Part II

APPENDIX 1

Design Documentation Format

Instructions for Documenting Design Intent and Basis of Design of Energy- and Comfort-Related Systems

1 Objective

This appendix presents a format for the building designers to use in documenting the design intent and fundamental operation of the building systems they have designed. Refer to Section 0 for a narrative on the need of a written design intent and clear sequences of operation and Section 5 for an example. The design-intent documentation requested here is primarily a narrative description of the building systems, what the objectives of the systems are, and how the systems will meet those objectives. This written documentation is intended for use by the designers, the commissioning authority, the installing contractors, and the building operators. This document does not constitute the required documentation and operations manual for these systems, but is a part of the O&M manuals.

The *design intent* provides the explanation of the ideas, concepts and criteria that are considered to be very important to the owner, resulting from the programming and conceptual design phases. The *basis of design* is the documentation of the primary thought processes and assumptions behind design decisions that were made to meet the design intent. The format below merges the salient parts of the design intent and basis of design.

Following these instructions is a form that is used for structuring the format and content of the design documentation.

This design intent document format contains examples for the following issues, equipment, and systems.

1. General building design and function
   - Overview
   - Sustainable construction and environmental compatibility
   - Indoor environmental quality—thermal, air distribution, acoustics, air quality, visual quality
   - Landscaping
2. HVAC systems—general
   - Overview
   - Design conditions and load assumptions
3. Chiller system (chillers, cooling towers, pumps)
4. Boiler and heating water system
5. Roof top packaged system, including all components
6. VAV terminal units (cooling only)
7. VAV terminal units (reheat)
8. Heat recovery unit
9. Computer room AC unit
10. Daylighting controls

11. Lighting sweep control
12. Building automation system
13. Split air conditioner or heat pump
14. Emergency power system

The design documentation for components or systems not listed above should follow the general form and content of this document and should describe the system, its purpose, why it was chosen above others, how it functions, and how it relates to other components and the parameters for its operation and control, including detailed sequences of operation. For additional details, refer to *ASHRAE Guidelines 1-1989R The HVAC Commissioning Process*, ASHRAE, 1996.

The design intent document may be filled out by hand for applicable systems, with attachments when necessary, or by preparing an entirely new document using the electronic version as a template.

2 Design Documentation for This Building

Adequate documentation of the design intent and basis of design of the energy- and comfort-related systems in a building is rarely found in bid documents. It is vital, however, that design intent and sequences of operation be documented adequately. That documentation serves as the goal that testing and verification seek to achieve. In addition, the design-intent document provides valuable information over the life of the building to the different parties involved in operating, maintaining, and troubleshooting the building systems.

Following are the primary areas related to energy use and comfort for which the design intent should be defined. Under each area or building system is an outline of pertinent questions concerning what should be included in the design-intent documentation and where additional clarification is needed. Sequences of operation for all outlined dynamic systems and components should be documented. Attaching equipment manufacturers' sequences is acceptable, but these sequences will generally require additional narrative. Sample sequences are found in Section 5.

To the right of the heading for each section, the party responsible for providing the design intent is indicated, as is the phase of the design construction process during which design intent should be established. For example:

4.2 System Description — Mech Engr — *Design Dev*

The above sample heading indicates that the mechanical engineer or designer is responsible for developing the design narrative that follows the heading and that it should be completed during the design development stage. The responsible parties and design phases are sometimes abbreviated as in the table below. The phases of the design construction process are as follows.

Programming — Design team and GSA Project Manager meet with representatives of the occupuying agency or client and determine the floor area and occupancy requirements of the building.

Conceptual Design	Architect develops block diagrams, building sizing, rough space planning and sketches of exterior types. Multiple choices are provided. Mechanical and electrical designers generally have no input in this phase.
Design Development	Additional detail is applied to the block diagrams and layouts. Interior and exterior features and finishes and general HVAC system types are determined and a rough floor plan is approved.
Construction Documents	Complete architectural drawings are completed. Specifications are completed, generally using the GSA Master Spec. Bid documents are prepared.

Item	Abbreviation	Refers To
Responsible Party	Arch	Architect
	Mech Engr	Mechanical Engineer
	Elec Engr	Electrical Engineer
	Ltg Des	Lighting Designer
	Ctrls Cont	Controls Contractor
Design Phase	Program	Programming Phase
	Concept Des	Conceptual or Schematic Design Phase
	Design Dev	Design Development Phase
	Const Doc	Construction Documents Phase
	Spec Dev	Specification Development (late Const. Documents Phase)

3 The Need for Written Design Documentation

Developing a statement of design intent and basis of design (design documentation) enables the parties involved with the building to better understand the building systems and better meet their responsibilities in designing, constructing, and operating the building.

The objective of specifically identifying and developing the design intent and basis of design is to provide the parties involved with the building, at each respective stage, an understanding of the building systems so as to better perform their respective responsibilities regarding the design, construction or operation of the building.

The design documentation differs from traditional specifications in that it gives a more narrative description of the system or issue and "frames" the issue or building component with background information useful and understandable to all parties. However, design documentation often includes specifications. In general, specifications tell what is to be done on a component level, where design documentation tells why something is done and, in general, how design and operating objectives will be accomplished. Sections of the design documentation can look like specifications, especially where conventional practice is departed from, e.g., energy-efficient design and construction.

Design documentation is needed from the architect so that the design engineers can design systems and write specifications. Design documentation is needed from the design engineers and architect so that the building contractors and technicians can properly construct the building. Final design documentation is needed from the building contractors and all of the above parties so that the building operator and maintenance contractors can properly maintain the original intent of the systems' operations over time.

The design documentation evolves from more general descriptors during the conceptual design, to more specific descriptors during actual design, to in-depth and specific descriptors during the specifying stage. The design documentation is completed by fine tuning and adding further detail and specificity for some components during the as-built documentation stage. Though design documentation for some components cannot be completed until the end of building fine-tuning, it is not warranted to allow design documentation to be general or incomplete prior to construction. Design documentation should be as firm and complete as possible as early as possible. The following table outlines these concepts including the parties responsible for defining the design documentation.

Stage	Issues Addressed	Responsible Parties
Programming	The owner's and tenant's needs are identified in detail. The applicable parts of the programming report become the initial design intent.	Owner Architect
Conceptual Design and Design Dev.	Design intent clarified. Basis of design begun: overall system descriptions, objectives of systems, general methods of achieving objectives, etc.	Owner Architect
Construction Documents and Specification Development	Same as above, but in more detail, including complete basis of design: complete system & component description, specific methods of achieving system objectives, design & load assumptions, applicable codes and standards, complete sequences of operation and control strategies	Architect Design Engineers
As-Built Documentation	Same as above, plus: Adjusted sequences with final control parameters	Design Engineers Installing Contractors Building Operator Architect

4 Sequences of Operation

Detailed written sequences of operation shall be developed with the following components clearly and completely described for each piece of dynamic equipment:

- An overview of the system (1 or 2 paragraphs) generally describing its purpose, components and function
- All interactions and interlocks with other systems
- Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable

- Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included, but will generally require additional narrative.)
- Startup sequences
- Warmup mode sequences
- Normal operating mode sequences
- Unoccupied mode sequences
- Shutdown sequences
- Capacity control sequences and equipment staging
- Temperature and pressure control: setbacks, setups, resets, etc.
- Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
- Effects of power or equipment failure with all standby component functions
- Sequences for all alarms and emergency shut downs
- Seasonal operational differences and recommendations
- Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful to know during testing and operating the equipment
- Planned schedules, if known
- All sequences shall be written in small statements, each with a numerical number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

5 Example Design Narrative and Sequences of Operation

Part of the design documentation involves providing a brief overview of the system in narrative form. This is very appropriate at the beginning of the sequences of operation. The following is an example for a simple packaged boiler system with some interface with the building automation system (BAS). Additional examples are found in the Guide Specifications.

Packaged Boiler Control Sequence—Example

System Overview

The boiler water system serves the space heating needs of the entire building. Heating is achieved through reheat coils in every terminal box. There are two atmospherically vented packaged boilers which work lead / lag: one boiler when outside air temperatures are less than 65F and both boilers at temperatures below 45F (adjustable). The boilers work to maintain a constant temperature output (currently 170F), and delivery to a 3-way mixing valve which mixes return water to maintain a hot water loop temperature setpoint. Each boiler has two burners and two stages of fire per burner. There are three levels of capacity: 1) both beds low fire, 2) one bed high and one low, 3) both beds high fire.

The water is delivered by two constant speed pumps, one for each boiler. Upon failure of the lead pump or boiler, the lag will start. Most coils have 2-way valves. There are a few that have

3-way valves to allow constant speed on the pumps. Each boiler has a small blend pump that circulates water through the boiler whenever the boiler is enabled.

The boiler has packaged controls that regulate the temperature of water it is supplying to the 3-way valve, prior to mixing. Those sequences are listed in Part I, below. The building automation system (BAS) enables the boiler, controls the temperature of the supply loop through a 3-way mixing valve and performs boiler lead/lag control and hot water temperature reset. Those sequences are listed in Part II, below.

Seasonal Settings

It is expected that the boilers will be shut off during summer. During the swing seasons, if the boiler will be enabled, the firing rate control should be set as low as possible. According to Proctor Sales who supplied the boiler, condensation can occur and be a potential problem if the Firing Rate Control setting is below 160F. If the control is ever raised above 170F during winter, it should be lowered back to 160F during spring and fall, to minimize energy use. The loop temperature (via the BAS) should be kept as low as possible and is automatically changed via a reset strategy.

Part I. Packaged Boiler Controls

Once the boiler is enabled, it tries to maintain the temperature of the output, prior to the mixing valve, at the boiler Operating Control Setpoint, in the following manner.

1. When the heating water system is enabled, via the outside air temperature setpoint (initially 65F) in the BAS, the lead boiler comes on with both burners at the high firing rate.
2. Once the water temperature climbs to the low limit setpoint of the Firing Rate Control (initially at 150F), one burner bed drops to low fire (less gas pressure). The low limit setpoint is the main dog on the low limit dial.
3. If the temperature continues to climb to the high limit setpoint of the firing rate control (initially at 160F), the other burner bed drops to low fire.
4. If the temperature continues to rise to the Operating Control setpoint (initially set at 170F), the boiler cycles OFF.
5. Upon cooling, when the temperature lowers to the Operating Control Setpoint minus the differential of 10F, the boiler starts at low fire on both beds.
6. If the temperature continues to drop to the high limit of the Firing Rate Control setting minus a fixed 10F differential, one burner bed goes to high fire.
7. If the temperature continues to drop to the lower setting (via the differential dog) of the Low Firing Rate Control setpoint, the other burner goes to high fire.

Setting recommendations: 1) Set the Operating Control Setpoint. 2) Set the High Limit of the Firing Rate Control 10F to 15F lower than the Operating Control Setpoint. 3) Set the main dog of the Low Limit of the Firing Rate Control 10 to 15F lower than the High Limit (of the Firing Rate Control), 4) Set the differential dog of the Low Limit of the Firing Rate Control to 5 to

15F below the Low Limit. 5) Set the High Limit Safety to 30F above the Operating Control Setpoint.

Boiler Safeties

8. Loss of power will shut burners OFF.

9. Low water level sensed via the water low limit control will shut burners OFF (manual reset required).

10. If the operating control fails or the sensor is bad, and the water temperature goes to 200F, the safety high limit shuts the burner off. Manual reset is required.

11. In all of the above three cases, the BAS will be sent an alarm.

12. If the electronic ignition tries to light the pilot and a flame is not sensed, the main gas valve will not open.

13. **Sensors.** The high limit safety, the Operating Control and the Firing Rate Control all have their own sensors.

Part II. Building Automation System Controlled Boiler Sequences

14. When the outside air temperature (OSAT) is less than the OSAT setpoint, initially at 65F (adjustable), the lead boiler and its integral blend pump and its associated heating water pump will start. Whenever a boiler is enabled, its associated hot water pump shall run and the lag boiler will be isolated by a automatic valve. Boilers are not scheduled by time.

15. The lag boiler isolation valve will open and the lag boiler and associated pumps will start when the OSAT is less than 45F (adjustable).

16. Via pump status monitoring, after the boiler system has been enabled and the lead pump ON status has not been established within 30 seconds, the lead pump shall stop, the lag pump shall be started and an alarm generated.

17. Via boiler status monitoring, after the boiler system has been enabled and the lead boiler ON status has not been established within 30 seconds, the lead boiler shall stop, lead boiler isolation valve close, lag boiler isolation valve open and the lag boiler shall be started and an alarm generated.

18. During unoccupied periods, during night low limit operation, the boiler will cycle ON and OFF with the air handlers to maintain the night low limit setpoint.

Hot Water Mixing Valve Control

19. The 3-way mixing valve in the hot water supply is modulated to mix return water with boiler-supplied hot water to maintain a hot water supply temperature (HWST) based on the OSAT, according to the following proportional reset schedule:

OSAT	HWST
23F	180F
70F	140F