voltages in all possible operating conditions and provides solutions to potential system deficiencies. A review of the analysis by the commissioning authority confirms that the main electrical system components are included in the documentation used by the project team and by operations and maintenance personnel in making future system changes and in conducting system evaluations.

c. Yale University determines the extent of the commissioning authority's participation in technical design reviews. As a participant, the commissioning authority's role is to review and comment on the designs, focusing on the clarity of the design documents and on the designated system's ability to meet the design intent criteria.

7. Commissioning Specification

(See design phase activity D5 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority, working with the design team specification authors, must develop a commissioning specification for each project for inclusion in Division 1 of the design team's project specification books. The draft specification extracts the contractors' responsibilities from the commissioning plan and converts them into standard specification language and format, thus binding the contractors to the commissioning process through their normal contracting document. The commissioning specification is updated with each issuance of the design documents.

b. The commissioning specification must reflect the bidding contractors' commissioning responsibilities (scope, process, rigor of testing) that Yale University requires. Yale University may direct the commissioning authority to incorporate features that enhance the university's involvement and contribute to the scope of training requirements or processes that increase the value of the project. The final outcome is a commissioning specification that describes the preferred approach to commissioning and identifies:
   - The systems to be commissioned
   - The preferred approach to commissioning
   - Required documents and forms
   - Detailed testing procedures
   - Training requirements
   - Commissioning schedule sign-off requirements
   - All other information needed to complete the commissioning process

c. In the sample commissioning specification, LEED (Leadership in Energy and Environmental Design) Certification is a requirement. Sustainable design, which LEED supports, is a Yale University project design requirement. The decision to pursue LEED certification depends on the unique requirements of each project. See Section 01352: Sustainable Design Requirements for additional information regarding sustainable design.

8. Commissioning Requirements in Technical Specifications

(See design phase activity D7 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority reviews the design team's technical specifications and suggests inclusions that alert the contractor to specific commissioning requirements and document coordination requirements.

9. Training Plan Development

(See design phase activity D8 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority reviews the training requirements included in the design team's technical specifications and meets with Yale University to understand the nature and extent of the necessary training. In addition, the commissioning authority customizes the commissioning specification and suggests modifications to the technical specifications that reflect the university's training preferences. The specification review and recommendations focus on making the training requirements measurable and enforceable.

b. See the sample commissioning specification for an example of the Operation and Maintenance Training Plan form used by contractors to submit their intentions for each training session and used by Yale University in reviewing, approving, and documenting the successful delivery of each training session.

10. Preventive Maintenance and Equipment Data Requirements

(See design phase activity D10 on the Yale University Commissioning Process Flow Chart.)

a. Researching preventive maintenance and data retrieval requirements ensures that they are included in the bid specifications. The installation contractors or equipment vendors supply all of the data required to populate Yale University's preventive maintenance system with information on new equipment. The commissioning authority and Yale University determine what data is needed and how it should be presented. See the sample Mechanical–Electrical Data Retrieval form in the sample commissioning specification.

b. During construction, the commissioning authority collects the data retrieval forms submitted by the contractors and reviews them for completeness.

11. System Readiness Checklists and Verification Test Procedures

(See design phase activity D14 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority develops all required system readiness checklists. The checklists are used to demonstrate complete system installation and readiness for operational testing. At the end of construction, the contractor uses the checklists to certify that the work is complete and the system is ready for independent verification testing.

b. The commissioning authority also develops preliminary verification test procedures—the functional component of testing. The test procedures provide the contractors with repeatable, unambiguous acceptance criteria that clearly define the level of rigor necessary in demonstrating system performance.

c. The system readiness checklists and verification test procedures are incorporated into the commissioning specification. Sample of these documents are included in the sample commissioning specification.

12. 100-Percent Design Review Backcheck

(See design phase activity D15 on the Yale University Commissioning Process Flow Chart.)

During the backcheck, the commissioning authority reviews the final design documents for engineer responses and the inclusion of outstanding commissioning authority comments.

F. Construction Phase Commissioning

1. Pre-Bid Meeting

(See construction phase activity C1 on the Yale University Commissioning Process Flow Chart.)

During the pre-bid meeting, Yale University introduces the design team to prospective bidders. The commissioning authority describes the benefits of the commissioning, and provides a 5–10 minute overview of the commissioning process. In addition, the commissioning authority presents the system readiness checklists to the group, reviews the required verification testing procedures, and answers any questions.

2. Pre-Construction Meeting

(See construction phase activity C2 on the Yale University Commissioning Process Flow Chart.)

During the pre-construction meeting, Yale University introduces the design team and commissioning authority to the installation contractors. The commissioning authority briefly reviews the commissioning specification with the construction team, answers their questions, and is prepared to discuss how the contractors benefit from the commissioning process. In addition, the construction phase commissioning kickoff meeting is scheduled. The kickoff meeting should be held within two to six weeks of the pre-construction meeting.

3. Construction Phase Commissioning Kickoff Meeting

(See construction phase activity C3 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority chairs the construction phase commissioning kickoff meeting, which is attended by all commissioning team members, including all responsible contractors and subcontractors. The commissioning authority presents a detailed overview of the commissioning process described in the commissioning plan and in the commissioning specification section of the construction documents.

b. At this meeting the commissioning authority in concert with the Yale Project Manager would establish regularly scheduled commissioning coordination meetings. This meeting establishes lines of communication, routing of submittals and documents, maintenance of schedule, and discussion of action items.

4. Shop Drawing Reviews

(See construction phase activity C5 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority, concurrently with the designers, reviews the equipment and system shop drawing submittals for systems being commissioned. The commissioning authority submits their comments, which based primarily on the four design review areas defined under the design development review task, to the designers. If the designers agree with the commissioning authority, they incorporate these comments into their formal response back to the contractors.

b. An ATC submittal review is mandatory.

5. Coordination Drawing Review

(See construction phase activity C6 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority reviews coordination drawings and documents, such as ductwork and piping coordination drawings or over-current protection coordination studies, to verify that equipment installations conform to the design intent and are easily accessible for on-going maintenance.

6. Equipment O&M Manual Review

(See construction phase activity C7 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning specification must require that the contractors submit operations and maintenance (O&M) manuals within two to three months after approval of all equipment submittals. Within the scope of systems being commissioned, the commissioning authority reviews all O&M manuals for completeness, accuracy, clarity, and project-specific customization. The commissioning authority may also gather test parameter data for use during final functional testing. The O&M manuals are then available for use during training.

b. The O&M manual review is project-specific and cannot be completed until the coordination drawings and equipment submittals have been reviewed and accepted.

7. Review Equipment Training Plan

(See construction phase activity C8 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority works with the contractors and Yale University to establish training dates; review contractor training plans, agendas, and outlines for all equipment training sessions required by contract; and assist in customizing the training to meet the needs of the building's operations and maintenance staff. The equipment training sessions focus on the operation and maintenance of individual equipment.

b. Training is project-specific and depends on the scope of services. Commissioning authority participation in training activities must be discussed with Yale University.

c. Training cannot be completed until the coordination drawings and equipment submittals have been reviewed and accepted.

8. Test, Adjust, and Balance Execution Plan Review

(See construction phase activity C9 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority, concurrently with the designers, reviews the execution plan, calibration information, and documentation for the planned testing and balancing approach and the instruments to be used in performing the balancing work. The execution plan must be submitted before starting any balancing work.

b. In many cases, the designers specify that the test, adjust and balance (TAB) contractor submit a TAB execution plan for approval before starting their fieldwork. The commissioning authority reviews the final TAB report to finalize the functional performance test procedures.

c. The test and balance approach must address such questions as:

(1) Does the plan include the need for the balancer to obtain any equipment from the controls contractor in order to balance a system?

(2) Does the balancer know how to use the equipment provided by the controls contractor?

(3) Must the controls contractor be on-site while the test and balance process is occurring?

(4) Does the test and balance contractor understand the direct digital control (DDC) system know how to enter and override control setpoints?

(5) Does the test and balance contractor understand project phasing and the need to visit the project site multiple times in order to accommodate the phasing process?

9. Electrical Test Agency Test Plan Review

(See construction phase activity C10a on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority reviews the electrical test agency test plan to confirm that electrical testing will meet the requirements of the design intent. The test plan review compares proposed tests to International Electrical Testing Association standards and other applicable standards as required by the design intent. In addition, the review helps confirm that required test results are documented properly for acceptance and as a baseline for future operations and maintenance needs.

b. Some steps in the functional performance tests developed by the commissioning authority may require special test instruments. The electrical subcontractor may be required to retain an electrical test agency. If one is retained, the electrical test plan is required to finalize functional performance tests procedures.

10. Technical Design Review

(See construction phase activity C10b on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority reviews and comments on the designs at several stages. The reviews focus on the ability of the designated systems to achieve the design intent criteria. The commissioning authority also reviews the design documents for clarity.

b. Technical design reviews are specific, may be multi-disciplinary, and might not be required on all projects. The decision to a conduct a review should be based on the size of the commissioning project. Participation by the commissioning authority in technical design reviews must be discussed with Yale University.

c. The following three technical design reviews serve as representative examples of the types of reviews that may be conducted.

(1) Short-circuit and power coordination study review.

(2) Electrical system short-circuit analysis review.

(a) The commissioning authority confirms that the study reports include adequate detail and that the resulting documentation provides an adequate reference for system evaluation, operations, and maintenance. The commissioning authority confirms also confirms that the study includes a comparison between short circuit analysis results and equipment ratings, which ensures that the supplied distribution equipment meets specification requirements.

(b) Documentation in the reports should include one-line diagrams, explanation of assumptions, utility-provided data, computer analysis program data, manufacturer's time current curves, original equipment manufacturer cut sheets, a listing of all final settings, and an explanation for the final settings of each function.

(3) Electrical harmonic study.

(a) The commissioning authority reviews electrical harmonic studies when 50 kva or greater variable-frequency drives are proposed for the project. The studies must be based on IEEE 519-1992 standards.

(b) System one-line input data includes emergency generator and primary fault current data. The study must include:

- All input data and assumptions
- An explanation of the method used to perform the analysis
- All calculations and computer analysis printouts
- Each point of common coupling on the secondary side of the transformer that feeds that group of drives meeting the required limits
- A system impedance diagram based on the one-line diagrams
- A detailed description of the tests and procedures to support the calculations

11. Preventive Maintenance Retrieval Forms

(See construction phase activity C11 on the Yale University Commissioning Process Flow Chart.)

a. During construction, the commissioning authority collects and reviews the completeness of the data retrieval forms submitted by the contractors for each piece of equipment associated with the systems being commissioned.

b. The commissioning authority tracks, receives, reviews, and accepts the equipment data retrieval forms submitted by the contractors. Acceptance is based on the contractors' forms being complete and meeting the specification requirements.

12. Field Record Drawing Review

(See construction phase activity C12 on the Yale University Commissioning Process Flow Chart.)

a. During construction, the commissioning authority must review field record drawings ("red-lines") periodically—typically monthly. These reviews confirm the accuracy and completeness of the red-line markups prior to concealment of system elements. Attention is given to the locations of critical O&M items, such as shutoff valves, fire/smoke dampers, disconnect switches, control system instrumentation, terminal units, and access panels. Except where gross deviations are obvious, attention is not focused on the actual pipe and duct locations, if the general routing is depicted accurately.

b. At the completion of construction, the commissioning authority compares the final as-built documents to the red-lined drawings previously reviewed and approved in the field.

13. Equipment Training Session Scheduling and Verification Testing

(See construction phase activity C16 on the Yale University Commissioning Process Flow Chart.)

a. As construction of the systems approaches completion, the commissioning authority conducts a commissioning team meeting to develop a detailed verification testing schedule.

b. The commissioning authority convenes a meeting with the contractors and O&M supervisors to schedule the equipment training sessions. The commissioning authority also assists ion coordinating training events to meet the needs of all participants and to ensure that resources are used effectively.

14. Systems Training Planning

(See construction phase activity C20 on the Yale University Commissioning Process Flow Chart.)

In addition to assisting with training coordination, the commissioning authority, in conjunction with the design engineers, provides additional training for the O&M staff on the design intent of the systems being commissioned. The design intent training includes a detailed review of how the systems and sub-systems work together. The training also includes a walk-through of each building to ensure that O&M staff members are familiar with the systems and with the associated control devices.

15. Final System Readiness Checklist Development

(See construction phase activity C21 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority makes any necessary revisions to the systems readiness checklists based on the final approved submittals and all project changes, such as change orders, architectural supplemental instructions, and proposal requests. The commissioning authority submits the final system readiness checklists to the contractor for use in performing final system checkouts.

b. The commissioning authority finalizes the checklists based on comments received during preliminary development.

16. Final Functional Performance Test Procedure Development

(See construction phase activity C21 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority, after having reviewed the approved project submittals and all project changes, such as change orders, architectural supplemental instructions, proposal requests, revises the preliminary functional test procedures to reflect the as-installed and as-programmed conditions. The contractors review their respective final functional test procedures before conducting the tests.

b. The commissioning authority finalizes the functional test procedures and issues them for testing, based on comments received during preliminary development.

G. Acceptance Phase Commissioning

1. Equipment Training Oversight

(See acceptance phase activity T1 on the Yale University Commissioning Process Flow Chart.)

a. The contractors deliver their respective O&M equipment training sessions. The commissioning authority is not always asked to attend and witness all of the training. Yale University's trainee representative must formally accept each training session, in writing, as being in compliance with that session's training plan. The commissioning authority collects and compiles the training plan/ agenda forms.

b. Training is project-specific, depending on the scope of services. The commissioning authority may not participate in training activities. Commissioning authority participation must be discussed with Yale University.

2. Systems Training

(See acceptance phase activity T2 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority plans and leads the delivery of Systems Training to supplement the equipment training provided by the contractors. Systems training consists of an explanation of the Design Intent Documentation and how the Designers' systems achieve the stated criteria. The goal of this training is to convey how all of the individual pieces of equipment are uniquely configured to operate as a "system." Such training is best delivered before the functional testing is performed, because the operators can then witness the tests and get as close to "hands-on" systems training as possible before the systems are turned over to them.

3. Contractor Test Report Tracking and Review

(See acceptance phase activity T3 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority reviews the Contractors' Test Reports to verify that each test is within the acceptable parameters identified in the contract documents. The commissioning authority maintains a current status log of all Contractors' Test Reports required to be submitted as part of the project. System functional testing must not occur until the Contractor Test Reports have been submitted and approved by the commissioning authority.

b. This cannot be reviewed or accepted until completed Equipment Startup Reports have been submitted by the Contractor to the commissioning authority.

4. Test, Adjust, and Balance Report Review

(See acceptance phase activity T4 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority, concurrent with the Designers, reviews the Report(s) submitted by the TAB contractors as they complete their work on individual systems (not all systems need to be balanced before the reporting process begins). The commissioning authority verifies that all required data has been collected and that the measured results are in compliance with the specification and the Design Intent. The commissioning authority also verifies that all air and hydronic systems have been adjusted and are reported to be within the acceptable design values.

b. The test and balance report also identifies specific system deficiencies that prevent proper balancing of a system. As a result, the commissioning authority issues a Corrective Action Report (CAR) to track the deficiency to resolution. The test and balance contractor is responsible for revisiting the system balancing after the deficiencies have been resolved.

c. TAB completion is required before the contractor can complete the System Readiness Checklists.

5. Test, Adjust, and Balance Field Verification/Spot Check

(See acceptance phase activity T5 on the Yale University Commissioning Process Flow Chart.)

a. Upon completion of testing and balancing, and the commissioning authority's review and approval of the test and balance report, the test and balance contractor re-measures a random sample of air flow values and hydronic flow rates documented in the test and balance report under the direction of, and witnessed by, the commissioning authority.

b. This is project specific and might not be included. Commissioning authority participation must be discussed with Yale University.

6. System Readiness Checklist Tracking and Review

(See acceptance phase activity T6 on the Yale University Commissioning Process Flow Chart.)

a. The Commissioning Specification includes the Systems Readiness Checklists and must be completed by the contractors as formal notification that each system is ready for its respective verification test procedure. These checklists recognize that "systems" are usually a collaborative effort of more than one subcontractor. As such, all contractors who have a role in successfully completing a system sign-off on a single checklist that their part of the system is complete.

b. The commissioning authority reviews the checklists to verify that they are complete as they are submitted. The commissioning authority maintains a current status log of all System Readiness Checklists required. System functional testing cannot occur until the System Readiness Checklists have been submitted and commissioning authority has approved them.

c. System Readiness Checklists cannot be completed until TAB reports have been reviewed and accepted. Testing cannot commence until completed SRC's have been submitted and accepted.

7. Direct and Document Functional Performance Testing

(See acceptance phase activity T15 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority coordinates functional testing with the responsible contractors and Yale University's operations and maintenance staff. During the functional testing process, the contractors are responsible for performing the functional tests under the direction of the commissioning authority. Yale University O&M staff are encouraged to participate in the testing as the culmination of their training program. The commissioning authority documents the results of the all functional tests.

b. The witnessing of testing cannot begin until the contractor has submitted and the commissioning authority has approved all necessary information and documentation.

8. Submit Daily Test Reports

(See acceptance phase activity T16 on the Yale University Commissioning Process Flow Chart.)

Upon completion of testing each day, the commissioning authority prepares a summary Verification Test Report for that day. This report lists the tests performed, describes the results, and provides immediate feedback to all commissioning team members.

9. Corrective Action Reports and Logs and Correction of Deficiencies

(See acceptance phase activity T17 on the Yale University Commissioning Process Flow Chart.)

a. For each deficiency found during testing, the commissioning authority prepares a Corrective Action Report (CAR) for communicating, tracking, and documenting the status and correction of each deficiency. The commissioning authority maintains a Corrective Action Report log to track the status of each CAR.

b. The commissioning authority gives the CAR to the Contractor who, upon correction of the problem, returns the form to the commissioning authority with an explanation of steps taken resolve the issue. Upon receipt of the completed CAR, the commissioning authority schedules and coordinates retesting with the contractors and Yale University O&M staff. The commissioning authority issues a functional test report summarizing the retesting efforts, plus any new CAR after each day of retesting. See a sample CAR and CAR Log in the sample specification.

10. Trend Log Evaluation

(See acceptance phase activity T18 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority identifies specific systems that require trend logs. Trend logs provide four forms of documentation: two are measures of system evaluation and two provide long-term records.

b. Trend logs:

(1) Prove the functionality of the digital control system to collect regular and continuing real time values, and proves the selected sensors work as expected.

(2) Reflect the performance of the mechanical and electrical systems the sensors represent. Comparing the data to similar units and to the DID affirms that the system is performing correctly.

(3) Establish a history of normal operations.

(4) Provide a detailed record of the test changes and resultant responses during functional testing.

c. This is project specific and might not be included for the commissioning authority to review. Commissioning authority participation must be discussed with Yale University.

11. LEED Recommissioning Management Manual

(See acceptance phase activity T20 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority gathers and assembles contributions from all commissioning team participants, organizes the information, prepares the recommissioning manual to meet LEED requirements, and presents the manual to Yale University.

12. Final Commissioning Report

(See acceptance phase activity T21 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority prepares the report and includes an executive summary followed by copies of the Commissioning Plan, Design Intent Document, Commissioning Specifications, O&M Training Record, Functional Performance Test Reports, and Corrective Action Report Log. In addition, the report incorporates appendices that include Design Reviews, System Readiness Checklists, Corrective Action Reports, and blank Functional Test Procedures for future recommissioning activities.

H. Warranty Phase Commissioning

1. Deferred Test Procedures and Associated Deficiency Tracking

(See warranty phase activity W1 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority schedules and coordinates all system functional testing that could not be completed during the acceptance phase because of issues such as seasonal constraints, construction phasing, or tenant fit-out. Trend logs for deferred testing must be included. Similar to the initial functional testing, all deficiencies discovered during the deferred functional testing process must be tracked, logged, and brought to resolution.

2. 10-Month Checkup and Lessons Learned Facilitation

(See warranty phase activity W2 on the Yale University Commissioning Process Flow Chart.)

a. Ten months into the typical twelve-month warranty period, the commissioning authority convenes the commissioning team to meet with Yale University staff. At this meeting, the commissioning team s solicits operation and maintenance staff comments, suggestions, and areas of concern regarding the systems and systems operations. The meeting generates the following:

- Warranty items to address
- Requests for system modifications to better meet operator and building occupant needs.
- lessons the team learned that can be applied to future projects.
- Systems training review

b. This is project-specific and may not be included. Commissioning authority participation must be discussed with Yale University.

3. Benefits of Commissioning Analysis

(See warranty phase activity W3 on the Yale University Commissioning Process Flow Chart.)

a. The commissioning authority documents specific examples of how the project benefited from the commissioning process, including deficiencies discovered during the commissioning process. The analysis also documents how the commissioning process, including training, affected the ability of the building operators to control their building more efficiently.

b. This is project-specific and might not be included. Commissioning authority participation must be discussed with Yale University.

4. Amendment to Final Commissioning Report

(See warranty phase activity W4 on the Yale University Commissioning Process Flow Chart.)

The commissioning authority updates the final commissioning report to include the results of warranty period activities, including deferred testing. Recommendations made as a result of the 10-month checkup are summarized in the final commissioning report.

End of Section

01820

Demonstration and Training

This document provides design standards only, and is not intended for use, in whole or in part, as a specification. Do not copy this information verbatim in specifications or in notes on drawings. Refer questions and comments regarding the content and use of this document to the Yale University Project Manager.

CONTENTS

A. Summary

This section contains administrative and procedural requirements for conducting system, subsystem, and equipment demonstrations and training.

B. Training Requirements

Before occupying the building, the facilities staff must be trained and fully capable of operating and maintaining building systems, subsystems, and equipment in accordance with the design intent.

C. Submittals

Submit the following demonstration and training documents to Yale University and designers for review and approval.

- Training plan
- Training materials

1. Training Plan

Develop and submit a training plan four weeks before the start of scheduled training that addresses the proposed training content and scope, instructional strategies, scheduling, resource requirements, and contingencies. Yale University will review the plan and discuss it with the training provider during the pre-training conference.

a. Training Content and Scope

(1) Provide the learning objectives for each classroom and hands-on training session. The learning objectives must describe observable and measurable behaviors (knowledge and skills), written in terms of what the trainees will know and be able to do following training.

(2) Provide a topic outline identifying all systems and equipment and listing the major topics and sub-topics in the order in which they will be presented during the training session.

b. Instructional Strategies

Describe the instructional methods planned for the training (classroom presentations, hands-on training, operational demonstrations, site walk-throughs, simulations and/or learning activities).

c. Scheduling

Provide a training schedule showing the proposed dates, times, location, and duration of the training session(s); the training session topic; and the name of the instructor.

d. Resource Requirements

Identify training resource needs, such as classroom space and training equipment (projectors, screens, whiteboards).

2. Training Materials

Prepare and submit an electronic version of all instructional materials, in native file format, for future use by Yale University. Develop the documents using Microsoft®-compatible software accessible through Windows-based operating systems.

D. Instructor Qualifications

Provide a qualified instructor for each training session. Qualified instructors must be subject matter experts with demonstrated training competence and recent, similar training experience.

E Instructional Design

1. Develop learner-centered, performance-oriented training based on the life-cycle operation and maintenance requirements of the system, subsystem, or equipment as described in the O&M manuals. Include in the training applicable O&M knowledge and skills listed in Table 1.
2. Design and develop training materials that Yale University can use to train/re-train their personnel in the future. The training materials shall include:
   - an instructional outline that reflects the sequence of instruction and that addresses the approved learning objectives,
   - visual aids or other prepared presentation materials,
   - trainee handouts, include the learning objectives, a topic outline, and appropriate drawings, diagrams, charts, tables, illustrations, and reference material.

Table 1. O&M Knowledge and Skills

System Description	• Design intent of new or modified systems, subsystems, equipment, and technology • System, subsystem, equipment, and component locations • Special design characteristics, construction features, and operational requirements • Theory and sequence of operations • Operating parameters, operating standards, regulatory requirements, limiting conditions, and performance curves • Materials and processes • Control systems, including control screens or devices; integrated sensors, switches, and other input devices • Safety hazards and precautions, including lockout/tagout procedures • Design features that mitigate safety hazards, such as guarding or other protective devices • Hazardous waste products and contaminants • Regulatory requirements and limitations, including special waste disposal and/or reclamation needs • Odors and other emissions • System, subsystem, and equipment interactions and interfaces, including utilities
Normal and Emergency Operation	• Normal operation, including startup, break-in, control, stopping, and normal shutdown • Automatic and manual control sequences • Routine, normal, seasonal, and weekend operation • Common failure modes and sudden power loss • Emergency operation, including trouble indications (error messages, warnings, alarms), emergency responses, stopping, shutdown, and abnormal or casualty operations • Required sequences for electric or electronic systems
Preventive and Predictive Maintenance	• Testing • Inspection • Adjustments, alignments, calibration, and balancing • Cleaning methods, surface care needs, and agents • Preventive and routine maintenance • Use of special tools and test equipment • Performance optimization, including how to maintain high operational reliability, economy, and efficiency; minimize noise and vibration transmission, and conduct seasonal changeover operations

Table 1. O&M Knowledge and Skills—Continued

Corrective Maintenance and Repair	• Troubleshooting • Diagnosis • Repair • Disassembly and disassembly
Consumables and Spare Parts	• Parts identification • Contractor-furnished spare parts and extra materials • Recommended “attic stock” inventory not furnished by the contractor • Recommended critical spare parts for on-site inventory • Procurement information for replacement parts, repair kits, and materials • Contact information for local suppliers and factory representatives • Lubricants, sealants, adhesives, fuels, filters, media, catalysts, chemicals, resins, desiccants, refrigerants, gases, and other consumable components and materials needing periodic replacement
Documentation	• Installation requirements • Identification systems • Format, content, and use of O&M data, manuals, and project record documents • Warranty and bond terms and conditions, points of contact, material return procedures, effective dates, expiration times, and extension options • Maintenance service agreements and other similar continuing commitments, except sales promotions

F. Instructional Delivery

Conduct training as outlined in the approved training plan. Provide an appropriate combination of classroom and hands-on instruction, using instructional methods and training materials that support the learning objectives.

1. General Requirements

a. State the purpose, and review the learning objectives at the start of each training session. Ensure that the trainees understand what they are expected to know and be able to do after completing the training session.

b. Promote active trainee involvement in discussions, and encourage them to share relevant knowledge and experiences.

c. Provide the trainees with opportunities to apply what they have learned.

d. Review and summarize the content at the conclusion of each training session.

2. Hands-On Demonstrations and Training

a. State the purpose of each operation and maintenance task; the expected outcome; the consequences of improper task performance; and the circumstances, frequency, and standards of task performance.

b. Demonstrate and describe each task step, using correct terminology and equipment nomenclature.

c. Demonstrate and explain proper use of all tools, equipment and materials.

d. Demonstrate and explain the proper use of all controls and instrumentation.

e. Provide the trainees with opportunities to learn operation and maintenance tasks by performing them, and to develop the necessary expertise through practice.

3. Safety

a. Ensure that the area is safe for training. Ensure adequate trainee supervision and strict adherence to all safety precautions to avoid injury to personnel or damage to the equipment.

b. Limit the size of the group in each training session to the number of trainees that can be safely supervised and who can hear the instructor over the background noise. Conduct additional training sessions, demonstrations, and walk-throughs, as necessary, to accommodate the total number of trainees.

c. Ensure that the trainees are wearing the appropriate attire and required personal protective equipment.

4. Session Documentation

Document the completion of each training session. Include the following information:

- Date
- Topic
- Instructor's name
- List of trainees
- Sign-off by Yale University or its designated representative

G. Training Coordination Meeting

Training providers may be required to participate in a pre-training coordination meeting to review the training plan, discuss training needs and expectations, and resolve potential problems, scheduling conflicts, and other logistic concerns.

End of Section