Design Phase Requirements of Total Building Commissioning

Chad B. Dorgan, P.E.
Member ASHRAE
Charles E. Dorgan, P.E., Ph.D.
Fellow ASHRAE

ABSTRACT

Due to significant problems with the quality of construction and the associated costs, delays and problems, the total building commissioning process has been developed and successfully applied in North America. To obtain the maximum results, a key focus of the total building commissioning process is during the development and completion of the design. In this paper, the tasks required during the design of a building to ensure the owner's requirements are met are presented.

INTRODUCTION

Since the early 1980's when ASHRAE Guideline 1 – *The HVAC Commissioning Process* was first being developed, there has been a slow evolution of how buildings are planned, design, constructed and operated in the United States. Disappearing are the days of high change order costs, blown schedules, and buildings and systems that do not work. Instead, owners are now receiving what they expect from day one within budget and on time.

Commissioning is being used as the quality process to plan and procure buildings and systems – commonly referred to as total building commissioning (TBCx). A key distinction of TBCx is that it is the process used and is not an add-on service to the existing process. No individual system can be commissioned alone; TBCx requires that the interdependence of building systems be addressed. However, the commissioning process can be used while focusing on a selected system or systems.

Chad B. Dorgan is President, Dorgan Associates, Inc., Madison, WI; Charles E. Dorgan is Professor Emeritus, Engineering Professional Development (EPD) Department, University of Wisconsin, Madison and Senior Consultant, Dorgan Associates, Inc., Madison, WI.

The design phase of a project is vital to the successful application of the TBCx process. This is when all of the decisions on the look, feel, and functionality of a building and it's systems are made. In this paper, the key TBCx activities that are completed during the design phase are identified and reviewed. This includes a review of the design process, the development of the design intent and basis of design, the use of design tools to ensure quality, and the development of the project specifications.

THE DESIGN PROCESS

The commissioning process avoids the old problem of "over-the-wall" design where the designer takes the owner's requirements, completes the drawings, and then "throws them over the wall" to the contractor to build. There is lack of communication in this old way of doing things that has often been the source of the majority of construction and operational problems. The manner in which the commissioning process avoids these problems is through increased communication and the use of design tools.

To implement a quality design process:

- Clearly document the owner's requirements and constantly refer back to these requirements throughout the design.
- Clearly document the assumptions made and provide these to the owner and contractors so they understand the physical limitations of the building and it's systems.
- Maintain responsibility for quality where it is determined – at the individual designer level.
- Verify the quality of the designers' documents using a clearly documented procedure focusing on the ability of the documents to meet the owner's design intent.

As can be seen from this list, the key focus of the commissioning effort is to document what is expected and to ensure that it is achieved – like any quality process. Designers still accomplish their tasks as they always have; therefore, the impact on the project cost is minimal. Many designers already document their work and assumptions, but this information is not provided to the owner for future

reference and use. The commissioning process ensures the information is recorded and supplied to the building owner.

DESIGN INTENT

The design intent is often considered the heart and soul of the commissioning process. When the design intent is absent, the owner, designer, contractors, and operation and maintenance (O&M) personnel each see the requirements for the building and their responsibilities differently. Unfortunately, while it is critical for a successful project, the design intent is rarely developed and explicitly stated.

The following sections detail an example format to follow in developing the design intent and a discussion on how to obtain the required information.

Format

While there have been many formats used for presenting the design intent criteria, one that has been well received by owners, designers, contractors and O&M personnel goes from general to specific (project to system) and is organized around the systems on which the process focuses. The key sections of a design intent document are:

- Background – A narrative description to provide context about which the project was completed.
- Objectives – For any project there are goals that must be met for the project to be considered successful. This can range from cost, to time, to number of change orders or life cycle cost. Regardless of what it is, it is summarized up-front for all to see.
- Green building concepts – This is an optional section for those owners wishing to focus on the sustainability aspects of their building.
- Functional uses and requirements – In addition to the documentation produced by the architect on the functional uses of the building (office, storage, kitchen, etc.), the specific

requirements for each functional area are documented. This can include such items as comfort and indoor air quality.

- Lifespan, cost and quality – It is important to clearly document the owner's expectations for the lifespan of materials, the expected cost to pay and the level of quality desired. By providing this information, unrealistic expectations are identified and eliminated.
- Performance criteria – Often the most difficult to define, the performance criteria details those items encompassing efficiencies and costs.
- Maintenance requirements – The maintenance requirements are a mixture of the level of knowledge of the current O&M personnel, either internal or external, (what can they maintain) and the expected complexity of the proposed systems (what they can learn). If there is a significant gap between the two, no matter how well the building is constructed, it will not be maintained or operated properly.
- Set-points – Specific set-points for each functional use area must be defined. This includes temperature, humidity, airflow, light, noise, and aesthetics (materials and colors). Typically upper and lower limits are provided for general spaces, with exceptions noted as required.
- Comfort problems to avoid – Since the comfort of the occupants is one of the main complaints in buildings, it is important to identify and document those comfort problems that have caused problems in the past. If these are not documented and the problem recurs, the occupants often see the entire project as a failure.
- Specific occupant requirements – More for miscellaneous items, this section details those items important to the various occupants in a building. In speculative-built buildings, this section would detail the limits of what occupants can do in the spaces. For example, a chemical laboratory cannot be put in a space designed and constructed for general office use without significant changes to the systems and possibly the building as a whole.

Obtaining the Information

While it is easy to obtain the information required to develop the design intent, it is difficult to obtain quality information that the owner, O&M staff and occupants all agree to. In quality processes, it is critical that input is obtained from all the users (user groups) and that consensus of the group is documented. This is not to say that the owner does not make any decisions. However, the owner and the rest of the commissioning team must be aware of all the requirements so that the final product will meet as many as these requirements as possible. A simple three-step process is used to develop the design intent:

1. Design Intent Workshop
2. Design Intent Documentation
3. Project Team Approval of the Design Intent

Design Intent Workshop

The design intent workshop, typically facilitated by the commissioning authority (CxA), elicits the primary concerns of the project team. The workshop is organized to identify all requirements, to encourage interaction and discussion among all team members, and to result in-group consensus of priorities for the design intent. This is accomplished through the presentation of multiple questions in an ordered structure:

- Provide question to each individual
- Five minutes of quiet writing time for each individual to respond with as many answers as they can
- Record individual responses in a round-robin fashion – no discussion at this point, just record the responses
- Review all responses, consolidate similar ones, and clarify so group has same understanding of all responses
- Individuals rank the responses for importance (1 through 5)

- Group ranking determined from individual rankings

The questions asked during this workshop must be broad in nature, elicit discussion, result in a variety of viewpoints, and do not lead the workshop. Therefore, the questions should not focus on such items as “at what temperature are you comfortable?” but should be broader, such as “how do you define comfort?”

Design Intent Documentation

The design intent workshop will provide the key items and priorities important to the project team. However, it does not provide specific values. For example, the number one design intent criteria may be good air circulation in the rooms. It is the responsibility of the CxA to take the individual criteria developed by the project team and translate them to physical properties that can be measured, designed and documented.

This transformation of the design intent often requires input from a variety of sources, including the design team, architects, engineers, contractors, specialists, standards, and guidelines. Typically, the CxA has experience in the planning, design, construction and operation of facilities to provide the oversight of such a task. If not, then experts are retained to aid in the development of the design intent.

Project Team Approval of the Design Intent

After several iterations and reviews of the design intent by the project team, they must approve it for the purposes of providing the design team adequate direction for their design. It is important to distinguish the design intent from the traditional role of the architect in the planning process. The design intent is defining the criteria required for success, whereas the architect’s document is capturing specific space size and flow requirements. Where the design intent may state that the functional use of the facility is X, Y, and Z, the architect’s document will specify the locations, size and flow of people through X, Y, and Z.

BASIS OF DESIGN

The basis of design is typically developed by the architects and engineers (A/E) to document their assumptions made during the design process. This includes codes, standards, design points, materials, manufacturers, and model numbers. It is important to capture this information so that the O&M staff and future A/E's can understand the limitations of the building during optimization and renovation. The main sections of a basis of design document are:

- Selection of system components – In this section, the reasoning behind the selection of each of the components chosen in the building is detailed. Typically, the focus is on the larger items (chillers, boilers, pumps, wall material, window type), but there are times when smaller items are detailed (the use of a specific door latch due to its unique characteristics).
- Maintainability – The assumed maintainability of a system is documented in this section. The reason for this is to ensure that the A/E team does not design a low capital cost, but high maintenance cost system without identifying the impact to the owner.
- Codes and standards – All codes and standards used are detailed in this section. This includes not only the title and year, but also the specific section and values chosen. For example: ASHRAE Standard 62-1999, *Ventilation for Acceptable Indoor Air Quality*, Office Space Ventilation = 10 L/s, Table 2, page 7.
- Fire and life safety – The fire and life safety assumptions are explicity included to ensure proper coordination between the various design disciplines and to properly convey assumptions to the contractors and owner.
- Assumptions – The remaining assumptions made by a designer are documented in this section. The general guidance to be followed in this section is to include any information required to make calculations or to re-design the system when future renovations are required. The following table is an example extracted from an assumption table for mechanical systems. The actual table had 61 entries.

Item	Description	Value
a	Latitude/Longitude	41.7°/86.3°
b	Elevation	773 feet
c	Clearness number	0.85
d	Summer outdoor air design dry bulb/wet bulb	89°F/73°F
e	Winter outdoor air design dry bulb	1°F
f	Ground reflectance	20%
g	Cooling setpoint	75°F/85°F[1], 50% rh
h	Heating setpoint	70°F
i	Cooling/heating setback temperatures	95°F/55°F

DESIGN TOOLS

TBCx is based on general quality principles and implements several tools throughout the process. These include the previously described design intent and basis of design, and the use of designer checklists. Designer checklists are developed uniquely for each project and are provided to the A/E team to help them ensure the level of quality of the documents. The checklists are used because the quality of a design can only be determined by one person – the person actually accomplishing the work. In many design firms, the person working on a project varies over time, and each individual working on the job may not know the specific requirements of the owner.

The designer checklists detail those items important to the owner (owner's design intent) for use by the individual worker. Prior to any submission to the owner from the A/E, the designers must complete the checklists to verify internally that the design intent has been met. While many A/E firms have some form of this checking already in place, their procedures are often general in nature and do not focus on the specific requirements of the owner.

PROJECT SPECIFICATIONS

The final TBCx item to be completed during the design phase is the integration of the commissioning requirements into the project specifications. Since TBCx is the process being used to plan, design and build the facility, there is not an explicit commissioning section. Instead, the requirements of the contractor to construct a quality facility are integrated into the specifications. This includes submittals, O&M manuals, and training.

Submittals

In addition to the typical submittals received on components and equipment, TBCx requires the following:

- Part load operating data – this is required to ensure that the system can be evaluated at off-design operating conditions as the system is rarely tested at design conditions.
- Installation and O&M manual from manufacturer – this is required to properly tailor the construction checklists (similar to designer checklists, but for the contractors) and the functional performance tests to the specific manufacturers.
- Warranty information – this is required at time of submittal to ensure the specifications are met and identify any unique O&M requirements to maintain the warranty.

O&M Manuals

Since the equipment to be installed is known once the submittals have been approved, it is possible to develop and approve the O&M manual for the facility well in advance of occupation. Therefore, in the TBCx process the O&M manuals are due 30 to 60 days after submittal approval. The O&M manual is organized by specification section (i.e. chiller) so the development of the manual can be piecemeal.

The O&M manual is submitted to the A/E, owner and CxA for review and approval. Once approved, the manual is used for training purposes throughout the construction process.

Training

The final item to be addressed in the project specifications is training. Often, training is specified strictly as “provide 8 hours of training on the chiller.” In TBCx, training is detailed to provide the contractor specific guidance of what is required to properly turn over the facility to the O&M staff. This typically includes training agendas, type of training (classroom, hands-on, factory), level of training, knowledge of O&M staff, and time for training (throughout construction and 1st year of operation).