COMMISSIONING HANDBOOK

TÜRKİYE CUMHURİYETİ
ÇEVRE, ŞEHİRCİLİK VE
İKLİM DEĞİŞİKLİĞİ BAKANLIĞI

KABEV
KAMU BİNALARINDA
ENERJİ VERİMLİLİĞİ PROJESİ

Contents

Abbreviations (in Alphabetical Order of Abbreviations)

ABBREVIATION	STANDS FOR
ABS (chiller)	Absorption chiller
Cx	Commissioning
DDC	Direct Digital Control
FCU	Fan-Coil Unit
HVAC	Heating, Ventilation, Air Conditioning
WP	Work Package
MCC	Motion Control Cabinet
M&V	Measurement and Verification
PC	Personal Computer
PIU	Project Implementation Unit
PV	Photovoltaic
VAV	Variable Air Volume
VSD	Variable Speed Drive

1 Introduction

1.1 Document Organization

The Commissioning Handbook consists of eight chapters with appendices, including the introduction and the commissioning process and steps that are required to be implemented for the EEPB project are defined in the first chapter. Planning in the second section, tests in the third section, commissioning process output in the fourth section, measurement & verification input in fifth section, training in the sixth section, report and documentation in the seventh section and energy performance assessment in the eight section are discussed.

In the annexes of this document, there are sample forms to help those who will do commissioning.

1.2 Process Overview

The commissioning process has in this context a sequential role in the delivery and occupation of the intervened building. As has already been observed in the M&V reports there are some steps perfectly sequenced with assigned responsible and with clear objectives that must be carried out. The main flow can be summarized like this:

Step/term	Description	Start	End
Commissioning functional test	First commissioning task. The supervision consultant, along with the facility manager and construction contractor, test the operation of all retrofitted/new systems to ensure their full functionality according to the designs and specifications.	After the construction and installation are completed and the retrofitted systems are fully operational.	If all systems are functional and achieving the contract/design performance, the supervision consultant issues the *certificate of commissioning acceptance*, after signing the final commissioning completion report.
Commissioning performance test	Second commissioning task. After or during the functional test, the same team confirms that all retrofitted/new systems meet the energy performance according to the designs and specifications.		

Step/term	Description	Start	End
Provisional acceptance	The supervision consultant oversees the provisional acceptance, setting a short timeframe for correcting small defects identified during the commissioning functional and performance test.	After the supervision consultant issues the *certificate of commissioning acceptance.*	The supervision consultant issues the *provisional acceptance certificate.*
Taking over	The building owner takes over the building to resume normal operation. The construction works are accepted.	After the supervision consultant issues the *provisional acceptance certificate.*	The supervision consultant issues the *taking over certificate*.
Energy Performance Certificate	The supervision consultant issues an Energy Performance Certificate, which provides information about the building's energy classification.	After the taking over.	The supervision consultant issues the *Energy Performance Certificate.*
M&V over a 1-year period	The supervision consultant carries out M&V over a 1-year period to confirm the energy savings achieved through the renovations.	Starting on the date of issuing the *provisional acceptance certificate.*	The supervision consultant submits a M&V report after a period of 12 months.
Defects Notification Period	The supervision consultant continues to be responsible for the supervision of works during the 12-month DNP, during which any defects must be rectified.	Starting on the date of issuing the *provisional acceptance certificate.*	The supervision consultant submits the final DNP report to the client at least 30 days prior to issuing the *defects notification certificate* for the completed works. The supervision consultant issues the *defects notification certificate* 12 months after the provisional acceptance certificate.
Final acceptance	After the 1-year M&V and the DNP ends, the client accepts the works.	After the *defects notification certificate* and the M&V report are issued by the supervision consultant and approved by the client.	The client issues the *final acceptance certificate*.

***Table 2.** Process overview*

1.3 Definitions

Commissioning (Cx) is a process that has no exact equivalent in Turkish and has been described more narrowly in the construction industry over the years. Although it is tried to be explained with expressions such as commissioning, acceptance, commissioning, start-up, it is a much broader concept that encompasses all of them.

Cx is a quality-based process that focuses on verifying and documenting that the equipment and systems used during the implementation of energy efficiency measures are designed, installed, tested, and properly operated to meet the described requirements.

Cx helps to deliver a safe and healthy project, optimizes energy use, reduces operating costs, provides adequate maintenance personnel orientation and training, and provides documentation.

Cx benefits the business through high energy efficiency, improved workplace performance due to high quality interiors, risk reduction and job loss prevention.

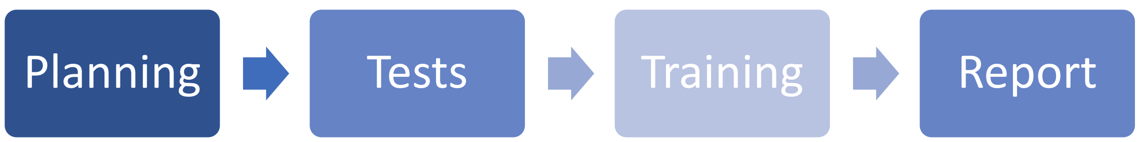
Cx is often perceived as focusing solely on testing at the end of the construction phase. But Cx is a collaborative process to plan, deliver and operate all processes so that they work as intended by the designer. Cx starts with project planning and includes design, construction, commissioning, acceptance and training, and warranty phase services.

The Cx process has four overarching principles that begin at project inception and continue throughout use and operation:

- Creating measurable project performance descriptors,
- Planning and executing the commissioning process
- Verifying and documenting compliance with requirements
- Effectively transfer all acquired knowledge to the business team

There are also different applications such as Continuous Cx (Ongoing Cx), Retro Cx (Retro Cx), Repeat Cx (ReCx).

Cx process in EEPB project consists of planning, testing, training, and reporting stages.



Scheme 1. *Cx Process for EEPB Project*

2 Planning

As with all management processes, the Cx process also requires good planning. In this context, the determination of the systems and equipment to be handled in the process and how the test and training activities to be developed on these in the next steps will be carried out should be discussed at the planning stage. Planning is the coordination and integration of systems and equipment in the Cx process with other construction phase activities. The detailed integration of the Cx works with the construction program is critical to maintaining the milestones in the project program. A responsible plan and teamwork are required for the healthy execution of the whole process. A Cx team is formed to oversee, implement, and perform Cx process activities. The leadership responsibility of the Cx team should be determined at the beginning of the project and a task assignment should be made. The term for the person generally responsible for the Cx process is "Cx Officer".

The responsibilities of the Cx team include:

a) Identify experts responsible for performing Cx activities for specific systems and assemblies.
b) Organizing a pre-construction Cx process meeting.
c) Planning the Cx process activities and integrating them into the project construction program.
d) Handling program changes.
e) Documenting and developing test procedures and data sheets.
f) Conducting and documenting Cx team meetings.
g) Monitoring compliance with project requirements by making periodic site visits.
h) Verifying completion of items specified in construction checklists.
i) Observing the tests.
j) To verify the tests and their results.
k) Verifying test data reports.
l) Verifying the training of operation and maintenance personnel and users according to project requirements.
m) Monitoring, diagnosing and documenting problems and deviations related to project requirements and documenting their solutions as well.
n) Writing and examining the progress reports of the Cx process.
o) Examining the construction progress reports.
p) Verify that new equipment and systems are incorporated into the maintenance management program.
q) Notifying all Cx team members of decisions that cause changes in project needs.

Buildings consist of static systems (eg building envelope, building structure etc.) and dynamic systems (eg HVAC, lighting etc.). During the Cx process, all systems and equipment that could have a significant impact on the building's ability to meet energy performance targets should be included in the study. Below is a typical list of systems and equipment that will be the subject of Cx works to be carried out within the scope of the EEPB project. Each project should create a list according to its specific energy efficiency measures and the systems/equipment that these measures contain, and build all test processes over this list.

Building Shell	**Cooling system**	**Electricity**	**Onsite Energy Generation**
Exterior Insulation	Chiller Units	Lighting Fixtures	Gas Engine
Windows	Cooling tower	Compensation System	ABS Chiller
Doors	Pumps	Distribution Boards	Distribution Boards
Heating system	Contraction Tanks	Transformers	Transformers
Boilers	Safety Valves	Wiring	Wiring
Pumps	Automatic Filling	Cable Transport System	Cable Transport System
Heat exchangers	Treatment System	Grounding	Grounding
Expansion tanks	Fan Coils	MCC Boards	Piping
Safety valves	Serpentines	**Automation**	PV Panels
Automatic filling	Piping	Field Equipment	PV Carrier System
Treatment system	**Ventilation system**	Wiring	Inverters
Hot water system	Air handling units	Cable Transport System	Energy Metering
Radiators, FCU	Fans	DDC Boards	Energy Monitoring Software
Coils	VAV Units	PC and Scenario	
Stack	Special Diffusers	Servo Motors	
Piping	Duct Installation	Variable Speed Drives	

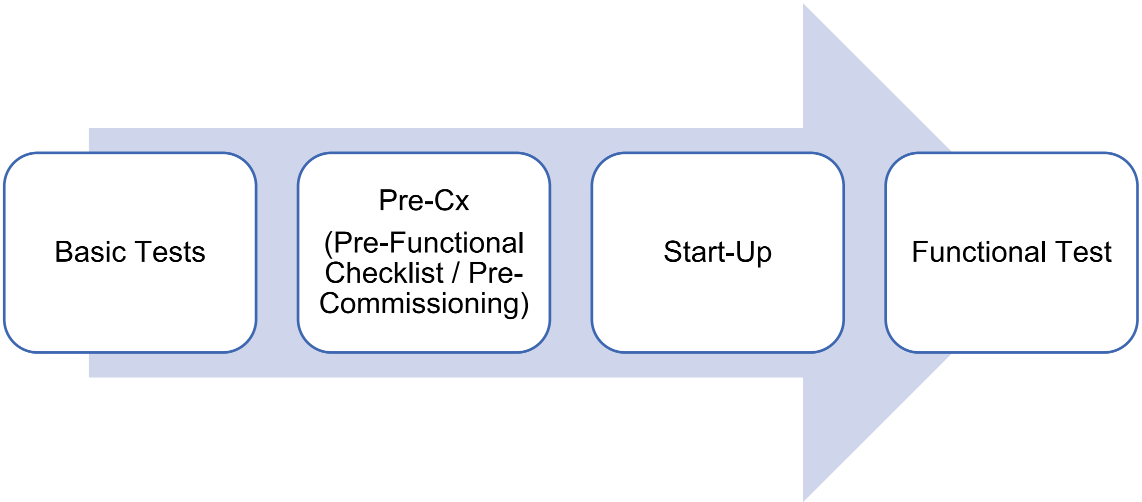
Table 2. *Sample System and Equipment List That May Be Subject to Cx Works*

3 Tests

3.1 Test Process

Within the scope of the EEPB project, activities are carried out to develop and implement solutions for more efficient energy use in public buildings. During these studies, it should be determined whether the established systems provide the expected increase in efficiency after a healthy Cx process.

In this context, the Cx test process in the EEPB project starts with the basic installation tests of the system and equipment. The process consists of the following steps:



Scheme 2. *EEPB Project Test Process*

3.1.1 Basic Tests

It covers basic installation tests for system and system equipment. At this stage, certain tests are applied for basic elements such as machinery, equipment, pipeline, cable circuit. For example, tests such as strength test for pipeline, leakage test for chimney, insulation resistance test for cable or grounding measurement will be performed in accordance with the methodology specified in the specification, and it will enable to determine whether the system is properly installed before operation and whether there is any defect in the material. With this step, problems such as water leaks that may be encountered later are prevented.

3.1.2 Pre-Commissioning (Pre-Functional Test)

At this stage, the system must be installed with all its elements, and the pipe and electrical connections must be completed. Before the first start-up, the system or equipment must be ready for commissioning with all its components. In order to determine that the equipment or system is ready, physical controls are made and the forms prepared are filled. In case of an undesirable situation or a problem that prevents the first start-up, the problem and the source of the problem, the issue log list is recorded and the problem log list is kept open until the problem is eliminated. The forms to be used in the Pre-Cx phase should be prepared specifically for the equipment and/or system installed in the relevant building. Some sample forms are included in the appendices of this guide.

It can be said that the system and/or equipment is ready for commissioning if no adverse events are encountered in the Pre-Cx phase. Afterwards, the equipment can be started up for the first time.

3.1.3 Start-Up

If the initial start-up of the system and/or equipment is to be done by the authorized service, the relevant service personnel are invited. After the service personnel make the necessary adjustments, they run the system and/or the equipment for the first time and issue the service commissioning form. Any negativity recorded in the commissioning form by the service personnel is immediately transferred to the problem record list and followed up, and this item is kept open until the negativity is eliminated. If there is no problem in the first start-up, the functional test phase is started to see whether the system and/or equipment performs its functions.

3.1.4 Functional Test

The purpose of functional tests is to observe how each equipment works according to the planned situation and to ensure that all kinds of machinery, equipment, and systems function in the desired way by eliminating the issues for unsuitable situations. Balancing (balancing), pressure settings, temperature settings, ventilation, regulations, leakage current tests, thermal examinations, etc. in systems that require need. All requirements will be met in this process. The employer or the consultant providing technical support may request additional tests and/or reports during this process. The Contractor will make the relevant tests and adjustments in this direction and submit the requested reports.
To perform functional tests on a system or equipment, firstly, the sequence of operation is determined by evaluating different situations such as the operating scenario, variations of connected elements, possible variables. In this direction, each scenario item is operated, and the equipment or system is tested whether it works in accordance with

this scenario. In case of any negativity, the related event is transferred to the problem record list and followed up and this item is kept open until the negativity is eliminated.

With the approval of the employer, functional tests can be carried out for some equipment over a reasonable sampling rate determined jointly (in cases where there are many FCU valve motors or lighting fixtures, etc., instead of 100% of the equipment or components, for example 5% representative of the general). Functional testing can be done for i or 10%).

Once an equipment and/or system has been determined to perform all its functions, it is considered to have passed the functional test.

3.2 Development of Test Procedures

Test procedures describe the devices and methods used to conduct tests performed during the construction phase. Test procedures provide the following:

a) which may include the main contractor, sub-contractors, design experts, Cx officer, operators, local competent authority and manufacturers of equipment, systems or installations; participants deemed necessary/relevant for testing.
b) Prerequisites for test performance for the completion of systems and assemblies and acceptable completion of other activities.
c) Step-by-step instructions are followed for running specific systems and assemblies under test. The instructions cover how to configure the system and assembly to start the test and how to restore the system to normal operation at the end of the test.
d) List of devices, tools and supplies required for testing. This list should indicate that participants are responsible for the items listed. List; The model must be specific to meet range, capacity, accuracy, calibration and other relevant performance requirements.
e) An indication and a set of acceptable results for each step of the recorded observation and measurement procedures.

The Cx team will develop a set of test validation procedures. These procedures should be described in such a way as to make the following verifications:

a) Component testing procedures: Component testing procedures should verify the performance of components under a set of actions and their response/response to inputs and loads.
b) System/assembly test procedures: System/assembly test procedures should verify the performance of subsystems, systems, and assembly under a range of

operating conditions (both emergency and normal), and their response/response to inputs and loads.

c) Inter-system testing procedures: Inter-system testing procedures should verify the interactions between systems and assemblies.

d) Test procedures related to the project's requirements should verify that the various systems and assemblies offered at the facility conform to the project's requirements in use.

e) Quality-based sampling should be used to validate each test identified in relation to the project requirements.

In the development of test procedures, special attention should be given to personnel safety, equipment/assembly protection, and manufacturer's recommendations to maintain warranty validity.

3.3 Development of Test Data Records

Test data records contain test data, observations, and measurements. The data may also be saved in a photograph, form, or other suitable form for the application. As a minimum, the following information should be recorded:

- Test number.
- The date and time of the test.
- Description of whether the recording is for initial testing or for retesting after a problem has been fixed.
- Description of the system, equipment, or assembly under test.
- Test was performed which conditions under. e.g; time to test, detailed description of ambient conditions, nominal values, invalidity, condition and operating conditions of instruments, systems, equipment that affect the results of the test.
- The predicted performance of systems and assemblies at each step of the test.
- Observed performance of systems, equipment, and assemblies at each step of the test. When using data forms, checkboxes are often insufficiently descriptive about system performance, so in many cases checkboxes should be avoided. Instead, a blank area into which observed or measured performance can be written provides further information for performance diagnostics and future baselines.
- Description of whether the observed performance at each step meets the predicted results.
- Other observations on system performance or test procedures.

- Issues log number generated because of the test, if any.
- Dated signature of the person performing the test and, if any, of the person witnessing it.

3.4 Test Execution

During test execution, tests can be witnessed, validation of tests or verification of reports of test data. A specific test or test sequence is performed under the supervision of the Cx supervisor. However, depending on the test type and complexity, in some cases it is possible to witness a portion of the test, validate the test through random sampling of components, and verify test data reports through random sampling of reported results.
The following must be observed at the completion of the tests:

a. Testing will be carried out according to approved written procedures. Results of test performance will be recorded and reviewed on test data sheets.
b. Deviations from approved procedures, if any, should be documented in writing.
c. Test data should be recorded under steady state and stable conditions.
d. If a problem is observed during the test, the test must be terminated under the contract. A problem report is generated during the observation. If the issue cannot be resolved within a reasonable time, it may need to be urgently tested with the agreed options in subsequent testing, after all issues have been resolved.
e. If a problem is detected during the review of its data, the problem will be fixed, or the test will be repeated in its entirety.
f. After completion of the test, the technician performing the test and the witness sign the test data records, verifying the authenticity of the recorded observations.

3.5 Systems performance

Adequate system performance requires both correct installation of the equipment and balancing and optimizing the system. So, there are two levels of analysis, the equipment and the system each of them with two step verifications, firstly the construction, assembling of the equipment and building mechanical and electrical networks, and secondly the operation behavior of the equipment.
it is not the objective of this report to teach the optimal mechanisms of individual commissioning knowledge but to draw the attention of all the actors of the important steps for not losing sight of the final objective of these projects, so we will then address the most important systems for verifying the quality of the installation and its adequacy

to the objectives of reducing energy consumption that maintaining or increasing the levels of existing service:

3.5.1 Stand-alone systems

There is some equipment were the individual components act as the system, that is, there is no significant interaction between the various components ie the equipment integral of the same system one obvious case of this example is lighting.
in these systems it is enough to follow the process already described above and check installation quality and the adequacy of the installed (vs the design). The system efficiency only depends on the individual equipment without any interaction with the other systems passive or active. In this case we may considerer, the lighting systems, the renewable production for example.
For example, the lights, especially the LED systems will always consume the same energy (if turned on) and the PV panels will only have all the important measurements always on real time given by the (normally) embedded control system.
The real effort in the second step of the Cx verification phase should be around the systems that are fundamental to check the overall building efficiency, especially as an indirect signal of the passive systems behavior. These are discussed in the next chapters.

3.5.2 Heating system

The production and distribution components should be checked individually for installation and construction (using the templates in Annexes), but also check the output quality (regarding the original design) and above all how the system work together (ie. equipment vs system). For heating systems (HVAC or sanitary hot water production) the approach is relatively simple. For DHW equipment it is important to define at least the following quantities (example only, others may apply):

- circulating water flow rates
- distribution and consumption temperatures (water side).
- production (boiler, or heat pump) water temperatures
- consumption of gas, electricity (or other mode of final energy used in production)
- distribution pressure measurement
- intermediate temperatures for renewable production and mechanical production
- effective storage capacity of the system
- flow rates consumed over a period

In addition to these measurements of quantities inherent to the system, it is also important to test and report on the operation of all control schemes of the various circuits and remote orders (if any) in the system.

In the case of heating for air conditioning or process measurements are similar however it is necessary to add the values likely to affect the performance of the system. For example, the following data is important:

- hydraulic distribution pressures (notably before and after electro pumps and before and after production equipment)
- air circuit temperatures before and after heating batteries
- Flow values (even if indirectly) in terminal and production systems
- General balancing of all air flow rates that serve heating batteries, want air treatment units want fan-coil units.
- BMS schemes, with testing and reporting of the actual operating conditions to check the input output effect in each existing operation

3.5.3 Cooling system

The commissioning of cooling systems follows in essence the same metric used in heating systems, After the analysis of the various distribution production elements and terminals from a construction and assembly perspective, the operation of the whole system shall be ensured in a coherent and complete manner. for this purpose, the following measurements (or tests) are required (only for example).

- Measurement of inlet and outlet water temperatures of production and terminal elements.
- Measurement of production water flow rates and terminal elements, which can be done indirectly through pressure drops in balancing valves.
- Balancing water flow rates, if necessary, through passive system in the installation (ie dynamic or passive valves).
- Measurement of the electrical consumption of the producing elements and hydraulic pumps.
- pressure measurement the inlet and outlet of hydraulic pumps
- measurement of temperature and air flow rates, inlet, and outlet of terminal elements
- Verification of all measured quantities in relation to the project definition.
- Validation of reporting systems to the BMS system, including alarms.

- Annalise and report possible implications of variable speed systems in the overall systema behavior.
- Verification and reporting of the control schemes of all equipment and systems.

Measurements should be adapted to the season in which they are performed. For electric consumption or for inlet and outlet temperatures, the analysis may be affected by parameters that can simulate the difference between current conditions and design conditions. It should be noted, however, that some systems are virtually independent of outside conditions, like for example distribution air systems is virtually independent of the exterior conditions so it can be run directly at any time.

3.6 Sensoring and Cx Infrastructure

In the last paragraphs, the steps to be taken in the commissioning process were mentioned and explained in a very descriptive way. It is not the purpose of this document to provide a practical guide to how effectively a contractor responsible should perform and carry out the tests and procedures indicated herein.

But in addition to the processes that must be effectively followed and documented as described in the previous chapters, it is of particular importance that there may be an infrastructure of sensors and measuring points that can help in the execution of all the tasks mentioned herein and that ensures that there is a coherent and easy communication between the behavior of the systems and who has the mission to manage this whole process.

It is critical that all sensors and meters are correctly calibrated (either from the manufacturer with a certificate or on-site following the prescribed calibration procedures).

Some items that could be defined are:

- Definition of the type and quality of data acquisition.
- Definition of type and quality of data storage and data handling
- Definition of necessary time resolution and duration (continuous or temporary) of measurements.
- Definition of performance metrics and typical benchmark values or ranges.
- Role and position in the control schematics, including narratives for operation and control sequences.
- Identification of components (uniform labelling)
- Operation manuals and guides.

This issue can be difficult to solve if the need for this sensor infrastructure was not originally foreseen in the project. it will not be after the awarded and executed project that will be raised the need to put this or that sensor or this or that communications network. it is therefore necessary that all projects consider that it is essential to create automatic systems for a reporting of operating data this objective is of particular importance in this typology of projects where it is required to periodically monitor the periodic compliance with energy efficiency requirements.

3.7 BMS

Following the previous point, we can also mention a particular case of BMS. are fundamental for the future management of systems and for obtaining real operating data. however due to the structure of these processes we can have 2 situations, the first on the list of measures to implement the creation or improvement of such a system, and on the other hand situations where this measure was not foreseen and in this case the process must be taken care of from the existing infrastructure.

In the event that a new system or remodeling of the technical management system was one of the proposed measures and is provided in the list of measurements of the project i.e. it is an obligation of the contractor to complete it is necessary to ensure that the whole system is aligned in terms of flexibility and usability with the future management objectives in this case all graphs all the historical all the screens including the schematic drawings of operation of the installation has to be easily noticeable and with optimal presentation of the actual situation on the ground. of particular importance are the exact locations of the sensor points and the real-time information of the data transmitted by them, the historical record of all the data and a point that should merit the verification and validation of the commissioning team.

there may, however, be cases where the refurbishment or introduction of the new system had not been foreseen in the work previously submitted for tender. in this case, the existence and state of use of the system should be simply checked and proposed if necessary in the commissioning reports to improve or introduce new functionalities according to the needs identified in the commissioning process.

4 Commissioning (Cx) Output

4.1 Objectives

As we have seen in the previous points the focus of the base of the commissioning tests should be the equipment. The fundamental idea is to ensure that each equipment and each system is in a state of use, that it has been well installed, and that it meets the objectives that were proposed in the design phase, especially in this situation where the whole final objective of the process and the energy saving and improvement of the conditions of energy use.

4.2 Mandatory equipment measurements data

As said before, the commissioning data, in particular the data necessary to validate the overall efficiency of each system and then the overall efficiency of the building are necessary to be able to measure at the right time (i.e.at the beginning of operation), whether we are ready to meet the basic requirements of the project. It is therefore necessary not to lose sight of the fact that the commissioning process, having its beginning in the validation of the quality of construction and assembly, continuing in the verification of compliance with the design requirements and ending in the training of users, should be able to provide the basic data for analysis of the achievement of energy efficiency objectives.

As such it is mandatory that the main equipment and its functional characteristics defined in the measures provided for in the initial energy audit are further tested and applied to the M&V principles referred to in the next chapters.

With this, all measurements and analyses shall ensure that at least the following parameters (whether direct or calculated) are obtained essences for defining the success of the project:

- Efficiency in cooling energy production and distribution
- Efficiency in heating energy production and distribution
- Renewable production and consumption (including grid injection)
- Electrical consumption of the main equipment in normal operation
- Distribution of indoor temperatures vs. outdoor temperatures
- Maintenance the increase of service levels according to initial project.
- Adequacy of BMS system

4.3 Bottom-up approach for whole building

The efficiency of each system or each equipment, such as the COP of a chiller or the efficiency of a Boiler ensure the compliance of the individual equipment in relation to the design specification, but it also becomes necessary, even by virtue of some measures that will tend to always be part of an efficiency process in buildings, such as exterior insulation, lighting, or others that have an indirect effect on installed thermal systems, analyze efficiency in global terms, i.e. how individual systems respond to the needs of the building.

5 Measurement & Verification (M&V) Input

5.1 Objectives

As described in the report on M&V, the process that is central to this project, the first phase of rapid measurement and verification of whether the proposed objectives are to be achieved is exactly in the commissioning process. the simple tasks of checking the good installation that are normal a commissioning processes and described in the first chapters of this work, must be complemented with the analysis required in the M&V process. we will not make an exhaustive description given that it has already been done in the cited report, but we will define and explain the main tasks that should be mirrored in this commissioning process.

Commissioning of installed equipment and systems is considered industry best practice. Commissioning ensures that systems are designed, installed, functionally tested in all modes of operation, and capable of being operated and maintained in conformity with the design intent (appropriate lighting levels, cooling capacity, comfortable temperatures, etc.).

Commissioning usually requires performance measurements to ensure that systems are working properly. Because of the overlap in commissioning and post-installation M&V activities, the two activities will eventually be done at the same time. The difference is that commissioning ensures that systems are installed per design criteria and functioning properly, whereas post-installation M&V quantifies how well the systems are working from an energy standpoint in support of the cost savings projections put forth by the designer/contractor.

5.2 Cx Process in the M&V Plan

5.2.1 Introduction

The measurement of energy savings must be made against the original audit baseline and should be carried away after the Cx process, when all systems are considered final, and the building is back to cruise operation. It is not the same process but because of the connection between the two, should be viewed together.

The M&V phases will be the following:

Type	Ex-post performance test

Buildings	All buildings	
When	After commissioning period	
Reporting period	1 month maximum, if not defined otherwise in the tender documents	Exact duration depending on building complexity and should be enough to picture the normal building operation. The objective is not to get final savings results, but accessing compliance to the audit requirements
Main IPMVP Option	Partial Option A or B	-
Responsible	Supervision consultant/PIU	

5.2.2 Ex-post performance test

For the ex-post analysis, which will follow the Cx process, the method should follow the project Operations Manual requisites.

Although the standard IPMVP approach is the Option C, in this project phase there is insufficient information to follow a strict M&V method, in fact there will not be enough historical data (from meters or invoices) regarding overall facility consumption with measures implemented to have data for Option C. In this case and to have a rough idea of the effect of measures taken, an estimate for the savings will be made for each individual measure, using the Option A where possible, and will be also done a quick estimation of the system efficiencies.

The idea is to Isolate the savings that can be easily (and with low margin of error) calculated by simple equipment measurements and access the overall compliance of measures construction with the original audit objectives.

For lighting and electrical motors:

IPMVP Option	A
Reporting period	Representative of the normal operation[1]
Estimated value	Operating Hours

[1] The M&V section for the ESCo Tender (1st package) writes that “The measurements will be made under the supervision of the administration for not less than 4 hours”, referring to lighting fixtures. While the 4-hour window can be followed, the main idea is that the period must be representative of the normal operation of the building, in the respective measure to be checked.

Measured Value	Absorbed Power
Sampling	Measure at least one item of the different fixtures that were changed. Measures the electrical circuits that can represent at least 10% of all fixtures.

For renewable production:

IPMVP Option	B
Reporting period	Representative of the normal operation, at least one full week
Estimated value/adjustments	Yearly production profile from design simulation
Measured Value	Intake KWh meter

Estimate for heating load related consumption:

Test made on Heating Season	Amount of energy consumed for heating is measured for at least one week (through meters for fuel or electricity intake, for example) Indoor and outdoor temperatures are recorded. The objective is to measure the ERR (heat pump) or efficiency of the boiler. Depending on the system the measurement can be done in different ways. Using just the boiler efficiency (flue gas temperature) or using the water in-out temperature vs water intake and pump performance, can be viable solutions.
Test made on Cooling Season	Thermal transmittance (U-value) measurement or calculation is made for thermal insulation and windows to compare with the expected audit values. The heating system is tested for its combustion and thermal efficiency against what was used during the audit phase.

Estimate for cooling load related consumption:

Test made on Heating Season	Short term measurements are made for the COP (Coefficient of performance) calculation to determine the performance of the cooling systems. This can be done in several ways, but always using the energy input (electrical power or gas intake, by meter or instant analysis grid) and the output (in-out water temperatures measured by installed sensors, or pipe measurement and water flow, using pipe meters, pump curves or ultrasonic portable sensors for example). The value found is compared with the value presented in the audit, for the same equipment, and for the same conditions (part load COP)

Test made on Cooling Season	The measurements required for the COP (Coefficient of Performance) calculation are made for at least a week (more time is convenient to fully gasp the changes in operation) to determine the performance of the cooling systems. This can be done in several ways, but always using the energy input (electrical power or gas intake, by meter or instant analysis grid) and the output (in-out water temperatures measured by installed sensors, or pipe measurement and water flow, using pipe meters, pump curves or ultrasonic portable sensors for example). The value found is compared with the value presented in the audit, for the same equipment, and for the same conditions (part load COP or full load COP depending on the water and outdoor temperatures)

6 Training

6.1 Objectives

In all kinds of systems, after it is determined that it is established and fulfills its functions in the light of employer's requests, beneficiary opinions, definitions in projects and specifications, manufacturer's documents and information, applicable standards, regulations, and relevant legislation and is approved by the employer, a training program for the enterprise will be created. During the trainings, a video recording will be taken, a report will be taken, and a training will be conducted in a way that will shed light on the people who will start working later. Training should be at the machine equipment.

The training process will start after an agreement with the employer and the people who will carry out the operation on a suitable schedule by making training planning specific to all kinds of machinery, equipment, and systems.

6.2 Preparation of Training

The training requirements of operation and maintenance personnel and users are determined by the systems and assemblies to be installed in the facility. It is important that operations and maintenance personnel have the knowledge and skills necessary to operate the facility to meet project requirements. Users need to understand the impact on the facility's use and its capacity to meet project requirements. In this context, the scope and details of the training and the training program should be determined by considering the following points.

- Systems, subsystems, and equipment that will require training.
- Knowledge and ability of users or operating and maintenance personnel.
- Training program; should be organized into a series of teaching modules, each covering part of plant systems, equipment, and assemblies.
- Measurable learning objectives and instructional guidelines should be developed to clearly define the specific knowledge and skills that participants need to master.

The first training session should naturally be general-purpose for operation and maintenance personnel and users and should examine project requirements and design fundamentals. This provides an understanding of why the facility was built and its limitations. Most of the training is at the construction stage, and most should be planned before completion. Use and operational training may be required for certain systems and assemblies to meet or maintain project needs. The system manual has a close functional relationship with staff training. A meaningful and useful training program in general; includes the use of the operating and maintenance components of the system manual as the basis for development. Reviewing documents during training consists of: Reviewing emergency content in the system manual, project minutes, system and equipment identification systems, warranties, maintenance service contracts in the system manual, and operation and maintenance information.

Training should specifically address the following:

a) Emergency instructions and procedures: Instructions for operating the facility in various emergencies, including step-by-step instructions for each type of emergency.
b) Operating instructions and procedures: Procedures necessary for the normal operation of the plant, including step-by-step instructions for daily operation.
c) Adjustment instructions: Information to maintain operational maintenance parameters.
d) Troubleshooting procedures: instructions for diagnosing operating problems and procedures for testing and inspection.
e) Maintenance and inspection procedures.
f) Repair procedures: Diagnosis of problems and instructions for disassembly, removal, replacement and reassembly of components.
g) Maintenance of the system manual and related maintenance documents and logs.

Materials of training should include or use the following items:

- Photocopy of the training plan, including the program, curriculum, and agenda.
- Guideline of system.
- Guideline of Manufacturer's training.
- Electronic training and service materials from manufacturers or vendors.

6.3 Operation Training

The commissioning process as explained in the previous points usually focuses on the start of the operation of the initial tests and it is natural that the base training also focuses on these systems. however this project has a very important strand of correct operation of the installed equipment, i.e. it is not simply an installation and entry into service theme but also to ensure that the ultimate goal of the project, the increase in energy efficiency, is guaranteed which presupposes that there is a relatively in-depth knowledge on the part of all users, mainly from building managers, how to ensure, or at least monitor, if the installed equipment is working according to the projected.

The training, besides the normal commissioning requirements, must include guidance in energy efficient operation of the installed equipment and the optimum set points for the equipment (e.g., temperature settings, flow). This includes training in monitoring the performance through checking key parameters and adjusting/operating the equipment to meet the optimum performance.

The training should also include at least:

- Verification methods of efficiency compliance (output).

Checking air temperatures, room temperatures, water temperatures operation schedules.

- Verification methods of water systems efficiency compliance.

Valve operation, chiller and boiler setpoints, pump pressure gain, water inlet and outlet temperatures of main systems, water flow, intake power of electrically powered thermal generators, gas (fuel) intake and flue gas temperature for heating systems.

- Verification methods of air systems efficiency compliance.

Air temperature in key circuit locations (outside, before/after coils), electrical fan consumption, air flow measurement of terminal devices, damper positions vs air temperature.

7 Reports and Documentation

After all the items in the problem registration list are closed and the trainings are completed, a Final Cx report is prepared, which includes the documentation and results of the work done.

All kinds of machinery, equipment and systems used in the project, user manuals, operation and maintenance manuals, handbooks that contain system diagrams and should be hung in technical places, manufacturer catalogues, authorized service contact information, as-built projects, calculations, test reports, Cx forms and minutes and other related documents will be submitted with the Cx report.

The report should consist of the following headings:

a) Equipment and systems included for works
b) Executive summary
c) Issues Log List
d) Floor plans and/or system flowcharts
e) Test checklist
f) Pre-Functional Checklist
g) Initial start-up forms
h) Functional test forms
i) Training documents
j) System guides
k) Other documents and images
l) Annex

8 Energy Performance assessment

8.1 Introduction

The commissioning work will not just be the functional test as normal. This will be also used for the first performance evaluation of the project implementation. The objective is to have a first indication of the system behaviour regarding energy performance and compliance with the audit objectives.

8.2 Main methodology

The commissioning process according to ASHRAE is the overall process including functional and performance testing, and oversight of operator training and record documentation. In this project, the performance testing will have the emphasis is accessing the overall efficiency of the new systems and equipment. The methodology for each individual analysis will require that the energy input will be measure against the functional output. This is not a deep dive on the efficiency, but a first view that will be taken to the next level in the following M&V process.

In the next pages there are several examples of analysis for the main energy efficiency measures. These should be used a guidance and adapted for simplicity where needed.

EE measure	Parameter to confirm	Method
Building envelope		
Building insulation	Insulation thickness, U-value	Inspect thickness and type of installed insulation in a sample of building elements. Confirm manufacturer specifications for insulation type(s) vs design specs
Windows	Window/glazing type, U-value	Visual inspection of windows. Confirm manufacturer specifications for windows or glazing type(s) vs design specs
Doors	U-value, air tightness	Visual inspection of doors. Confirm manufacturer specifications for doors, vs design specs
Lighting		

EE measure	Parameter to confirm	Method
Luminaires	Wattage efficacy (e.g., lm/W)	Visual inspection of luminaires. Confirm manufacturer specifications for luminaires vs design specs
Lighting control (e.g., motion control)	Dimmer/timer/light level setting	Inspect settings. Check real behaviour (dimmer, motion control)
HVAC		
Boiler	Efficiency	Confirm manufacturer specification vs design requirements Measure Flue gas temperature for combustion efficiency Check for Gas/electricity/fuel intake (using installed/portable meters) Measure water flow (using pipe meters, pump curves or ultrasonic portable sensors for example). Measure water in-out temperature (fixed or contact thermometers or BMS sensors) Compare measurements vs design data
Chiller	Efficiency	Confirm manufacturer specification vs design requirements for power, COP etc Measurements are made for the COP/ERR calculation to determine the performance of the cooling systems using a representative timeframe for analysis Measure energy input (electrical power, by grid or portable meter) Measure outdoor temperatures Measure In-out water temperatures (fixed or contact thermometers or BMS sensors) for evaporator and condenser (if water cooled) Measure or estimate In-out water flow (using flow meters, pump curves or ultrasonic portable sensors for example) The values are compared with design conditions and catalogue values

EE measure	Parameter to confirm	Method
Split AC/reversible heat pump	Efficiency (COP, sCOP, EER), temperature setting, fan coil temperature	Confirm manufacturer specification vs design requirements for power, COP etc Visual inspection of local thermostat temperature setting. Measure fan coil temperature (if possible, using contact thermometer) Measure Outside temperature (condenser) Measure Gas pressure Measure Temperature and RH air flow (in-out) for indoor evaporator units Measure electrical power consumption (using installed power meter or portable meter) Visual inspection of temperature setting (thermostat vs evaporator) Check for centralized control input vs output Check catalogues for COP, sCOP vs measured values
Pumps	Efficiency, operating conditions (pressure, flow)	Confirm manufacturer specification vs design requirements Measure Energy consumption using sub/dedicated or portable meter Measure Pressure head (differential pressure meters fixed or portable or BMS sensors) Measure (or estimate) water flow (using pump curves, differential pressure meters fixed or portable, hydraulic meters, or BMS sensors) Compare real output flow vs design flow output and Absorbed power vs design power
Motors	Efficiency	Confirm manufacturer specification vs design requirements Measure Energy consumption using sub/dedicated or portable meter Compare absorbed power vs design power (assuming design conditions)
AHU (or other air-to-water systems)	Chilled/Hot water temperature in/out	Confirm manufacturer specification vs design requirements

EE measure	Parameter to confirm	Method
	Fan efficiency Controls	The air/water systems shall have their overall efficiency analysed from the behaviour of fluid temperatures in accordance with the operating regimes imposed by the user. Check Water Valve position Check damper position Estimate fan performance (absorbed power vs fan curves) Measure Water temperature in-out terminal devices or coils Measure (or estimate) water flow (using pump curves, differential pressure meters fixed or portable, hydraulic or ultrasonic meters or BMS sensors) Measure air temperature in-out terminal devices or coils (portable thermometer) Measure/estimate air flow in coils (fan curve or portable anemometer) Check and analyse water delta vs valve position Check and analyse air delta temperature (terminal) vs water coil valve position Compare measured data vs design data for system overall behaviour
Radiators and Heating system circulation loop	Efficiency	Measure radiator water in/out temperature (with contact thermometers, for example) Measure radiator face temperature (with contact thermometers, for example) Measure (or estimate) water flow (using pump curves, differential pressure meters fixed or portable, hydraulic meters, or BMS sensors) Check Thermostatic valve behaviour (open/close) Compare measured data vs design data for system overall behaviour
Boiler/chiller room: Insulation of piping, valves, fittings	Insulation thickness, U-value	Inspect thickness and type of installed insulation. Confirm manufacturer specifications for insulation type(s).

EE measure	Parameter to confirm	Method
		Inspect thickness and type of installed insulation. Confirm manufacturer specifications for insulation type(s). Check for thermal bridges and installation quality
Energy monitoring and automation systems		
Building automation and energy monitoring system	Automation and monitoring parameters	Confirm that the parameters are displayed and logged, and setpoints properly defined. Inspect if sensors are properly installed and operational. Confirm that the parameters are displayed and logged and setpoints properly defined. Inspect if sensors are properly installed and operational. Check if control sequences are defined for the main processes/systems Visual analysis of Automation and monitoring parameters. Check system behaviour during all CX equipment analysis.
Distributed generation		
Solar PV	Efficiency Output	Confirm manufacturer specification vs design requirements Measure Total production for the PV plant, grid injected power and used building power in a suitable and representative timeframe Check Physical Installation requirements (azimuth, tilt) Check System electrical structure (arrays, inverters) Check and calculate Real vs simulated output in a selected yearly timeframe, using average values. Using theoretical data for accessing the production for the chosen panels and inverters (like PVsyst software) and comparing it with the real field production. A weather file from a

EE measure	Parameter to confirm	Method
		nearby (and representative) station should be used
Solar hot water system	Efficiency Output	Confirm manufacturer specification vs design data Measure In-out water temperatures (fixed or contact thermometers or BMS sensors Measure (or estimate) water flow (using pump curves, differential pressure meters fixed or portable, hydraulic meters, or BMS sensors) Check thermostat and valve settings for storage Check Control schematics Check physical Installation requirements (azimuth, tilt) Compare measurements vs design data
Co-/trigeneration	Efficiency output	Confirm manufacturer specification vs design data Measure Flue temperature for combustion efficiency Check for Gas/electricity/fuel intake (invoices, meters) Measure water flow (using flow meters, pump curves or ultrasonic portable sensors for example). Measure water in-out temperature (fixed or contact thermometers or BMS sensors) Check Control schematics Compare measurements vs design data

Annexes

A. Sample Hot Water Boiler Cx Form
B. Sample Centrifugal Chiller Cx Form
C. Sample Air Handling Unit Cx Form
D. Sample VSD Cx Form
E. Sample Pipeline Cx Form
F. Sample Canal System Cx Form
G. Sample Canal System Cx Form
H. Sample Training Content Form
İ. Sample Training Evaluation Form
J. Sample Air Handling Unit Pre-Cx Form
K. Sample DDC Board Pre-Cx Form
L. Sample Lighting Automation Pre-Cx Form
M. Sample Issues Log

Annex - A Sample Hot Water Boiler Cx Form

4. Boiler, Hot Water: B-1
ASHRAE Guideline 1.1 Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item			Task Description	Response	
1			**Delivery Book**		
	A		**Model Verification**	Submitted	Delivered
		1	Manufacturer		
		2	Model		
		3	Serial Number	N/A	
		4	Total Heating Capacity (MBH)		
		5	Voltage / Phase / Frequency (V / - /Hz)	/ /	/ /
		6	Entering / Leaving Hot Water Temperature (°F)	/	/
	B		**Physical Checks**		
		1	Unit is free from physical damage	Yes	No
		2	The water openings are sealed with plastic plugs	Yes	No
		3	All components present	Yes	No
		4	Installation and startup manual provided	Yes	No
		5	Unit tags affixed	Yes	No
2			**Construction Checklist**		
	A		**Installation of Boiler**		
		1	Unit secured as required by manufacturer and specifications	Yes	No
		2	Adequate clearance around unit for service	Yes	No
		3	All components accessible for maintenance	Yes	No
		4	Unit can be removed from building	Yes	No
		5	Flue completely installed and properly sloped	Yes	No
		6	Unit labeled and is easy to see	Yes	No
	B		**Piping**		
		1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
		2	Piping arranged for ease of unit removal	Yes	No
		3	Piping supported as required by specifications	Yes	No
		4	Piping is clean	Yes	No
		5	Piping insulation is complete and installed as per specifications	Yes	No
		6	Thermometers and pressure gauges on supply and return lines	Yes	No
		7	All valves and test ports are easily accessible	Yes	No
		8	Valve tags attached	Yes	No
	C		**Electrical**		
		1	Local disconnect installed in accessible location	Yes	No
		2	All electrical connections are tight	Yes	No
		3	All electrical components are grounded	Yes	No
	D		**Controls – Installation**		
		1	Control panel accessible and labeled properly	Yes	No
		2	Remote start and stop verified	Yes	No
		3	Hot water temperature reset signal verified (if applicable)	Yes	No
		4	Test ports installed near all control sensors	Yes	No
		5	Actuators installed and calibration verified	Yes	No

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4. Boiler, Hot Water: B-1
ASHRAE Guideline 1.1 Example Checklist *(Continued)*

E		**Mechanical – Startup**		
	1	System flushed, filled, and air purged	Yes	No
	2	Burner adjusted to proper settings	Yes	No
	3	System starts and runs without any unusual noise or vibration	Yes	No
	4	Manufacturer's startup checklist completed and attached	Yes	No
	5	CO_2 and CO values from burner adjustment (ppm/ppm)	/	/
F		**Controls – Startup**		
	1	Low water switch operational	Yes	No
	2	Temperature sensors operational and calibrated	Yes	No
	3	Flow switch operational	Yes	No
	4	High pressure / temperature cut out operational	Yes	No
	5	Unit operating sequence verified and correct	Yes	No

"No" Responses

Item	Date	Reason for "No" Response

Annex - B Sample Centrifugal Chiller Cx Form

5. Centrifugal Chiller: C-1
ASHRAE Guideline 1.1 Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item			Task Description	Response	
1			**Delivery Book**		
	A		**Model Verification**	Submitted	Delivered
		1	Manufacturer		
		2	Model		
		3	Serial Number	N/A	
		4	Capacity (tons)		
		5	Condenser Fluid Type		
		6	Condenser Fluid Flow rate (gpm)		
		7	Chilled Fluid Type		
		8	Chilled Fluid Flow Rate (gpm)		
		9	Refrigerant Type		
		10	Compressor Motor Power (kW)		
		11	Compressor Motor Voltage / Phase / Frequency (V / – / Hz)	/ /	/ /

5. Centrifugal Chiller: C-1
ASHRAE Guideline 1.1 Example Checklist ***(Continued)***

	B	**Physical Checks**		
	1	Unit is free from physical damage	Yes	No
	2	Openings are sealed with plastic	Yes	No
	3	All components present (cooler, condenser, compressor, motor, etc.)	Yes	No
	4	Motor bearings are double sealed and permanently lubricated	Yes	No
	5	Electrical disconnect is provided	Yes	No
	6	Installation and startup manual provided	Yes	No
	7	Unit tags affixed	Yes	No
2		**Construction Checklist**		
	A	**Installation of Chiller**		
	1	Unit secured as required by manufacturer and specifications	Yes	No
	2	There is a minimum of 36 inches of clearance around entire unit	Yes	No
	3	There is a minimum of 48 inches of clearance in front of starter or VFD	Yes	No
	4	There is a minimum clearance of one unit length for tube pull space	Yes	No
	5	All components are accessible for maintenance	Yes	No
	6	Unit labeled and is easy to see	Yes	No
	B	**Refrigerant**		
	1	Full operating charge of refrigerant and oil	Yes	No
	2	Unit factory leak tested and report is attached	Yes	No
	3	Relief piped to outdoors	Yes	No
	4	Refrigerant monitor installed and operational before refrigerant loaded	Yes	No
	5	Drip leg and flex connector at unit connection to relief piping	Yes	No
	C	**Electrical**		
	1	Lugs tightened by chiller startup technician	Yes	No
	2	Safety disconnect switch installed in an accessible location	Yes	No
	3	Lug sizing matches wire size requirement	Yes	No
	4	Primary and secondary fused control power transformer provided	Yes	No
	5	Star-delta starter provided	Yes	No
	6	AIC and Withstand ratings exceed available fault shown on electrical drawings	Yes	No
	7	VFD installed (if applicable)	Yes	No
	D	**Controls - Installation**		
	1	Control panel accessible and labeled properly	Yes	No
	2	All sensors are installed and calibrated	Yes	No
	3	Safety items installed and verified	Yes	No
	E	**Controls - Startup**		
	1	Unit voltage and amps verified	Yes	No
	2	Remote start and stop signal verified	Yes	No
	3	Chilled water reset signal verified	Yes	No
	4	Demand limiting signal verified	Yes	No
	5	Unit "run" sequences verified	Yes	No
	6	Unit "alarm" sequences verified	Yes	No

5, Centrifugal Chiller: C-1
ASHRAE Guideline 1,1 Example Checklist *(Continued)*

F		**Mechanical – Startup**		
	1	Manufacturer's startup checklist completed and attached	Yes	No
	2	The following safety controls are operational and have been verified:		
	3	Low chilled water temperature	Yes	No
	4	High refrigerant pressure	Yes	No
	5	Low oil flow protection	Yes	No
	6	Loss of chilled water flow	Yes	No
	7	Loss of condenser flow	Yes	No
	8	Loss of refrigerant protection	Yes	No
	9	Motor current overload	Yes	No
	10	Phase reversal/unbalance/single phasing	Yes	No
	11	Over/under voltage	Yes	No
	12	Failure of water temperature sensor used by controller	Yes	No
	13	Full load test to verify load limiting	Yes	No
	14	System starts and runs without any unusual noise or vibration	Yes	No
G		**TAB**		
	1	Chilled water strainer is clean	Yes	No
	2	Evaporator pressure drop (ft)		
	3	Chilled water flow rate (gpm)		
	4	Condenser water strainer is clean	Yes	No
	5	Condenser water pressure drop (ft)		
	6	Condenser water flow rate (gpm)		

"No" Responses

Item	Date	Reason for "No" Response

Annex - C Sample Air Handling Unit Cx Form

3. Air Handling Unit, CW & HW: AHU-1
ASHRAE Guideline 1.1 Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item			Task Description	Response	
1			**Delivery Book**		
	A		**Model Verification**	Submitted	Delivered
		1	Manufacturer		
		2	Model		
		3	Serial Number	N/A	
		4	Cooling Capacity (MBH/gpm)	/	/
		5	Heating Capacity (MBH/gpm)	/	/
		6	Supply Air flow, Design / Minimum (cfm)	/	/
		7	Supply Fan Motor Power / Speed (hp / rpm)	/	/
		8	Return Air flow, Design / Minimum (cfm)		
		9	Return Fan Motor Power / Speed (hp / rpm)		
		10	Voltage / Phase / Frequency (V / - / Hz)	/ /	/ /
	B		**Physical Checks**		
		1	Unit is free from physical damage	Yes	No
		2	Coil surface areas are free of damage	Yes	No
		3	The air openings are sealed with plastic	Yes	No
		4	The water openings are sealed with plastic plugs	Yes	No
		5	All components present and in proper order	Yes	No
		6	All access doors are operable	Yes	No
		7	Installation and startup manual provided	Yes	No
		8	Unit tags affixed	Yes	No
2			**Construction Checklist**		
	A		**Installation of AHU**		
		1	Unit secured as required by manufacturer and specifications	Yes	No
		2	Adequate clearance around unit for service	Yes	No
		3	All components accessible for maintenance	Yes	No
		4	Unit can be removed from the building	Yes	No
		5	Cooling coil drain pan slopes correctly	Yes	No
		6	Internal vibration isolators in good condition and shipping bolts are removed	Yes	No
		7	Belts are tight	Yes	No
		8	Unit labeled and is easy to see	Yes	No
	B		**Chilled Water Piping**		
		1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
		2	Piping arranged for ease of unit/coil removal	Yes	No
		3	Piping supported as required by specifications	Yes	No
		4	Piping is clean	Yes	No
		5	Piping insulation is complete and installed as per specifications	Yes	No
		6	All valves and test ports are easily accessible	Yes	No
		7	Valve tags attached	Yes	No

3. Air Handling Unit, CW & HW: AHU-1
ASHRAE Guideline 1.1 Example Checklist *(Continued)*

C		**Hot Water Piping**		
	1	All piping components have been installed (in the correct order) as required by detail drawing	Yes	No
	2	Piping arranged for ease of unit/coil removal	Yes	No
	3	Piping supported as required by specifications	Yes	No
	4	Piping is clean	Yes	No
	5	Piping insulation is complete and installed per specifications	Yes	No
	6	All valves and test ports are easily accessible	Yes	No
	7	Valve tags attached	Yes	No
D		**Ductwork**		
	1	Adequate locations available for testing and balancing of unit	Yes	No
	2	All dampers and sensors are accessible (access panels)	Yes	No
	3	Outdoor and return air arrangement will not freeze coils, i.e. outdoor air and return air is adequately mixed before reaching coils	Yes	No
	4	Vibration isolators installed	Yes	No
	5	All dampers close tightly and stroke fully and easily	Yes	No
	6	Ductwork is clean and free of debris	Yes	No
E		**Electrical**		
	1	Local disconnect installed in accessible location	Yes	No
	2	Motor rotation in the proper direction	Yes	No
	3	All electrical connections are tight	Yes	No
	4	All electrical components are grounded	Yes	No
	5	VFD installed (if applicable)	Yes	No
F		**Controls – Installation**		
	1	Control panel accessible and labeled properly	Yes	No
	2	Temperature, humidity, pressure, and CO_2 sensors (as applicable) are installed and calibrated	Yes	No
	3	Dampers actuators installed and calibration verified	Yes	No
	4	Hot and chilled water actuators installed and calibration verified	Yes	No
	5	Safety items installed and verified (freezestat, high pressure, motor overload, etc.)	Yes	No
G		**Mechanical – Startup**		
	1	Unit is clean	Yes	No
	2	Internal isolators free to move	Yes	No
	3	Fans and motors lubricated and aligned	Yes	No
	4	Fan belts have proper tension and are in good condition	Yes	No
	5	Protective shrouds for fans and belts in place and secure	Yes	No
	6	Terminal unit dampers manually opened or are controllable and open	Yes	No
	7	Filters installed properly (no bypass air) and are clean	Yes	No
	8	System starts and runs without any unusual noise or vibration	Yes	No
	9	Manufacturer's startup checklist completed and attached	Yes	No

3. Air Handling Unit, CW & HW: AHU-1
ASHRAE Guideline 1.1 Example Checklist *(Continued)*

H	**Controls – Startup**		
	1 Cooling sequence of control verified	Yes	No
	2 Heating sequence of control verified	Yes	No
	3 Warm-up sequence of control verified	Yes	No
	4 Cool-down sequence of control verified	Yes	No
	5 Economizer sequence of control verified	Yes	No
	6 Unoccupied sequence of control verified	Yes	No
I	**TAB**		
	1 Filters and coils are clean	Yes	No
	2 Motor rotation verified - each motor	Yes	No
	3 Motor voltage and amps verified - each phase of each motor	Yes	No
	4 Fan RPM verified - each fan	Yes	No
	5 Entering and leaving cooling coil air temperatures (°F)	/	/
	6 Entering and leaving heating coil temperatures (°F)	/	/
	7 Entering and leaving chilled water temperatures (°F)	/	/
	8 Entering and leaving hot water temperatures (°F)	/	/
	9 Coil flow and air/water pressure drops verified - each coil	Yes	No

"No" Responses

Item	Date	Reason for "No" Response

Annex - D Sample VSD Cx Form

23. Variable Speed Drive: VSD-1
ASHRAE Guideline 1.1 Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.

Item			Task Description	Response	
1			**Delivery Book**		
	A		**Model Verification**	Submitted	Delivered
		1	Manufacturer		
		2	Model		
		3	Serial Number	N/A	
		4	Service Area		
		5	Maximum Capacity (amps)		
		6	Voltage / Phase / Frequency (V / – / Hz)	/ /	/ /
	B		**Physical Checks**		
		1	Unit is free from physical damage	Yes	No
		2	All components present	Yes	No
		3	Installation and startup manual provided	Yes	No
		4	Wiring schematics (electrical & controls) for this application attached	Yes	No
		5	Unit tags affixed	Yes	No
		6	Manufacturer's ratings readable/accurate	Yes	No
2			**Construction Checklist**		
	A		**Installation of VSD**		
		1	Unit secured as required by manufacturer and specifications	Yes	No
		2	Adequate clearance around unit for service	Yes	No
		3	All components are accessible for maintenance	Yes	No
		4	Unit can be removed from building	Yes	No
		5	Unit labeled and is easy to see	Yes	No
		6	Wiring schematic inside enclosure and includes bypass section	Yes	No
	B		**Electrical**		
		1	Drive to motor leads are in grounded metal conduit	Yes	No
		2	All electrical connections are tight	Yes	No
		3	All electrical components are grounded	Yes	No
	C		**Controls – Installation**		
		1	Control panel accessible and labeled properly	Yes	No
		2	Low voltage control signals are shielded and in own conduit	Yes	No
		3	Auxiliary safeties (F/A shutdown, etc.) are installed and operational	Yes	No
		4	Analog output to control unit is "isolated type	Yes	No
	D		**Electrical – Pre-Startup Checks**		
		1	Motor full load amps less than max rating, design / actual	/	/
		2	Input voltage, design / actual (within 10% of rating)	/	/
		3	All grounds verified	Yes	No
		4	All fuses verified	Yes	No

23. Variable Speed Drive: VSD-1
ASHRAE Guideline 1.1 Example Checklist *(Continued)*

E	**Electrical – Startup**		
1	VSD properly powers up	Yes	No
2	Stop button works	Yes	No
3	Motor rotation is in the proper direction	Yes	No
4	Minimum and maximum speeds reached using remote command	Yes	No
5	"Accel" and "Decel" adjustments are made within the drive and do not depend on ramping signal from the DDC controls	Yes	No
6	VSD restarts automatically	Yes	No
7	No disconnect on load side of VSD	Yes	No
8	Critical frequencies have been programmed out of VSD (if applicable)	Yes	No
9	Motor runs in bypass mode while servicing or removing unit	Yes	No
10	Motor overload protection and phase loss protection provided during bypass mode	Yes	No
11	System starts and runs without any unusual noise or vibration	Yes	No
12	Manufacturer's startup checklist completed and attached	Yes	No

"No" Responses

Item	Date	Reason for "No" Response

Annex - E Sample Pipeline Cx Form

17. HVAC Piping: Installation
ASHRAE Guideline 1.1 Example Checklist

Instructions:
Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.
Step 3: Samples of installed ductwork will be periodically reviewed to verify compliance.

Item	Task Description	Response	
1	System Checks		
A	Installation Checks	Submitted	Delivered
1	Piping is clean and free of damage prior to installation.	Yes	No
2	Piping is free to expand and contract without noise or damage to hangers, joints, or the building.	Yes	No
3	Piping is installed with sufficient pitch and arranged in a manner to ensure drainage and venting of the entire system.	Yes	No
4	Manual air vents are provided at high points in close water systems.	Yes	No
5	Changes in pipe sizes are made with the proper size reducing fittings, reducing fittings, reducing elbow or reducing tees. Bushings are not allowed.	Yes	No
6	All piping supports and hangers meet criteria set in Section 15140 of the specifications.	Yes	No
7	All fittings meet specification requirements.	Yes	No
8	All equipment requiring maintenance is accessible (valves, junction boxes, etc.).	Yes	No
9	Piping does not block access to equipment that is part of this system or another system (e.g., air terminal units).	Yes	No
10	Piping is installed in a manner to ensure that insulation will not contact adjacent surfaces.	Yes	No
11	All pipe openings are temporarily sealed to maintain piping system cleanliness.	Yes	No
12	Record drawings have been updated to reflect any changes made.	Yes	No
13	Nipples are made of the same material as the pipe.	Yes	No
14	Connections between copper and steel pipes are made with dielectric fittings.	Yes	No
15	A union is provided ahead of each screwed valve, trap, or strainer, and on each side of each piece of equipment and whatever needed to dismantle piping.	Yes	No
16	Mechanical coupling if used is only used for piping and locations as described in the specification section 15060.	Yes	No
17	The chilled water system is installed with high pressure fittings, flanges and unions.	Yes	No
18	Auxiliary drain valves are provided at all low points in hose bib piping to facilitate seasonal draining.	Yes	No
19	A clearance of 8 ft 2 in. is maintained throughout the parking structure. Walker's drawings have been consulted for exact location of pipe spaces, ceilings heights, and other details before installing piping.	Yes	No

Annex - F Sample Canal System Cx Form

9A. Ductwork: Installation
ASHRAE Guideline 1.1 Example Checklist

Instructions: Step 1: Circle Yes or No and fill in with requested information.
Step 2: Explain all "No" responses at the bottom of the checklist.
Step 3: Samples of installed ductwork will be periodically reviewed to verify compliance.

Item			Task Description	Response	
1			**System Checks**		
	A		**Sheet Metal Ductwork Installation Checks**	Submitted	Delivered
		1	Ductwork is clean and free of damage prior to installation.	Yes	No
		2	Ductwork is installed in accordance with SMACNA HVAC Duct Construction Standards, 2005	Yes	No
		3	All hat sections and standoff brackets are at the same height as the duct lining.	Yes	No
		4	Access doors are installed in all casting, plenums, ductwork adjacent to fire dampers, automatic dampers, smoke dampers, and reheat coils, and as indicated on drawings.	Yes	No
		5	The access doors on casings or housings open to the inside on the discharge side and to the outside on the suction side.	Yes	No
		6	All galvanized sheet metal is separated from aluminum and copper with lead or felt gaskets.	Yes	No
		7	Ductwork is structurally sound to prevent drumming and sagging.	Yes	No
		8	All transverse and longitudinal joints are sealed.	Yes	No
		9	All branch and tee connections are 45 degree.	Yes	No
		10	All medium pressure branch and tee connections are expanded 30 degrees on at least three sides.	Yes	No
		11	Ductwork meets static pressure requirements specified below and leakage class A for these pressures as defined by SMACNA HVAC Duct Construction Standards, 1985.	Yes	No
		12	All ductwork except as noted in the specification is leak tested.	Yes	No
		13	Elbows have an inside radius equal to a minimum of 3/4 of the width of the duct.	Yes	No
		14	All square elbows and radius elbows larger than 18 inches have turning vanes.	Yes	No
		15	All wall and floor penetrations are sealed.	Yes	No
		16	Volume dampers are at minimum provided for each horizontal branch from vertical risers serving two or more floors and branches serving two or more outlets.	Yes	No
		17	All equipment requiring maintenance is accessible (valves, junction boxes, etc.).	Yes	No
		18	All duct openings temporary sealed to maintain duct system cleanliness.	Yes	No
		19	Record drawings have been updated to reflect any changes made.	Yes	No
	B		**Flexile Ductwork Installation Checks**		
		1	Flexible ductwork is clean and free from damage prior to installation.	Yes	No
		2	Flexible ductwork is free of sags and kinks.	Yes	No
		3	Flexible ductwork is installed using extra heavy flexible duct straps.	Yes	No
		4	The maximum length of flexible ductwork is 5 feet.	Yes	No
		5	Flexible ductwork does not penetrate walls.	Yes	No
		6	Flexible ductwork does not have 90 degree bends.	Yes	No
	C		**Ductwork Type Static Pressure Classification Installation Checks**		
		1	From fan discharge to and including vertical risers, +6 in. static pressure	Yes	No
		2	Branch supply ductwork, +4 in. static pressure.	Yes	No
		3	Branch supply ductwork from terminal to room outlet, +1 in. static pressure.	Yes	No
		4	Exhaust/return ductwork, ± 1 in. static pressure.	Yes	No
		5	All other ductwork, ± 2 in. static pressure.	Yes	No

Annex - G Sample Canal System Cx Form (Sequence of Operation)

Sequences of Operation for Common HVAC Systems
CV Air Handler Supply Fan, Chilled Water Coil, Staged Heat, Economizer

SECTION I – DESCRIPTION OF EQUIPMENT

Sequence Designation: CV 1B1-XSX12

Quick Summary	
SA Temp Control	Varies to Maintain Space Temp Setpoint
Space Pressure Control	None
Minimum OA Control	Fixed Minimum Position
Humidification	None
Dehumidification	None
Economizer	Dry Bulb Differential Temperature
Morning Pre-Cooling	Economizer Cooling

A. OVERVIEW

This sequence of control describes the direct digital control requirements for a simple constant volume air handling system. These air handling units are typically in the 2,000 to 7,000 cfm range (4 to 12-ton), serving a single zone with a single exposure.

B. THINGS TO CONSIDER BEFORE APPLYING THIS SEQUENCE:

- There is no measurement of outside air volume. The minimum outside air flow rate is established by the outside air damper minimum position set by the balance contractor. The maximum outside air flowrate is determined by the outside air intake configuration.
- A fixed minimum outside air volume is provided. This is useful in facilities with a consistent number of people in the facility or a fixed exhaust requirement.
- There are no humidification or de-humidification cycles.
- In humid regions an enthalpy-based economizer may be desired.
- Pumped coils may be desired for low temperature protection and turbulent flow through the coil tubes. Pumped cooling coils lower the chilled water Delta T that may adversely affect the chillers. Additional freeze protection strategies may be needed depending on climate.
- A single space temperature setpoint controls the unit. This applies to units serving a single space or units serving multiple spaces that have similar exposures and internal loads.
- Cooling coils are shown with normally closed valves. This convention is typical in cold climates and may be different in warm climates. Actuators that fail in the current position may be considered for some applications instead of the fail open/closed type. Edit the control drawing to reflect the actual system.
- The location and quantity of duct smoke detectors is regulated by code. Verify code requirements and revise the system schematic accordingly.
- An outside air temperature sensor is shown. This value may be available through the network. Revise the system schematic if this sensor is not required.

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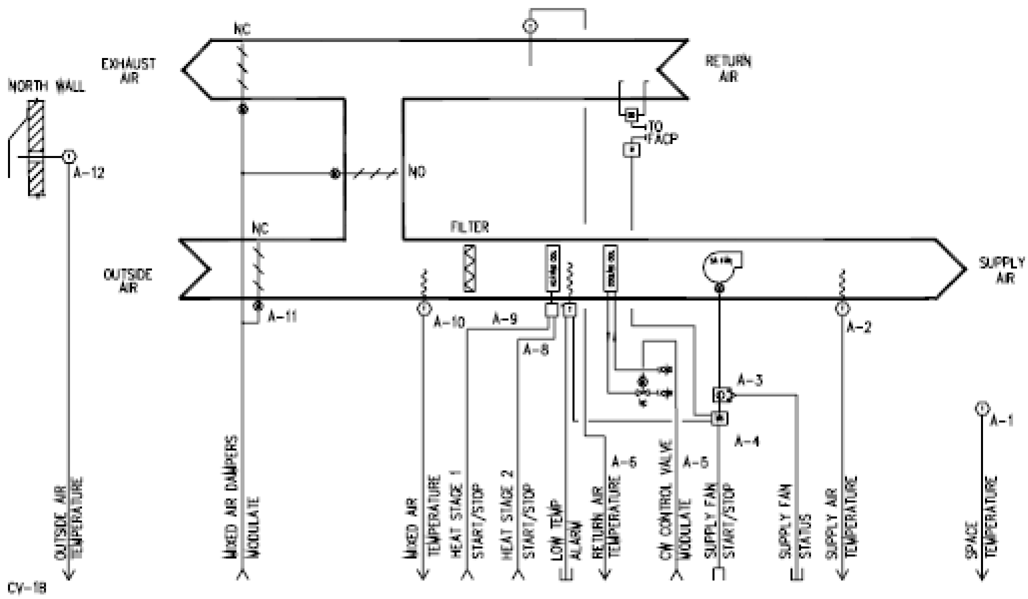
- When operating in economizer mode, the return and exhaust air paths will be required to handle up to 100% of the system airflow as circulated only by the pressure differential between the space and outside, unless an alternative path is defined for relief air. To avoid over pressurization of the space, the return air, exhaust air and/or relief air duct work and accessories must be sized appropriately.

C. SYSTEM SCHEMATIC



D. CONTROL SYSTEM 0[2]

Tag	Object Name	Type	Alarm	Graphic	Trend	Notes
A-1	AHU-1 Space Temperature	AI	65/80[1]	AHU1	5 min	Report 1
A-2	AHU-1 Supply Air Temperature	AI	40/100[1]	AHU1	5 min	Report 1
A-3	AHU-1 Supply Fan Status	BI	Fail	AHU1	COV	
A-4	AHU-1 Supply Fan Start/Stop	BO		AHU1	COV	Report 1
A-5	AHU-1 CW Coil Valve Modulate	AO		AHU1	5 min	
A-6	AHU-1 Return Air Temperature	AI		AHU1	5 min	Report 1
A-7	AHU-1 Low Temp Alarm	BI	Yes	AHU1	COV	Report 1
A-8	AHU-1 Stage 2 Heat Start/Stop	BO		AHU1	COV	Report 1
A-9	AHU-1 Stage 1 Heat Start/Stop	BO		AHU1	COV	Report 1
A-10	AHU-1 Mixed Air Temperature	AI	35/100[1]	AHU1	5 min	Report 1
A-11	AHU-1 Mixed Air Dampers	AO		AHU1	5 min	
A-12	AHU-1 Outside Air Temperature	AI		AHU1	5 min	
A-13	AHU-1 Run Time	AV	10,000	AHU1	5 min	
A-14	AHU-1 Occ Space Setpoint	AV		AHU1		
A-15	AHU-1 Mixed Air Low Temp Setpoint	AV				
A-16	AHU-1 Unoccupied Space Temp Setpoint	AV		AHU-1		
A-17	AHU-1 Heating Interstage Differential	AV				
A-18	AHU-1 OA Damper Min Position	AV				
A-19	AHU-1 Warm-up OA Temp Setpoint	AV				
A-20	AHU-1 Pre-Cool OA Temp Setpoint	AV				

[1] *Lockout alarm when unit is de-energized. Provide 15-minute startup delay prior to enabling alarm*

[2] *Not all virtual points are shown. Provide all points required for software operation.*

SECTION II – SEQUENCE OF OPERATION

The occupancy mode (Occupied or Unoccupied) shall be determined through a user-adjustable, graphical, seven-day schedule with holiday schedule.

Whenever the supply fan is de-energized, as sensed by the status switch, the outside and exhaust air dampers shall be closed and the return air damper shall be open, the cooling valve shall be closed or positioned as described below, heating shall be de-energized or staging as described below.

A. OCCUPIED MODE

1. The supply fan shall be energized.

2. The outside air damper shall open to the predetermined minimum position. The OA damper shall not close below the minimum position required for outside air ventilation. This position shall be set in conjunction with the balance contractor.

3. There shall be separate heating and cooling space temperature setpoints with a 5°F deadband between the heating and cooling

4. The heating shall stage and the mixed air dampers and cooling coil valve shall modulate in sequence to maintain space temperature setpoint. Provide deadband between heating and economizer cooling setpoints. Heating shall stage off-low-high. High shall not be energized unless low has been energized for at least 5 minutes or the supply air temperature is more than 15°F below setpoint. Provide a 2°F (adjustable) inter-stage differential for heating.

5. Economizer cooling is enabled whenever the outside air dry bulb is less than the return air dry bulb minus differential. When the outside air dry bulb is greater than the return air dry bulb, economizer cooling is disabled. When economizer cooling is enabled, mixed air dampers will modulate to maintain space temperature setpoint. There shall be a mixed air low limit function to modulate the mixed air dampers closed to prevent the mixed air temperature from dropping below the mixed air low limit setpoint of 45°F (adjustable).

6. The heat stages shall be energized only when the supply fan is energized; the heater's internal air flow and high temperature safeties are satisfied.

7. The software shall prevent:
   a. The heating setpoint from exceeding the cooling setpoint minus 5°F (i.e. the minimum deadband shall be 5°F);
   b. The unoccupied heating setpoint from exceeding the occupied heating setpoint; and the unoccupied cooling setpoint from being less than the occupied cooling setpoint.

B. UNOCCUPIED MODE

1. Unoccupied Off: The supply fan shall be de-energized except when operation is called for as described below. Outside air dampers and exhaust dampers shall be closed and return air damper open.

2. Unoccupied OFF Coil Protection: When the supply fan is de-energized and the outside air temperature is below the Outside Air Low Temperature Protection Setpoint of 35°F (adjustable) and the mixed air temperature is less than the Mixed Air Low Temperature Protection Setpoint of 45°F, OR the Low Temperature Limit trips, then open the cooling coil valve 100%.

   When the outside air temperature is above the Outside Air Low Temperature Protection Setpoint of 35°F + deadband, or the mixed air temperature is greater than the Mixed Air

Low Temperature Protection Setpoint of 45°F + deadband; the cooling coil valve shall be closed.

3. Unoccupied Setback: The supply fan shall cycle on with the outside and exhaust dampers closed and return damper open when the space temperature drops below the unoccupied space temperature setpoint of 65°F (adjustable). When the fan is energized, the heating shall stage off-low-high until the space temperature equals the unoccupied space temperature setpoint.

4. Morning Warm-up: If the space temperature is below the occupied temperature setpoint and the outside air temperature is below 40°F (adjustable) Morning Warm-up shall be initiated by the optimum start program. If the space temperature is below the occupied space temperature setpoint, the supply fan shall energize, the outside and exhaust dampers shall remain closed, the return air damper open, and the heating coil shall stage off-low-high until the space temperature equals the occupied space temperature setpoint. If the space reaches the occupied space temperature setpoint before occupancy, the system shuts off. If occupancy occurs before the space reaches the heating setpoint, the system switches to occupied mode. Morning warm-up shall occur only once in a day.

5. Morning Pre-cooling: Pre-cooling shall occur only during the summer months of May through September. If space temperature exceeds the pre-cooling space temperature setpoint, and the outside air temperature is below 60°F, Morning Pre-cooling may begin. The unit shall start in the morning pre-cool mode as determined by an optimum start program at the latest possible time to have the space at the Pre-cooling space temperature setpoint at occupancy time. The outside air, return and exhaust air dampers shall modulate to provide 55°F (adjustable) supply air until the space temperature falls below the pre-cooling space temperature setpoint. Heating shall be disabled. If the space reaches the pre-cooling setpoint before occupancy, the system shuts off. If occupancy occurs before the space reaches the pre-cooling setpoint, the system switches to occupied mode. Morning Pre-cooling shall occur only once in a day.

C. SAFETY SHUTDOWNS

1. Duct smoke detection, space smoke detection, and low temperature limit trips shall de-energize the supply fan and close the outside air and exhaust air dampers. Manual reset of the tripped device shall be required to restart the system.

2. When the OA temperature is below the outside air low temperature protection setpoint, 35°F (adjustable), and the air handler has shut down in alarm, the heating and cooling valves shall cycle as described in unoccupied mode.

SECTION III – CONTROL MODE SUMMARY

Device	Occupied	Unoccupied				Safeties
		Off	Setback	Warm-up	Pre-Cooling	
S fan	On	Off	Cycles	On	On	Off
OA damper	Fixed min. position modulates when economizer mode is enabled.	Closed	Closed	Closed	Closed or modulates when economizer mode is enabled.	Closed
RA damper	Track opposite of OA Damper	Open	Open	Open	Open or tracks opposite OA damper	Open
EA damper	Track OA Damper	Closed	Closed	Closed	Closed or tracks OA damper	Closed
Heat	Stage Off-Low-Hi in sequence with dampers and CW valve	Off	Stage	Stage	Off	Off
CW valve	Modulate in sequence with heat and dampers	Open If OAT <35, otherwise closed	Closed	Closed	Modulates in sequence with dampers	Open If OAT<35, otherwise closed

Annex - H Sample Training Content Form

TRAINING AGENDA TOPICS

(Suggested General Topics to Be Included)

	Suggested List of Subjects	**Requested by D-I-R, Inc. (✓)**	**Desired Duration (h)**
1.	Overview and description of the purposes of the system		
2.	System troubleshooting: description of diagnostic step-by-step procedures for determining the source of problems on the system level; review technical service manual in detail		
3.	Component maintenance: instruction of required procedures for weekly, monthly, and annual preventive checks and timely repairs to preserve system integrity		
4.	Component troubleshooting: description of diagnostic procedures for determining the source of problems on the component level		
5.	Review of control drawings and schematics (have copies for attendees)		
6.	Startup, loading, normal operation, unloading, shutdown, unoccupied operation, seasonal changeover, etc., as applicable		
7.	Integral controls (packaged): programming, troubleshooting, alarms, manual operation		
8.	Building automation system (BAS) controls: programming, troubleshooting, alarms, manual operation, interface with integral controls		
9.	Interactions with other systems, operation during power outage and fire		
10.	Relevant health and safety issues and concerns and special safety features		
11.	Energy-conserving operation and strategies		
12.	Any special issues to maintain warranty		
13.	Common troubleshooting issues and methods, control system warnings and error messages, including using the control system for diagnostics		
14.	Special requirements of tenants for this equipment's function		
15.	Service, maintenance, and preventive maintenance (sources, spare parts inventory, special tools, etc.)		
16.	Question and Answer Period		
	Total hours requested		
	Total hours required by specifications		

Annex - I Sample Training Evaluation Form

Training Evaluation

Session: ______________________________

Date: ___________ **Location:** ______________________

Purpose: This form is used to evaluate each training session. Based upon this evaluation, later sessions can be improved. This form will be completed by the Commissioning Authority and one D-I-R employee in the training session after each session.

Every attendee fills out one copy of this form. Mark questions that are not applicable with N/A.

		1 = very well to 5 = not at all					
1.	How were the objectives of this training session met?	1	2	3	4	5	N/A
2.	Do you know where the components/systems are located?	1	2	3	4	5	N/A
3.	Do you know what area the components/systems are serving?	1	2	3	4	5	N/A
4.	Do you understand the various types and purpose of these components/systems?	1	2	3	4	5	N/A
5.	Do you understand/know how to systematically troubleshoot common problems with these components/systems?	1	2	3	4	5	N/A
6.	Do you know how the components/systems operate under all normal modes?	1	2	3	4	5	N/A
7.	How well do you understand the importance of meeting the design intent for the systems covered?	1	2	3	4	5	N/A
8.	Are you able to efficiently find the relevant information in the Systems Manual to operate and maintain the systems/components you were trained for in this session?	1	2	3	4	5	N/A
9.	Do you know how to perform the needed maintenance on the equipment and/or do you know to get the information you need?	1	2	3	4	5	N/A
10.	Do you know how to get updated technical service information for the components/systems?	1	2	3	4	5	N/A

Explain why any questions got very low or very high ratings from you:

What topics would you desire to be covered that were absent from this training session?

You may provide other comments concerning anything about this training session (e.g., information prior to training, content):

Annex - J Sample Air Handling Unit Pre-Cx Form

1. **Model Verification**

Eq. TAG		**Floor**	
Building Name		**Zone Name**	
Zone Number			
	Submitted	**Delivered**	
Manufacturer			
Model			
Cooling Capacity			
Heating Capacity			
Supply Air Flow			
Return Air Flow			
Supply Fan Motor Power			
Return Fan Motor Power			
Equipment of checked Air Handling Unit	☐ Filter 1 – F Type ☐ Filter 2 – G Type ☐ Filter 3 – Hepa Type ☐ Filter 4 – Act.Carbon ☐ Heating Coil ☐ Cooling Coil ☐ Electrical Heater ☐ Supply Fan ☐ Return Fan ☐ Plate HRV ☐ Rotary HRV ☐ Mixing Section ☐ Other	☐ Filter 1 – F Type ☐ Filter 2 – G Type ☐ Filter 3 – Hepa Type ☐ Filter 4 – Act. Carbon ☐ Heating Coil ☐ Cooling Coil ☐ Electrical Heater ☐ Supply Fan ☐ Return Fan ☐ Plate HRV ☐ Rotary HRV ☐ Mixing Section ☐ Other	

2.Installation Checks

	ITEM/TASK	YES	NO	N/A
A. UNIT CHECK				
A-1	**Unit is free from physical damage.** *Görsel kontrol, belirgin bir hasar yoktur.*	☐	☐	☐
A-2	**Coil surface areas are free of damage.** *Batarya yüzey alanları hasarsızdır.*	☐	☐	☐
A-3	**All duct works installation completed** *Tüm Hava kanallarının montajı tamamlanmıştır.*	☐	☐	☐
A-4	**All pipe works installation completed** *Tüm boru hatlarının montajı tamamlanmıştır.*	☐	☐	☐
A-5	**All components present and in proper order.** *Bütün hücreler/ekipmanlar mevcuttur ve uygun şekilde bağlanmıştır.*	☐	☐	☐
A-6	**All access doors are operable.** *Bütün erişim kapıları kullanılabilirdir.*	☐	☐	☐

A-7	**Unit tags affixed.** *Ünitelere ait etiketler mevcttur.*			
B. INSTALLATION				
B-1	**Unit secured as required by manufacturer and specifications.** *Ünite güvenliği, standartlar doğrultusunda üretici tarafından sağlanmıştır.*			
B-2	**Adequate clearance around unit for service.** *Servis müdahalesi için yeterli boşluk vardır.*			
B-3	**All components accessible for maintenance.** *Bütün ekipmanlar bakım için ulaşılabilir durumdadır.*			
B-4	**Unit can be removed from the building.** *Ünite sökülebilir durumdadır.*			
B-5	**Cooling coil drain pan slopes correctly.** *Soğutma bataryası drenaj tavası/borusu doğru eğimdedir.*			
B-6	**Internal vibration isolators in good condition and shipping bolts are removed.** *Santral içindeki titreşim izolatörleri uygun durumdadır ve taşımada kullanılan cıvatalar sökülmüştür.*			
C. PIPING				
C-1	**All piping components have been installed (in correct order) as in draws.** *Bütün tesisat elemanları çizimlerde olduğu gibi monte edilmiştir.*			
C-2	**Piping arranged for ease case of unit/coil removal.** *Borulama sistemi unitenin kolay çıkarılabileceği bir şekilde düzenlenmiştir.*			
C-3	**Piping supported as required by specifications.** *Boru tesisatı şartnamelerde olduğu gibi askılanmıştır.*			
C-4	**Piping is clean (FLUSHING)** *Boru tesisatı temizdir (Kimyasal yıkama raporuna bakılacak)*			
C-5	**Piping insulation complete and installed as per specifications.** *Boru yalıtımı şartname doğrultusunda yapılmıştır.*			
C-6	**All valves and test ports are easily accessible.** *Bütün vanalar ve test noktaları kolayca ulaşılabilir durumdadır.*			

D. DUCTWORK				
D-1	**Adequate locations available for testing and balancing of unit.** *Test ve ayar işlemleri için yeterli yer vardır.*			
D-2	**All dampers and sensors are accessible.** *Bütün damper ve sensörler ulaşılabilir durumdadır.*			
D-3	**Vibration isolators installed.** *Titreşim izolatörlerinin montajı yapılmıştır.*			
D-4	**All dampers close tightly and stroke fully and easily.** *Bütün damperler sıkıca kapalıdır, kolay ve tam olarak dönüş yapabilmektedir*			
D-5	**Ductwork is clean and free of debris.** *Kanallar temizdir.*			
E. ELECTRICAL				
E-1	**Motor rotation in the proper direction.** *Fan motor dönüş yönü doğrudur.*			
E-2	**All electrical connections are tight.** *Bütün kablo bağlantıları sıkıdır. Gevşek nokta yoktur.*			
E-3	**All electrical componennts grounded.** *Bütün elektriksel ekipmanlar topraklanmıştır.*			
E-4	**VFD installed.** *VFD monte edilmiştir (Varsa).*			

F. CONTROLS-INSTALLATION				
F-1	**Control panel accessible and labeled properly.** *Kontrol paneli ulaşılabilir durumdadır ve uygun şekilde etiketlenmiştir.*	☐	☐	☐
F-2	**Temperature, humidity, pressure, and CO_2 sensors (as applicable) are installed.** *Sıcaklık, nem, basınç ve CO_2 sensörleri montajlıdır.*	☐	☐	☐
F-3	**Dampers actuators installed verified.** *Damper motorları uygun şekilde monte edilmiştir.*	☐	☐	☐
F-4	**Hot and chilled water actuators installed.** *Sıcak ve soğuk su vana motorları monte edilmiştir.*	☐	☐	☐
F-5	**Safety items installed (freezesat, high pressure, motor overload etc.).** *Emniyet elemanları monte edilmiştir (Donma, yüksek basınç, motor aşırı yüklenmesi vb.).*	☐	☐	☐
G. MECHANICAL STARTUP				
G-1	**Internal isolators free to move.** *İç izolatörler kolay hareket edebilmektedir.*	☐	☐	☐
G-2	**Fan belts have proper tension and are in good condition.** *Fan kayışları uygun gerginliktedir ve iyi durumdadır.*	☐	☐	☐
G-3	**Protective shrouds for fans and belts in place and secure.** *Fanlar için koruyucu örtüler ve kayışlar yerindedir ve sağlamdır.*	☐	☐	☐
G-4	**Filters installed properly and are clean.** *Filtrelerin montajı uygundur ve temizdir.*	☐	☐	☐
G-5	**System starts and runs without any unusual noise or vibration.** *Sistem gürültüsüz ve titreşimsiz çalışmaktadır.*	☐	☐	☐
G-6	**Manufacturer's startup checklist completed and attached.** *Üreticiye ait devreye alma formu tamamlanmıştır ve eklidir.*	☐	☐	☐

"No" Responses	
ITEM	**REASON/CLARIFICATION FOR "NO" RESPONSE**

Annex - K Sample DDC Board Pre-Cx Form

1. Model Verification

Panel Name		**Eq. Tag**	
Building Name		**Floor**	
Zone Number		**Zone Name**	
		Submitted	**Delivered**
Manufacturer			

2. Installation Checks

	ITEM/TASK	YES	NO	N/A
A. UNIT CHECK				
A-1	**Location of panel is correct.** *Panonun yeri doğrudur.*	☐	☐	☐
A-2	**Approved control materials are used.** *Onaylı kontrol ürünleri kullanılmıştır.*	☐	☐	☐
A-3	**Panelboard installed is free from damages. Door interlock is operating.** *Panoda darbe, çizik yoktur. Pano kapağının kilidi çalışır durumdadır*	☐	☐	☐
A-4	**Panelboard installed has clear accessibility for operation.** *Pano, bakım onarım için kolay ulaşılabilir durumdadır.*	☐	☐	☐
A-5	**Installation, placement nad wiring system per approved diagram.** *Montaj-yerleşim,kablolamalar onaylı proje çizimlerine uygundur.*	☐	☐	☐
A-6	**Labeling is approved to Point List.** Etiketlemeler, nokta listesine uygundur.	☐	☐	☐
A-7	**All connections tight.** *Bütün kablo bağlantıları sıkıdır. Gevşek nokta yoktur*	☐	☐	☐
A-8	**Neutral and earth cables are terminated to respective bars.** *Nötr ve topraklama kabloları ilgili kısımlara bağlıdır.*	☐	☐	☐
A-9	**Approved projects are available.** *Onaylı proje çizimleri vardır.*	☐	☐	☐
A-10	**Illumination in the panel.** *Pano içi aydınlatma vardır.*	☐	☐	☐

"No" Responses

ITEM	REASON/CLARIFICATION FOR "NO" RESPONSE

Annex - L Sample Lighting Automation Pre-Cx Form

1. Model Verification

Eq. TAG		**Floor**	
Building Name		**Zone No**	
Zone Name			
	Submitted	**Delivered**	
Model			
Manufacturer			

2. Installation Checks

	ITEM/TASK	YES	NO	N/A
A. UNIT CHECK				
A-1	**BUS cables installed per approved drawings.** BUS kabloları projeye uygun çekilmiştir.	☐	☐	☐
A-2	**Panel interior connections are appropriate.** *Pano iç bağlantıları uygundur.*	☐	☐	☐
A-3	**Connections of energy and line cables in panel are in good condition.** *Pano enerji ve linye kablolarının bağlantıları iyi durumdadır.*	☐	☐	☐
A-4	**Line and load of installed fixtures is controlled.** *Takılı olan armatürlerin linye ve yük kontrolü yapılmıştır.*	☐	☐	☐
A-5	**Fixture and module capacity are appropriate for dimmable loads.** *Dim kontrolü yapılacak yükler için armatür ve modül kapasitesi uygundur.*	☐	☐	☐
A-6	**Products with ballasts are selected as correct.** *Balastlı ürünlerin seçimi doğru yapılmıştır.*	☐	☐	☐
A-7	**Boxes that installed for automation switches are appropriate.** *Otomasyon anahtarları için konulan kasalar uygundur.*	☐	☐	☐
A-8	**Wiring of used panels (Touch panel etc.) is correct.** *Kullanılan panellerin kablolaması (Touch panel vs.) doğru şekilde yapılmıştır.*	☐	☐	☐
A-9	**Projects that used, is appropriate to installation.** *Montaj için kullanılan projeler imalat ile uyumludur.*	☐	☐	☐
A-10	**Connection between Automotion system and network central is controlled.** *Otomasyon sistemi ile network merkezi arasındaki bağlantılar kontrol edilmiştir.*	☐	☐	☐

"No" Responses

ITEM	REASON/CLARIFICATION FOR "NO" RESPONSE

Annex - M Sample Issues Log

ISSUES LOG / HATA KAYITLARI LİSTESİ

Proje İsmi (Project Name)	
Proje Yeri (Location)	
Proje Tanımı (Project Description)	
Version (Sürüm)	
Tarih (Date)	

ID	Tespit Tarihi (Date Identified)	Teknik Kategori (Technical Category)	Bina (Building)	Konuyu Tanımlayan Kişi (Entered By)	Referans (Referance)						Konu (Issue)	Öncelik (Priority)	Sorumlu Kişi (Responsible)	Aksiyon Adımları (Action Steps)	Planlanan Çözüm Tarihi (Expected Solution Date)	Konunun Kapanma Tarihi (Resolution Date)	Şu anki durum (Current Status)	Proje Yönetimi-İşveren Son Kararı (Final Resolution of Project Management-Owner)
					Ekipman Etiketi (EQ.TAG)	Kat (Floor)	Bölge (Zone)	Form	MADDE (ITEM)	FOTO NO (PIC NO)								
5	30-Apr-16	Mekanik (Mechanical)	WAREHOUSE	CK	WH-EF-02	Zemin Kat	B	F.PFC-009	Pre-Functional Checlist		Test ayar için mesafe yok,kanal flanşında ezilme tespit edildi.	Orta(Medium)					Açık(Open)	
6	30-Apr-16	Mekanik (Mechanical)	WAREHOUSE	CK	WH-FC-02	Zemin Kat	A	F.PFC-001	Pre-Functional Checlist		Filtre hasarlı, hava kanalları yeterince mesnetlenmemiş, ısıtma boruları da yeterince sabitlenmemiş, izolasyonda eksikler var,sıcaklık sensörü görülemedi, müdahale kapağı yok, flex kanallar çok uzun.	Yüksek(High)					Açık(Open)	
77	30-Apr-16	Mekanik (Mechanical)	U2	AG	00-BU-1001-1	Zemin Kat		F.PFC-003	Pre-Functional Checlist		Pompa Gövdesinde Su Kaçağı var ! Manometre yok.	Yüksek(High)					Açık(Open)	
78	30-Apr-16	Mekanik (Mechanical)	U2	AG	00-BU-1001-2	Zemin Kat		F.PFC-003	Pre-Functional Checlist		Manometre yok.	Düşük(Low)					Açık(Open)	
97	30-Apr-16	Mekanik (Mechanical)	U2	AG	HP-UH-06-4	Zemin Kat	Compressor	F.PFC-002	Pre-Functional Checlist		Hava alma noktası ve sıcaklık sensörü görülemedi	Düşük(Low)					Açık(Open)	
133	30-Apr-16	Elektriksel (Electrical)	WAREHOUSE	KT		Zemin Kat	Genel		Other		Mevcut as-built proje, saha uygulaması ile uyumlu değil. Commissioning sürecindeki saha ve ofis çalışmaları için, as-built projesinin hızlı bir şekilde güncellenmesi gerekir.	Yüksek(High)					Açık(Open)	
134	30-Apr-16	Elektriksel (Electrical)	L1	KT		Zemin Kat	Genel		Other		Mevcut as-built proje, saha uygulaması ile uyumlu değil. Commissioning sürecindeki saha ve ofis çalışmaları için, as-built projesinin hızlı bir şekilde güncellenmesi gerekir.	Yüksek(High)					Açık(Open)	
135	30-Apr-16	Elektriksel (Electrical)	L1	KT		Mezzanine	Genel		Other		Mevcut as-built proje, saha uygulaması ile uyumlu değil. Commissioning sürecindeki saha ve ofis çalışmaları için, as-built projesinin hızlı bir şekilde güncellenmesi gerekir.	Yüksek(High)					Açık(Open)	
149	30-Apr-16	Elektriksel (Electrical)	L2	KT		1.Kat	BIG BAG HANDLING AREA (L2-2-002)	F.PFC-005	Pre-Functional Checlist		Armatürlere gelen kablolar koruyucu boru (spiral boru) içinde değildir.	Orta(Medium)					Açık(Open)	
150	30-Apr-16	Elektriksel (Electrical)	L2	KT		1.Kat	BATTERY ROOM (L2-2-011)	F.PFC-005	Pre-Functional Checlist		Armatürlere gelen kablolar koruyucu boru (spiral boru) içinde değildir.	Orta(Medium)					Açık(Open)	
151	30-Apr-16	Elektriksel (Electrical)	L2	KT		1.Kat	MCC ROOM-1 (L2-2-009)	F.PFC-005	Pre-Functional Checlist		Armatürlere gelen kablolar koruyucu boru (spiral boru) içinde değildir.	Orta(Medium)					Açık(Open)	
152	30-Apr-16	Elektriksel (Electrical)	L2	KT		1.Kat	1.850 WIDE PASSAGE (L2Y8 - L2Y4 ile L2X3 - L2X4 arası)	F.PFC-005	Pre-Functional Checlist		Armatürlere gelen kablolar koruyucu boru (spiral boru) içinde değildir.	Orta(Medium)					Açık(Open)	
153	30-Apr-16	Elektriksel (Electrical)	L2	KT		1.Kat	PROD ENG. ROOM (L2-2-013)	F.PFC-005	Pre-Functional Checlist		Armatürlere gelen kablolar koruyucu boru (spiral boru) içinde değildir.	Orta(Medium)					Açık(Open)	
154	30-Apr-16	Elektriksel (Electrical)	L2	KT		1.Kat	PCL CABINET (L2-2-003)	F.PFC-005	Pre-Functional Checlist		Armatürlere gelen kablolar koruyucu boru (spiral boru) içinde değildir.	Orta(Medium)					Açık(Open)	