KABEV

Energy Efficiency in Public Buildings

(EEPB/DB/MoEU/QCBS-SUBPR-01)

II. Workshop & Training

21-23 September 2022

Commissioning

23 September 2022

T.C. ÇEVRE, ŞEHİRCİLİK VE
İKLİM DEĞİŞİKLİĞİ BAKANLIĞI

Program for today

9:30-10:45	Commissioning Introduction
10:45-11:00	Coffee Break
11:00-12:30	Pre-functional checks
12:30-13:30	Lunch
13:30-15:00	Functional performance tests I
15:00-15:15	Coffee Break
15:15-16:30	Functional performance tests II
16:30-17:00	Assessment/Q&A with participants

Part I

CX Introduction

DEFINITIONS

What does commissioning means

Commissioning (Cx) is a process that has no exact equivalent in Turkish.

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.

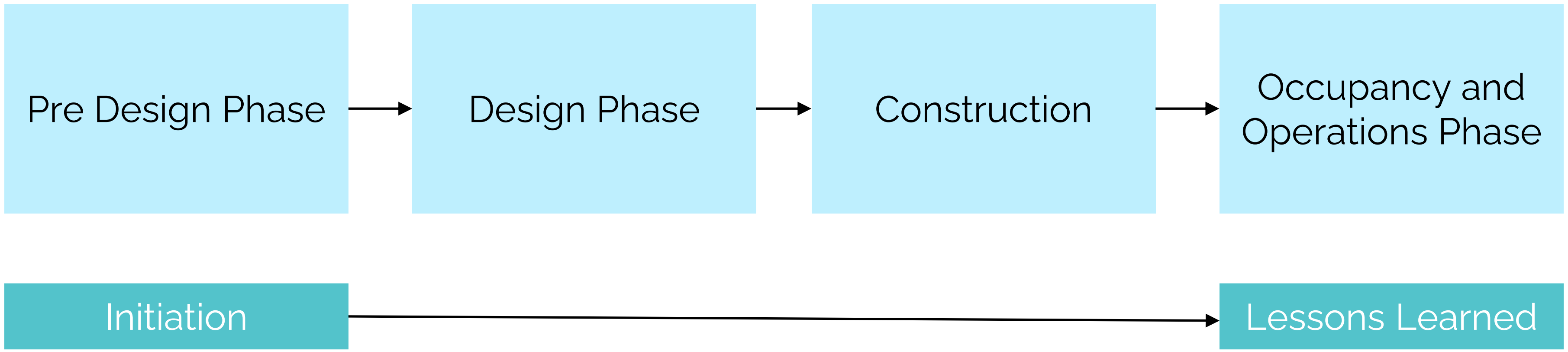
Cx is often perceived as focusing solely on testing at the end of the construction phase. But Cx is a collaborative process to plan, deliver and operate all processes so that they work as intended by the designer. Cx starts with project planning and includes design, construction, commissioning, acceptance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

Cx FOLLOWS ALL PROJECT LIFE CYCLE, AND IS NOT JUST ENERGY RELATED

The structure is very similar to the PMI-project management rules



….WE WILL FOLLOW THE NEED AND WILL FOCUS ONLY ON A SMALL PART OF THE PROCESS,

The full normal Cx process and standardization will be adaptated to suit KABEV needs

The pre-design and design are assumed done, and expected to give all the necessary data and guidance for a testing process

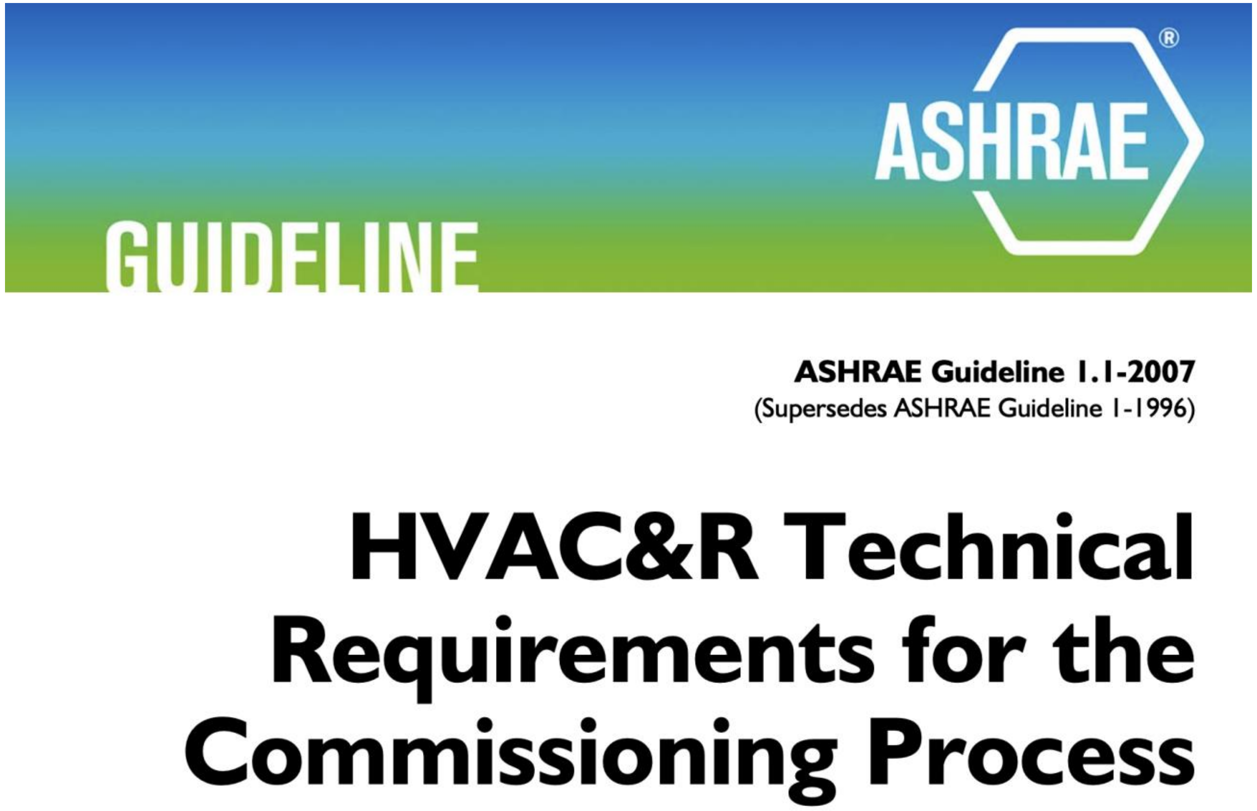
The process will be centred around TAB and performance testing

Pre Design Phase → Design Phase → Construction → Occupancy and Operations Phase

- Construction Phase Activities [pre TAB]
- Testing, adjusting and Balance [TAB]
- Functional Performance Testing

STANDARDS AND THEORY

Cx is mainly a US operational idea


GUIDELINE

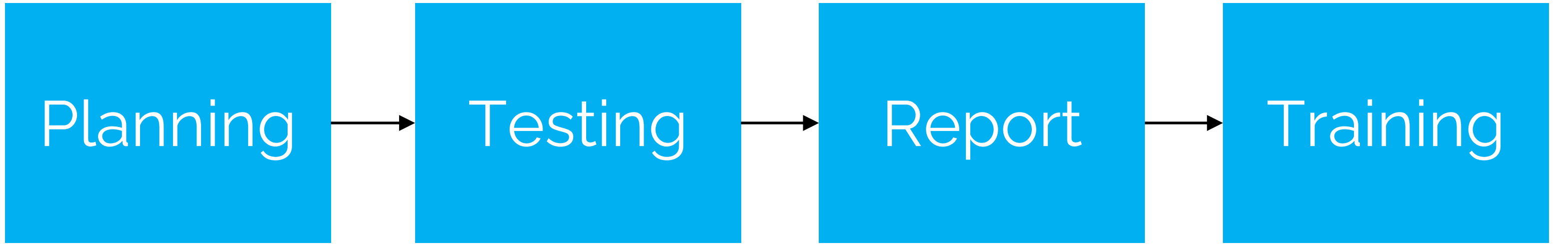
ASHRAE

ASHRAE Guideline 1.1-2007
(Supersedes ASHRAE Guideline 1-1996)

HVAC&R Technical Requirements for the Commissioning Process

THIS Cx ANALYSIS STARTS WITH CAREFUL PLANNING AND FOLLOWS A SIMPLES PROCESS

The flow is adapted to suit the Construction/Occupancy phases



PLANNING: WHAT TO DO, WHO WILL DO IT AND WHEN

Planning is the coordination and integration of systems and equipment in the Cx process with other construction phase activities

What

- Systems and equipment to be analysed
- Functional/performance steps in each system

Who

- Team in charge (normally
- Main team responsibilities
- Interface with other teams (contractor,

When

- Define calendar and schedule
- Importance of needed level of service and weather seasons to perform real live testing

- CX SHOULD BE EXTERNAL TO THE CONTRACTING AND DESIGN TEAM
- PLANNING MUST BE TANGIBLE AND REAL
- ALL RELEVANT STAKEHOLDERS SHOULD BE ONBOARD

Cx TEAM HAS SEVERAL WELL KNOWN RESPONSIBILITIES….

The Cx should be managed using Project management tools and concepts for optimal outupt

- Identify experts responsible for performing Cx activities for specific systems
- Planning the Cx process activities and integrating them into the project construction program.
- Handling program changes.
- Documenting and developing test procedures and data sheets.
- Conducting and documenting Cx team meetings.
- Monitoring compliance with project requirements by making periodic site visits.
- Verifying completion of items specified in construction checklists.
- Observing the tests to verify the tests and their results, including test data reports.
- Verifying the training of operation and maintenance personnel and users according to project requirements.
- Monitoring, diagnosing and documenting problems and deviations related to project requirements
- Writing and examining the progress reports of the Cx process.
- Examining the construction progress reports.
- Verify that new equipment and systems are incorporated into the maintenance management program.

...AND WILL HELP DEFINE THE SYSTEMS THAT SHOULD BE INCLUDED IN DETAILED TESTING

Cx can be a consinuoes enormous task, so the choices have to be clear and effcincnt

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.

Static

- Building envelope
- Building structure
- (...)

Dynamic

HVAC,
Lighting
BMS
(:...)

AFTER PLANNING....THE MOST IMPORTANT STEP: TESTING

Testing is the central step and the overall objective of the whole process

Testing Process Flow

1. Basic Tests →
2. Pre-Cx (Pre-Functional Checklist / Pre-Commissioning) →
3. Start-Up →
4. Functional Performance Test

BASİC TEST

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, cables circuit.

For example, tests such as strength test for pipes, leakage test for chimneys, insulation resistance test for cable or grounding measurement will be performed in accordance with the methodology specified, 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.

1

BASIC TESTING AND COMPLIANCE ANALYSES, NORMALLY TO TRANSVERSAL BUILDING INFRASTRUCTURE DURING CONSTRUCTION PHASE

PRE-FUNCTİONAL TEST

At this stage, the system must be installed with all its elements, and the piping, ducting 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.

START UP

After all checks are made, it is time to start the systems for normal operation

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 non conformity 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.

START UP MARKS THE BEGİNNİNG OF OCCUPATION PHASE AND ALSO THE START OF PERFORMANCE TESTING

FUNCTIONAL PERFORMANCE TEST

The Functional performance test is the last step for the installation tune in

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 pressure settings, temperature settings, ventilation, regulations, leakage current tests, thermal examinations, etc. in systems that may require.

All requirements made in design and pre design will be met in this process.

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 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 non-conformity is eliminated.

ALL SYSTEMS RUNNING AND READY TOR TAB. CHECK ALL THE CONNECTIONS AND DEPENDENCIES OF SYSTEMS FOR OPTIMIZED PERFORMANCE

TESTİNG PROCEDURES

Defining what to do is paramount for success

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

- Who will be there. May include the main contractor, sub-contractors, design experts, Cx officer, operators, local competent authority and manufacturers of equipment, systems or installations; all participants deemed necessary/relevant for testing.
- Prerequisites for test performance for the completion of systems and assemblies.
- Step-by-step instructions for running specific systems and assemblies under test. The instructions will also cover how to configure to start the test and how to restore the system to normal operation at the end of the test.
- List of devices, tools and supplies required for testing. This list should indicate that participants are responsible for the items listed. List; Should meet all relevant performance requirements.
- An indication and a set of acceptable results for each step of the recorded observation and measurement procedures.

TESTING PROCEDURES MUST BE DEFINED BEFORE HAND. WHAT TO DO, WHEN TO DO IT,

TESTİNG VALİDATİON

What is a valid test, and what is the playbook to follow.

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:

- Component testing procedures, should verify the performance of components under a set of actions and their response/response to inputs and loads.
- System/assembly test procedures which should verify the performance under a range of operating conditions (both emergency and normal), and their response/response to inputs and loads.
- Inter-system testing procedures: Inter-system testing procedures should verify the interactions between systems and assemblies.
- 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.

WHAT IS A SATISFACTORY TEST, HOW SO SAMPLE, AND HOW TO SET THE VERIFICATION QUALITY

LOGS AND RECORDS

The way records are made will tell about the quality of the overall process moving forward

The records should achieve and keep the following info:

- Test number, 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 Conditions. 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 at each step of the test. When using data forms, checkboxes are often insufficiently descriptive about system performance,
- 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.

LOG AND RECORD OF TESTİNG AND ALL DATA BEFORE AND AFTER THE TEST İS VERY MUCH PART OF THE PROCESS SUCCESS

ENABLİNG A GOOD CX PROCESS: SENSORS AND AUTOMATİON

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

It is mandatory 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.

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.

ONE CAN ONLY ANALYSE WHAT CAN BE MEASURED. THE SENSORS AND AUTOMATION INFRASTRUCTURE ARE VITAL FOR A GOOD CX

CX OUTPUT

Output of the process must be kept always in sight. Provide the basic data for analysis of the achievement of energy efficiency objectives and compliance from the as built to the design.

The Cx starts with 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.

With this, all measurements and analyses shall ensure that at least the following parameters (whether direct or calculated) are used for project improvement:

- Efficiency in cold production and distribution
- Efficiency in heat 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.

THE CX OUTPUT MUST BE PART OF THE CONTINUOUS IMPROVEMNT OF THE BUILDING ENERGY MANAGEMENT. HAS TO BE USEFUL AND MADE IN A TANGIBLE SENSE

CX AND M&V

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.

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.

KABEV PLACES EMPHASIS ON ENERGY EFFICIENCY TARGETS. THE PERFORMANCE TEST IS VITAL SO SET UP GOOD QUALITY M&V FOR CONTRACT MANAGEMENT

TRAINING

Training is one of the most important steps. Learn how the system works for future O&M and M&V and lessons learn process

Training on systems data	Operation and maintenance	Performance and improvement
Basic	Basic O&M	Performance Operation
• Equipment Schedules • System structure and relations • Start up/down	• Daily operation • Emergency situations • Repairs and problem analysis • Maintenance logs and reports	• Adjustments • Setpoints and BMS • Level of Service • M&V procedures

DOCUMENTATİON REQUIREMENTS

Cx and training are all about documentation and report of the issues taken

All equipment and systems used in the project, user manuals, operation and maintenance manuals, 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 have at least the following structure:

- Equipment and systems including plans, cuts and system flowcharts
- Test checklist
- Pre-Functional Checklist
- Initial start-up forms
- Functional test forms
- Issues Log List
- Training documents
- System guides and control narratives

DOCUMENTATİON IS NOT ONLY AN OUTPUT OF THE CX PROCESS BUT ALSO INPUT

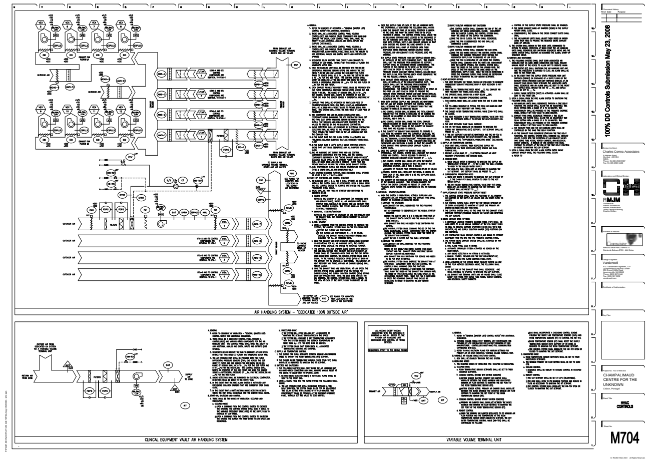
The design should give all the input needed to understand system behaviour. Example of control:

Control narratives

- Control and system description will tell the contractor and Cx team how the system supposed to work.
- Equipment schedule and drawings show the physical system and assembly, but the narratives give the brains behind the hardware.
- Theses narratives will be the input for the performance tests and system output analysis

Narrative detail should increase with system complexity

Split has to cool the room when powered up

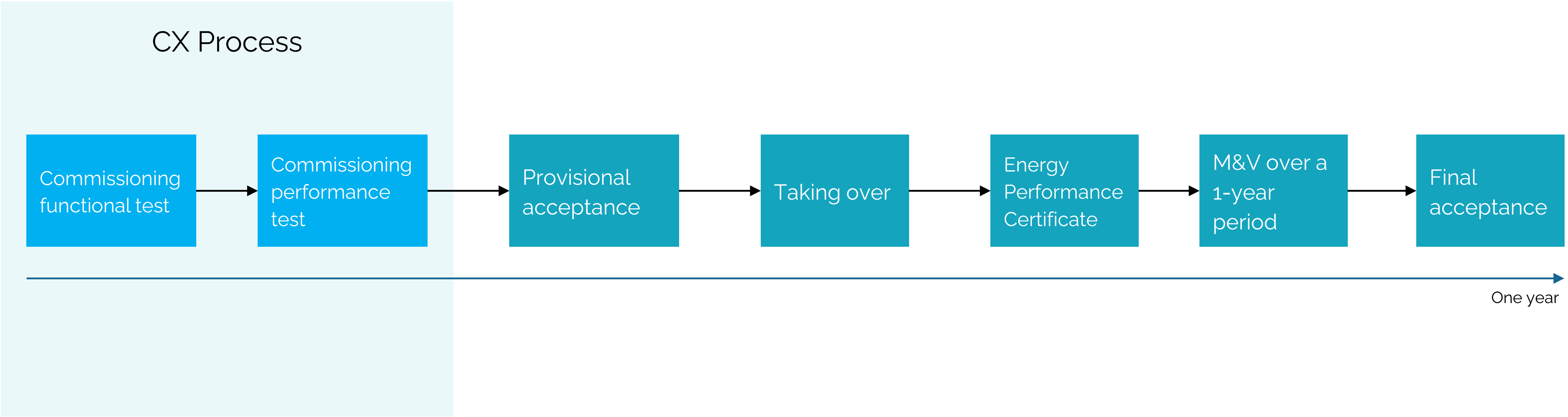


Simple system

Complex System

KABEV HAS A SPECIAL HANDOVER STRUCTURE…

Commissioning is very important for KABEV contracts, paving the way for M&V results



….witch starts with Cx, in two steps

The Cx process is very important for KABEV contracts, paving the way for M&V results

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.		
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.

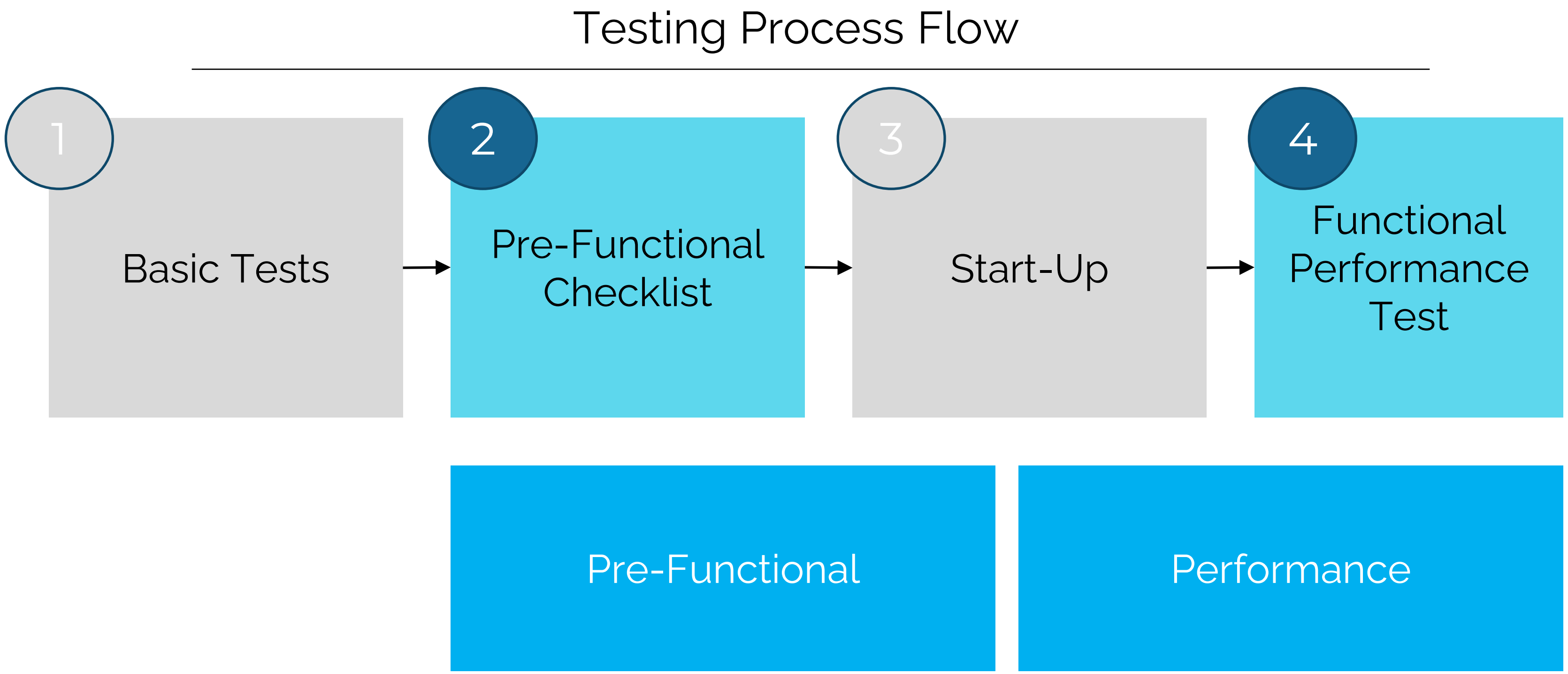
USE CX STRUCTURE FOR ASSESSING KABEV TARGETS

Kahve Molasi

Part II

Pre-Functional Test

Lets go back to the Testing Flow Chart



In this workshop for simplicity this will be the setting going forward

THE TESTING COMPLEXITY WILL DEPEND ON THE PLANNING AND OBJECTIVES….

Cx effort will be dictated by project objectives and by external project context

Minimal Cx Effort	↔	Maximum Cx Effort

Minimal Cx Effort

- Simple systems
- No external controls
- Easy set up
- Small construction cycle
- One contractor/one owner
- No/Low Budget

Examples:

- VRV and/or split system in a small shop

Maximum Cx Effort

- Complex systems with lots of interactions
- Large construction setting
- Multiple contractors and stakeholders
- Complex project objectives
- ESCo or other future contract requirements
- Assigned Cx Budget

Examples:

- KABEV type projects

...AND EQUIPMENT TYPE

The type of equipment will tell us if the Cx work can handle inputs or just look for outputs

Systems with built in controls and algorithms

Closed systems

- Factory sourced closed and out-of-box systems
- No external controls
- VRV, split systems, some Heat pumps.
- Cx only for output and external system interconnection

Systems with external components

Open systems

- Systems made of several equipment's and components
- External control
- Custom made algorithm
- Air to water systems, complex buildings with external BMS direct control

PRE-FUNCTIONAL TESTS ARE THE FIRST ASSESSMENT OF ACTUAL SYSTEM WORK

The functioning of individual systems will be assessed. It is mainly a input based analysis

Input → Internal (Equipment) → Output

Input

- Design equipment compliance
- Design assembly compliance
- Catalogues and schedules
- Control sequences

Internal

- Assembly inspection
- External connections (piping, electrical ducting)
- Start up/cool down sequences
- Emergency sequences

Equipment Centric

- The main object is single component7euipemt checking
- Systems will have normally different control and testing settings
- Interactions and performance btw equipment's will be analysed later
- This should be and expedite and clean process

PRE-FUNCTIONAL TEST EXAMPLES: BUILDING ENVELOPE

The functioning of individual systems will be assessed. It is mainly a input based analysis

EE measure	Parameter to confirm	Method
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

PRE-FUNCTIONAL TEST EXAMPLES: LIGHTING

The functioning of individual systems will be assessed. It is mainly a input based analysis

EE measure	Parameter to confirm	Method
Luminaires	Wattage	Visual inspection of luminaires.
	Efficacy (e.g., lm/W)	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)

PRE-FUNCTIONAL TEST EXAMPLES: HVAC

The functioning of individual systems will be assessed. It is mainly a input based analysis

EE measure	Parameter to confirm	Method
Radiators and Heating system circulation loop	System and design	Inspect number and model of elements
		Leaks and hydraulic connections
		Valve placement and connection if any
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).
		Inspect thickness and type of installed insulation.
		Confirm manufacturer specifications for insulation type(s).
		Check for thermal bridges and installation quality

PRE-FUNCTIONAL TEST EXAMPLES: HVAC

The functioning of individual systems will be assessed. It is mainly a input based analysis

EE measure	Parameter to confirm	Method
Motors	Power Consumption	Confirm manufacturer specification vs design requirements
		Measure Energy consumption using sub/dedicated or portable meter
		Compare absorbed power vs design power (assuming design conditions)

PRE-FUNCTIONAL TEST EXAMPLES: HVAC

The functioning of individual systems will be assessed. It is mainly a input based analysis

EE measure	Parameter to confirm	Method
Boiler	Design compliance and construction	Confirm manufacturer specification vs design requirements
		Built assembly structure
		Noise and Vibrations
		Terminal Connections
		Chimney
		Measuring ports
Chiller	Design compliance and construction	Confirm manufacturer specification vs design requirements for power, COP etc
		Built assembly structure
		Noise and Vibrations
		Terminal Connections (hydraulic and electrical)
		Refrigerant Load
		Measuring ports
		Control connections and outside communications
		Electrical consumption at start up (adequacy of Breakers, cables ground wiring etc)
		Simple control schematics

PRE-FUNCTIONAL TEST EXAMPLES: ENERGY MONITORING AND AUTOMATION SYSTEMS

The functioning of individual systems will be assessed. It is mainly a input based analysis

EE measure	Parameter to confirm	Method
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.

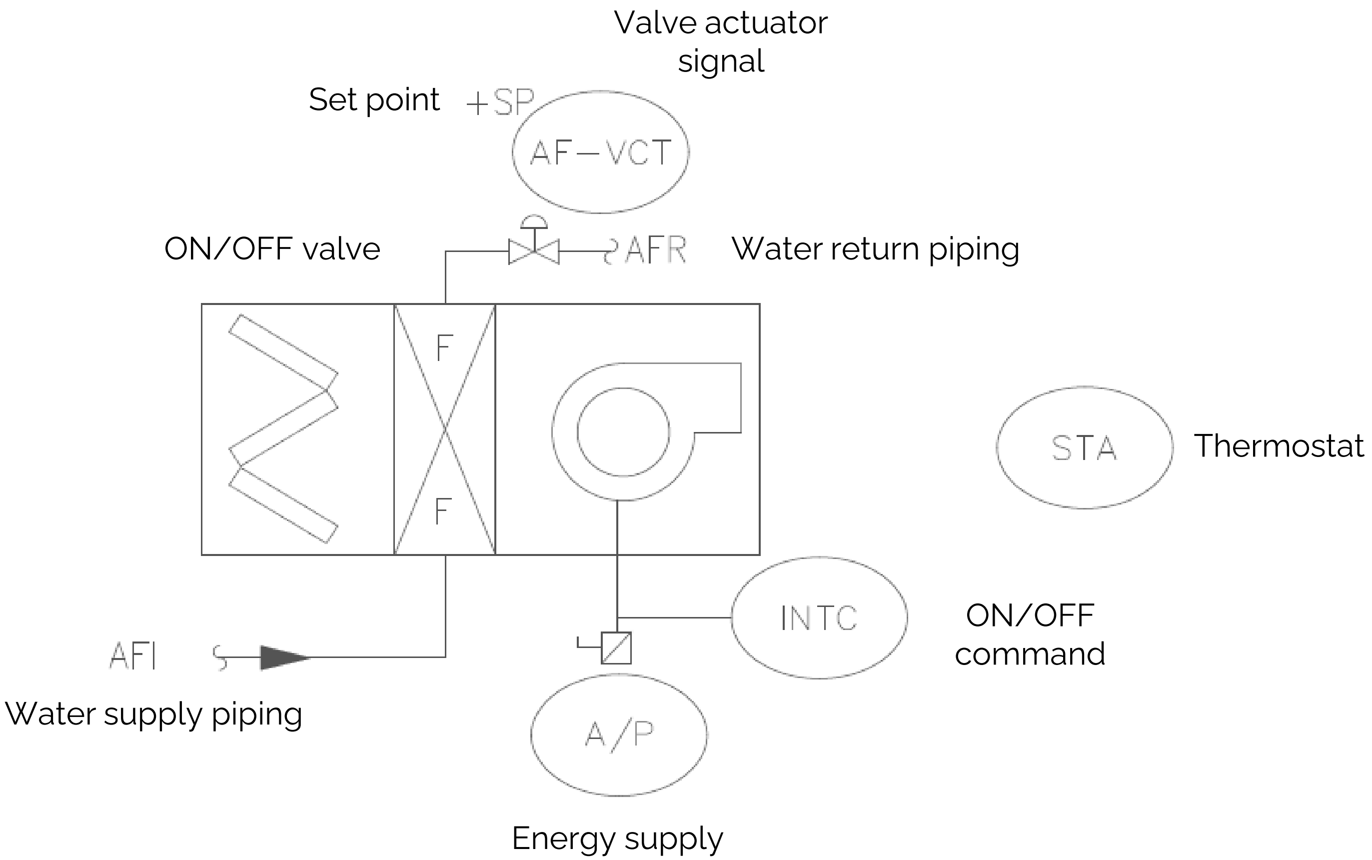
PRE-FUNCTIONAL TESTS EXAMPLES: RENEWABLES

The functioning of individual systems will be assessed. It is mainly a input based analysis

EE measure	Parameter to confirm	Method
Solar PV	Design compliance, construction and 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 nearby (and representative) station should be used
Solar hot water system	Design compliance and construction	Confirm manufacturer specification vs design data
		Check thermostat and valve settings for storage
		Check Control schematics
		Check physical Installation requirements (azimuth, tilt)
		Check connections (hydraulic, electrical and insulation

PRATICAL APPROACH: 2-PIPE FAN COIL

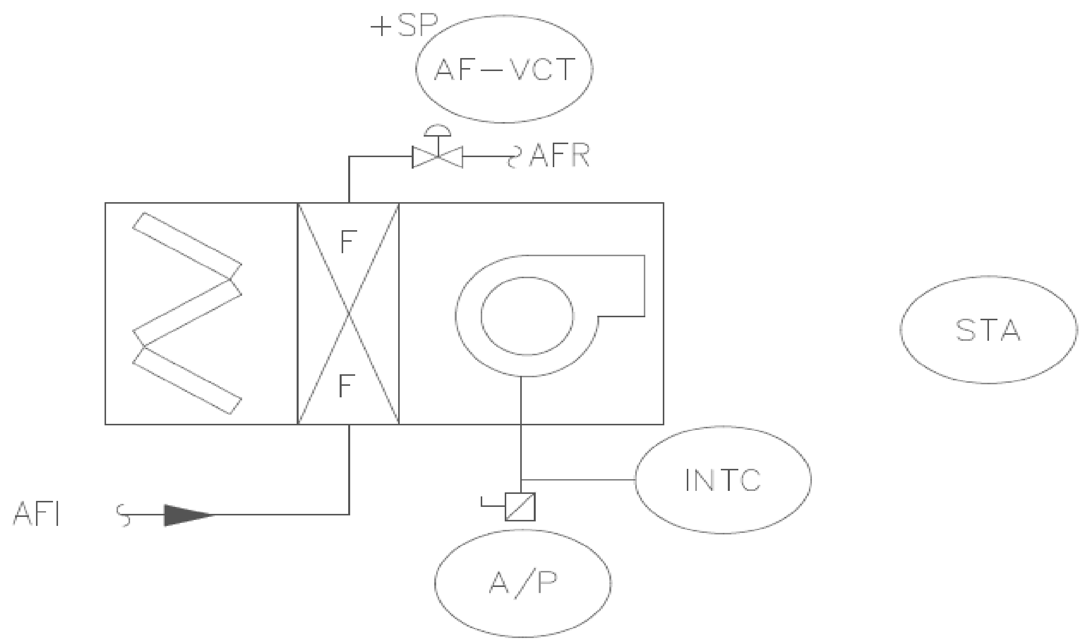
1st example 2-pipe Fan Coil



THE Cx PROCESS STARTS WITH COMPLIANCE AND WALK THROUGH ANALYSIS

1st example 2-pipe Fan Coil

Example of System schematics

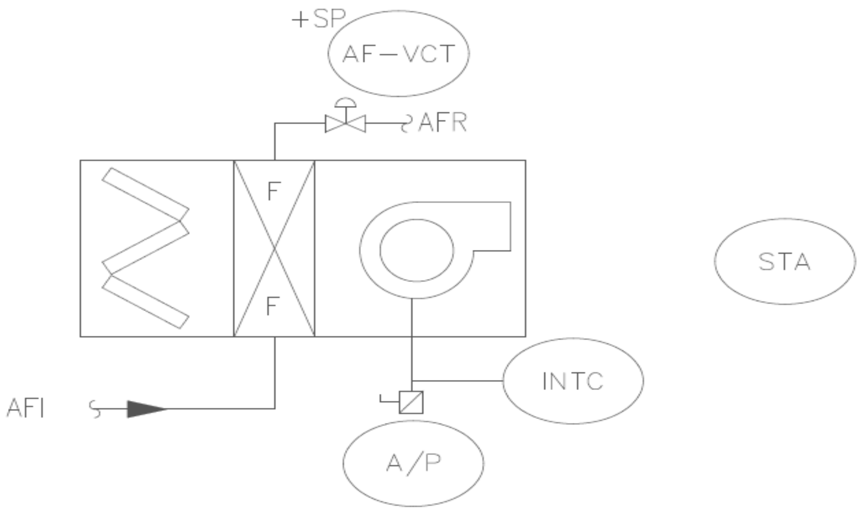


Data Points to annalyse

- In this phase all hardware should be inspected, prior to the start-up operation.
- Equipment schedule compliance to the design has to be checked, not only for the main equipment (chillers, boilers, AHU, fan-coils etc) but also for valves, controls, insulation etc.
- A sampling of the most important equipment can be done for economical efficiency.
- Documentations from design and as-built should then be checked for consistency and corrected if needed.

THE DATA SHOULD ADDRESS COMPLIANCE WITH DESIGN REQUIREMENTS

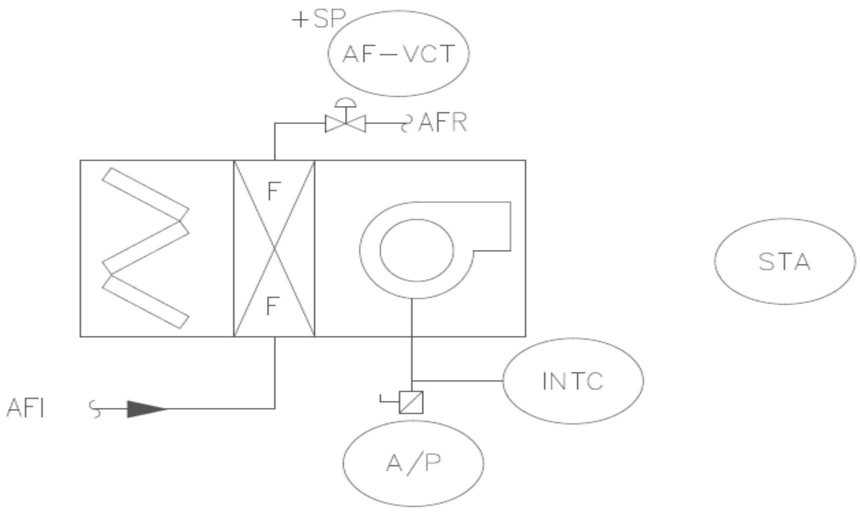
Fan coil unit (2 pipe). Example for compliance checklist



EQUIPMENT		CHECK		DESIGN	REAL
		YES	NO		
FAN-COIL	CATALOGUE				
	MODEL				
DINAMICAL FLOW VALVE	CATOLOGUE				
	MODEL				
ON-OFF VALVE	CATOLOGUE				
	MODEL				
DUCTS AND MOUNTING	ANTI VIBRATION BOLTS				
	ANTI VIBRATION DUCT CONNECIION				
	VIBRATIONS				
	OTHER				
HIDRAULIC CONNECTION	LEAKS				
	CONNECTION OF CONDENSATE PAN				
	INSULATION				
	MARKS AND SIGNS				
	OTHER				
ELETRICAL CONNECTION	LOOSE WIRINGS				
	ELETRICAL PROTECTION				
	CORRECT CABLE TYPE				
	CIRCUIT BREAKER				
	OTHER				

IN THIS Cx PHASE THE ANALYSIS SHOULD END AT POWER UP

Fan coil unit (2 pipe). Individual power up analysis



Power Up Check

Control	Check ?		Design	Real
	Yes	No		
THE FAN-COIL IS POWER CONNECTED				
POWER OFF AND POWER DOWN SEQUENCE				
ELETRICAL CONSUMPTION (PROJECT SPEED) [A]				
BREAKER SUITS FAN POWER				
WATER IS PRESENT AT PIPING				
WATER VALVES POWERED AND WORKING WITH POWER UP/DOWN				
FAN IS BALANCED WITHOUT NOISE				
WATER IS PRESENT AT PIPING				
WATER VALVES POWERED AND WORKING WITH POWER UP/DOWN				
THERMOSTAT IS CONNECTED AND FOLLOWS POWER DOWN/UP				

PREPARATION AND DOCUMENTATION FOR THE TEST SESSION

Documentation and logs have to be prepared in advanced for all tests

Test data will be registered in sample spreadsheet

- Tables to be filled in every test flowing the test requirements
- Necessary design docs always present (plans, cuts, catalogue, schedules)
- Pics, movies should be taken to document test
- Issues should be taken to the log issue for follow up

10A. Ductwork: Insulation
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	Ductwork is clean, dry and free of damage prior to insulation installation.	Yes	No
	2	Insulation is clean and dry during installation and application of any finish.	Yes	No
	3	Pressure and leakage tests performed and reports have been submitted prior to insulation installation.	Yes	No
	4	All equipment requiring maintenance is accessible (valves, junction boxes, etc.).	Yes	No
	5	Insulation is continuous through openings and sleeves in non-rated construction, and is butted tightly against the fire stop with butt joints taped in rated construction.	Yes	No
	6	All insulation edges temporary sealed to maintain duct insulation cleanliness.	Yes	No
	7	Insulation is removable at access panels with metal corner beads.	Yes	No
	8	Insulation is omitted at all equipment name plates and/or data plates.	Yes	No
	9	All outdoor intakes, housing, plenums from point of entry into the building to the fan or supply discharge and to exhaust duct from damper to outside and elsewhere be indicated on drawings are insulated with 1 1/2 inch rigid insulation board w/ vapor barrier.	Yes	No
	11	All exposed conditioned supply ductwork within the building is insulated with 1 inch thick rigid insulation board with vapor barrier.	Yes	No
	12	All non flexible ductwork insulation is fastened by applying Foster No. 85-20 adhesive in 4-inch wide continuous bands on 12-inch centers and further secured by welded mechanical pins applied on 12-inch centers as specified.	Yes	No
	13	All concealed flexible and round ductwork is insulated with 1 1/2 inch thick insulation and secured by the means of metal staples using the stitching methods of application and as detailed in the specifications.	Yes	No
	14	All exterior corners are sealed with a 5-inch wide tape.	Yes	No

IN SOME SYSTEMS THE PRE TESTS ARE CLOSE TO THE PERFORMANCE TESTS

Closed systems with no external connections can perform from the moment one presses “on”

Closed system's have little room to TAB....

- Factory sourced closed and out-of-box systems
- No external controls
- VRV, split systems, some Heat pumps.
- Cx only for output and external system interconnection

...If they are built according to design

- Factory sourced closed and out-of-box systems
- No external controls
- VRV, split systems, some Heat pumps.
- Cx only for output and external system interconnection

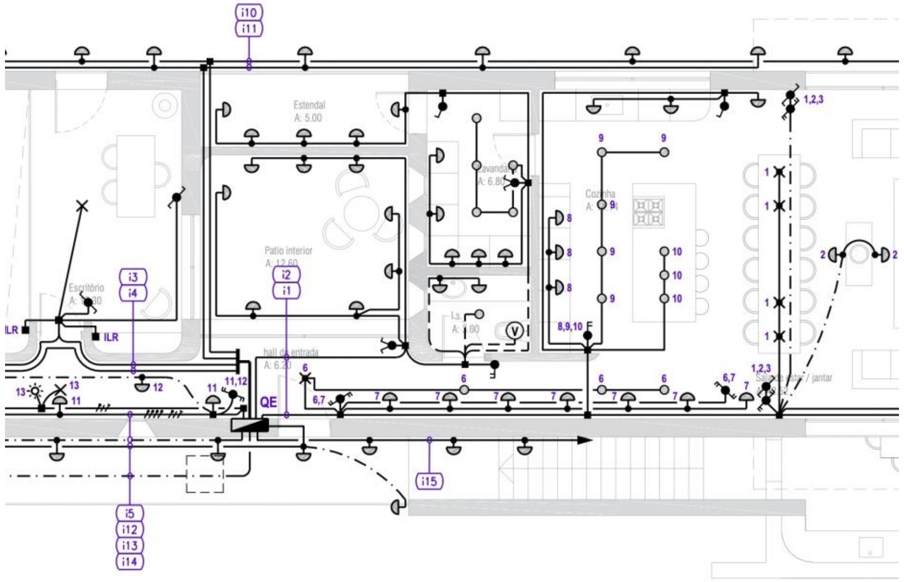
...And the room for measuring is small

- Factory sourced closed and out-of-box systems
- No external controls
- VRV, split systems, some Heat pumps.
- Cx only for output and external system interconnection

CLOSED SYSTEM EXAMPLE: LIGHTING SYSTEM

2st example: LED REFURBISMENT

Example of System schematics



Data Points

- Hardware installation quality
- Equipment schedule compliance to the design has to be checked,
- A sampling of the most important equipment can be done for economical efficiency.
- Power UP/Power down and emergency use
- Luminance at working/design zone
- Documentations from design and as-built should then be checked for consistency and corrected if needed.

DESIGN COMPLIANCE WILL ALSO MEAN FUNCIONALITY AND PERFORMANCE

LED Lights. Example for checks

For some systems pre testing equals all the testing

- For example LED systems with no external control , have limited room for performance testing
- In this case the pre-functional test will end the Cx analysis
- More elaborate testing would be necessary if dimming, or external BMS integration (for natural lighting use, for example) was employed.

Design requirements	Check ?	
	Yes	No
CATALOGUE (PER MODEL)		
CERTIFICATES AND WARRANTY		
RATED LED POWER (PER MODEL)		
NUMBER LAMPS PER CIRCUIT		
ON/OFF SCWITCH PER AREA CORRECT		
WATER VALVES POWERED AND WORKING WITH POWER UP/DOWN		
CABLES AND CONNCETERS WELL CONNCETED		
MOUNTING AND ASSEMBLY CORRECT		
CERTIFICATE FOR RECYLING (FOR REFURBHISMENTS)		

Control and Power UP	Check ?		Design	Real
	Yes	No		
THE LED LAMPS ARE POWER CONNECTED				
POWER OFF AND POWER DOWN SEQUENCE				
ELETRICAL CONSUMPTION (PER CIRCUIT [A])				
BREAKER SUITS LED POWER				
EMERGENCY SYSTEM				
ON/OFF SWITCH WORKING				
LUMINANCE AT WORKING SPACE (PER LOCATION) [LUX]				

KABEV

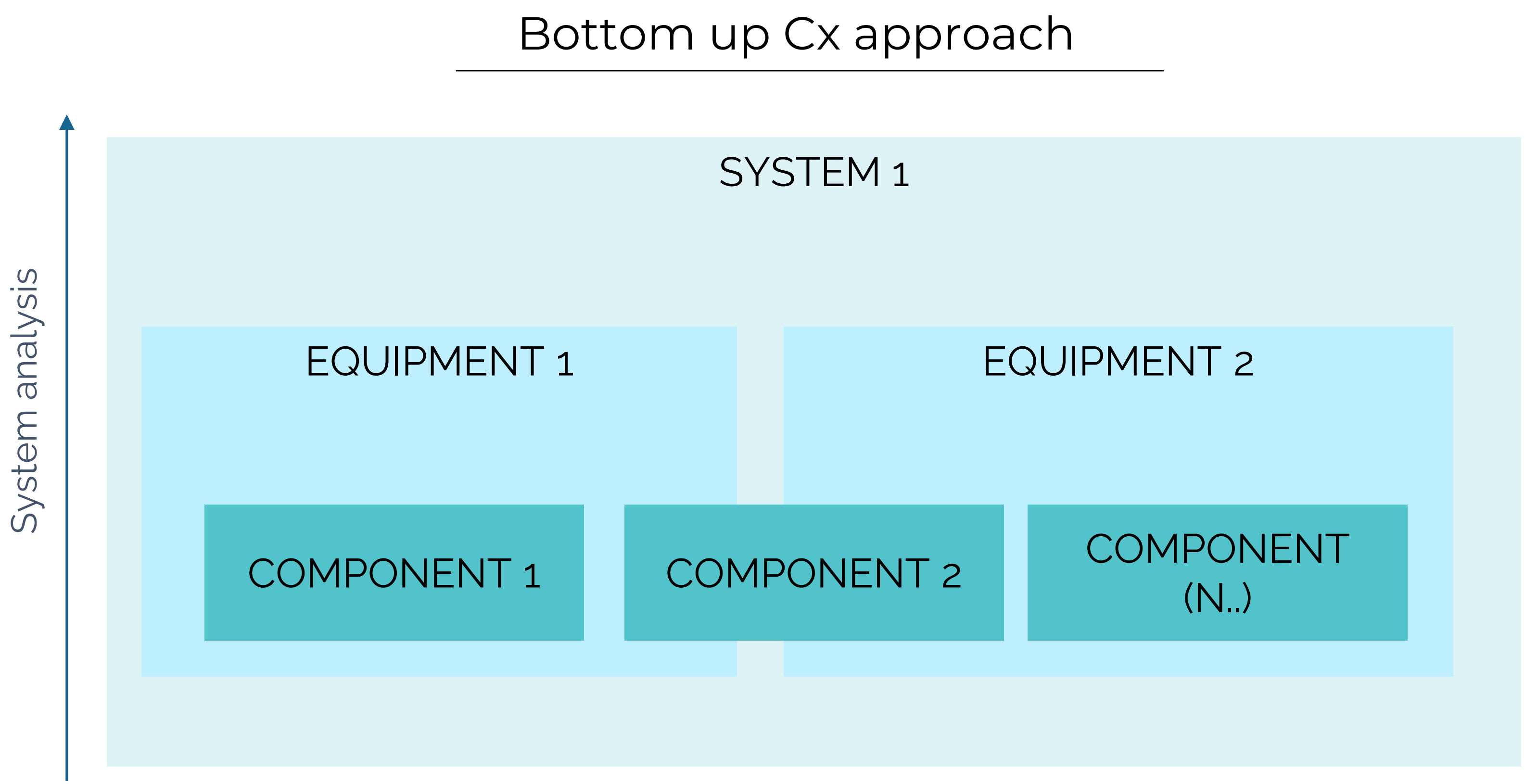
Part III

Performance Test

KABEV

PERFORMANCE TESTS WILL CHECK THE OVERALL PROJECT OUTPUT

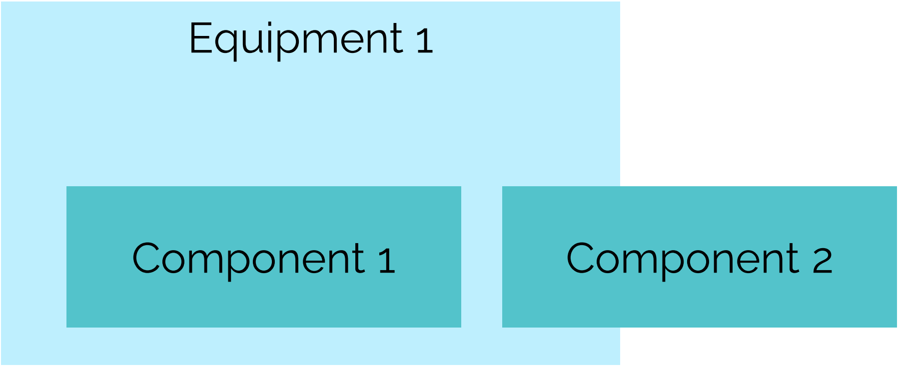
The overall system and the relations between individual equipment and components will be tested. It is a output based analysis



PRE VS PERFORMANCE TESTS ? WHAT TO DO IN EACH….

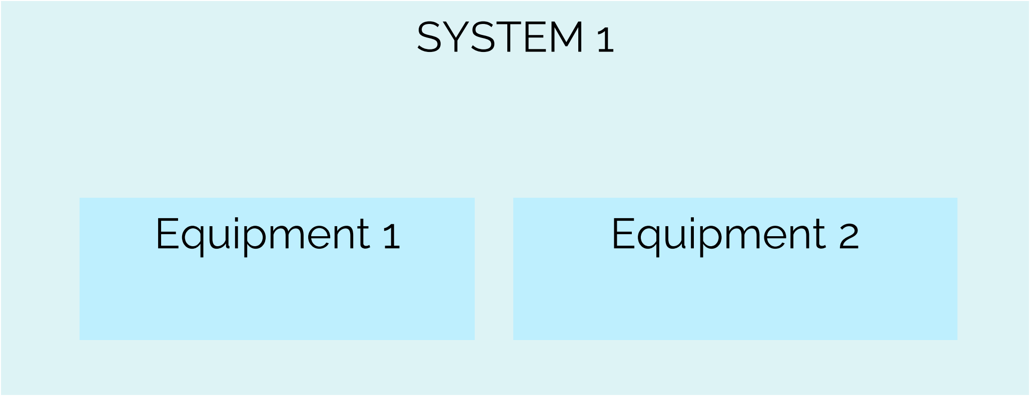
The structure may depend on the actual project, but we may find a suitable definition

Pre-testing



- Design Compliance
- Documentation
- Assembly
- Build
- Connections
- Power up operations

Performance Testing



- Control sequences
- Relations btw equipment's
- Ability to achieve outputs
- Setting Set Points and operating schedules
- Part Load efficiency
- Testing for several schedules and climate situations

PERFORMANCE TESTS WILL LOOK IN HOW COMPLEX SYSTEMS BEHAVE:: HVAC

The functioning of multi component systems will be assessed. It is an input/output analysis

EE measure	Parameter to confirm	Method
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

PERFORMANCE TEST EXAMPLES: HVAC

The functioning of multi component systems will be assessed. It is an input/output analysis

EE measure	Parameter to confirm	Method
Pumps	Efficiency, operating conditions (pressure, flow)	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
		Check control sequences and BMS (or external equipment) commnad

PERFORMANCE TEST EXAMPLES: HVAC

The functioning of multi component systems will be assessed. It is an input/output analysis

EE measure	Parameter to confirm	Method
AHU (or other air-to-water systems)	Chilled/Hot water temperature in/out 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
		Check control sequence (with BMS or external commands)

PERFORMANCE TEST EXAMPLES: HVAC

The functioning of multi component systems will be assessed. It is an input/output analysis

EE measure	Parameter to confirm	Method
Solar hot water system	Efficiency Output	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 water flow (storage, panels, boiler)
		Check Control sequences
		Compare measurements vs design data
		Check production flow vs consumption flow (primary vs secondary)
		Final Consumption circuit connection and pressure availability

PERFORMANCE TEST EXAMPLES: HVAC

The functioning of multi component systems will be assessed. It is an input/output analysis

EE measure	Parameter to confirm	Method
Boiler	Efficiency	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
		Check control sequences
		Check interface with external pumping system
		Check flue temperature, and other data for combustion efficiency calculation

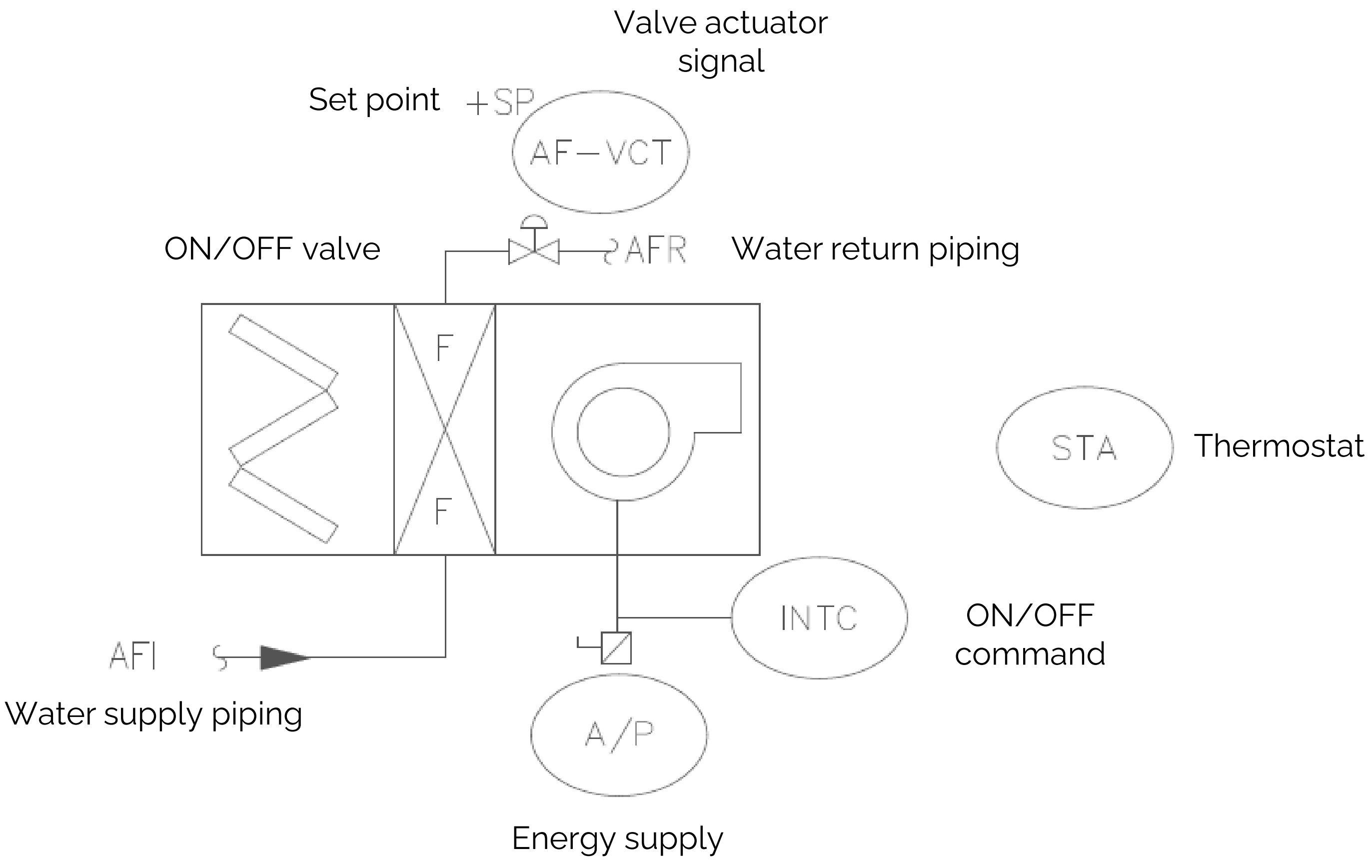
PERFORMANCE TEST EXAMPLES: HVAC

The functioning of multi component systems will be assessed. It is an input/output analysis

EE measure	Parameter to confirm	Method
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 temperature
		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

LETS GO BACK TO OUR PREVIOUS EXAMPLE…WITH PRE TESTING ALREADY DONE…

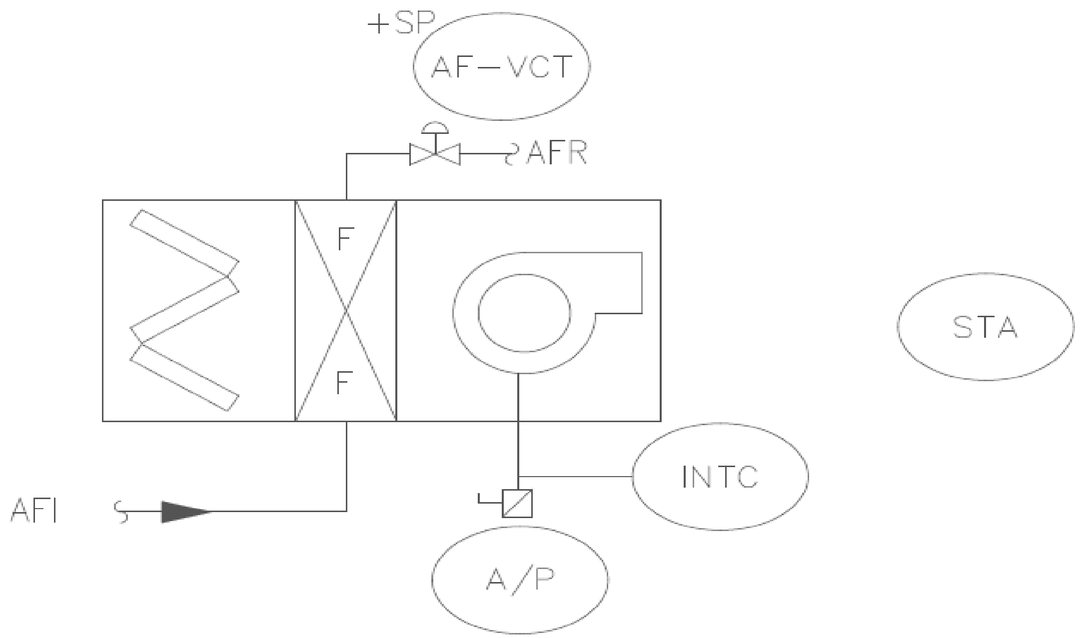
1st example 2-pipe Fan Coil (open system with external BMS action)



THE Cx PROCESS STARTS WITH SIMPLE SYSTEMS.....

1st example 2-pipe Fan Coil (open system with external BMS action)

System schematics



Control narrative sample

A. GENERAL
  1. REFER TO SEQUENCE OF OPERATION – "GENERAL (MASTER LIST) CONTROL NOTES" FOR ADDITIONAL SEQUENCES.

B. START–UP, SHUTDOWN AND CONTROL
  1. THE FAN COIL SHALL BE ENERGIZED BY THE CONTROL SYSTEM.
  2. THE FAN COIL FAN SHALL CYCLE TO MAINTAIN THE ROOM TEMPERATURE SETPOINT.
  3. THE CHILLED WATER TEMPERATURE CONTROL VALVE (CHW–TCV) SHALL MODULATE TO MAINTAIN THE ROOM TEMPERATURE SETPOINT.

....BUT EVEN THEY SHOULD BE INTEGRATED IN THE OVERALL BUILDING CONTROL

Example of master control notes

General Control narrative

A. ALL SEQUENCES OF CONTROLS SHALL BE PERFORMED BY DIRECT DIGITAL CONTROLS (DDC). FOR EACH SYSTEM PROVIDE CASCADING GRAPHIC SCREENS WITH EQUIPMENT AND ALL CONTROL/SENSING POINTS WITH THE ABILITY TO CHANGE THE SETPOINTS DIRECTLY ON THAT GRAPHICS SCREEN.

B. ALL SYSTEMS SHALL BE ABLE TO OPERATE INDEPENDANTLY FROM THE FRONT END COMPUTER IN THE EVENT THE COMMUNICATION IS LOST BETWEEN TEH FRONT END AND THE DISTRIBUTED CONTROLLERS.

C. SENSORS/DEVICES WHICH SERVE AS PART OF GLOBAL FUNCTIONS SHALL BE CONNECTED TO A GLOBAL CONTROLLER(S) AND NOT TO CONTROLLERS WHICH ARE DEDICATED TO ANY ONE PIECE OF EQUIPMENT.

D. WHERE LOCAL CONTROLLERS ARE DEPENDANT ON LOGIC THAT IS BEING PERFORMED AT GLOBAL/COMMON CONTROLLERS, IN THE EVENT THAT COMMUNICATION IS LOST BETWEEN CONTROLLERS, THE SYSTEM SHALL CONTINUE TO OPERATE BASED ON THE DATA/SIGNAL BEFORE THE DISRUPTION IN THE CONTROL NETWORK.

E. ALL TEMPERATURES LISTED ARE IN CELSIUS.

F. NAMES OF ALL POINTS AND VARIABLES SHALL BE COORDINATED WITH THE OWNER, THEIR REPRESENTATIVE AND SITE STANDARDS.

G. FAIL SAFE POSITIONS ARE POSITIONS THAT DEVICES GO TO WHEN THE SYSTEM IS DEENERGIZED OR THE SYSTEM IS SHUTDOWN DO TO A LACK OF ELECTRICAL POWER. NO = NORMALLY OPEN AND NC = NORMALLY CLOSED.

H. ALL SENSORS SHALL BE MONITORED AT THE DDC SYSTEM/FRONT END. ALL SENSOR SETPOINTS AND TIME DELAYS SHALL BE ADJUSTABLE AND SHALL HAVE HIGH AND LOW ALARM LEVELS.

I. THE DDC CONTROL SYSTEM SHALL MONITOR THE STATUS OF ALL FANS. FANS CONTROLLED BY VARIABLE FREQUENCY SHALL BE INTERFACED TO THE DDC SYSTEM THROUGH MODBUS, BACNET OR LON. THE ABOVE INTERFACE SHALL COMMUNICATE ALL AVAILABLE DATA FOR MONITORING PURPOSES AT THE FRONT END. THE VFDs SHALL ALSO BE HARD WIRED TO THE DDC SYSTEM FOR THE FOLLOWING FUNCTIONS: START/STOP, SPEED CONTROL INPUT, SPEED CONTROL OUTPUT, RUN INDICATION AND FAULT ALARM. CONSTANT SPEED FANS SHALL BE MONITORED VIA THEIR RESPECTIVE CURRENT SWITCH (CS). THE CONTROL SYSTEM SHALL SEND AN ALARM ANYTIME AFTER A 30 SECOND DELAY, THE CONTROL SYSTEM SENSES NO STATUS AFTER A FAN IS ENERGIZED.

J. OUTSIDE AIR TEMPERATURE SENSOR AND OUTSIDE AIR RELATIVE HUMIDITY SENSOR SHOWN IN THE VIVARIUM AIR HANDLING UNIT DIAGRAM ARE INTENDED TO BE GLOBAL SENSORS. ONE PAIR OF SENSORS ARE TO BE LOCATED IN THE OUTDOOR INTAKE PLENUM OF ONE OF THE VIVARIUM AIR HANDLING UNITS. THESE SENSORS SHALL BE UTILIZED BY THE DDC SYSTEM TO PROVIDE THE OUTDOOR AIR DRY BULB TEMPERATURE, RELATIVE HUMIDITY, WET BULB (CALCULATED), AND DEW POINT (CALCULATED).

K. SOME BUILDING HVAC SYSTEMS REFERENCE AN OCCUPIED AND UNOCCUPIED MODE. THE OWNER SHALL DETERMINE THE HOURS IN WHICH DIFFERENT PARTS OF THE BUILDING WILL BE IN THE OCCUPIED MODE AND THE UNOCCUPIED MODE.

L. ALL CONTROL VALVES SHALL BE PROVIDED WITH A VARIABLE POSITION FEEDBACK SENSOR (+PF). SIGNAL SHALL REPRESENT THE VALVES POSITION IN PERCENT OPEN. THIS INFORMATION SHALL BE DISPLAYED ON THE GRAPHICS SCREENS ALONG SIDE EACH CORRESPONDING CONTROL VALVE. IN THE EVENT THAT THE OUTPUT SIGNAL TO THE CONTROL VALVE DOES NOT MATCH THE FEEDBACK SIGNAL AN ALARM SHALL BE SENT TO THE FRONT END.

M. ALL DAMPERS SHALL HAVE END SWITCHES TO VERIFY THE DAMPER IN THE CLOSED (ESC) AND THE OPEN (ESO) POSITIONS. DDC SYSTEM SHALL INCORPORATE ALARMS IN THE EVENT THAT THE DAMPER END SWITCH IS NOT CONFIRMING THE DAMPER POSITION.

N. THE DDC CONTROL SYSTEM SHALL MONITOR THE STATUS OF ALL PUMPS. PUMPS CONTROLLED BY VFDs SHALL BE INTERFACED TO THE DDC SYSTEM THROUGH MODBUS, BACNET OR LON. THE ABOVE INTERFACE SHALL COMMUNICATE ALL AVAILABLE DATA FOR MONITORING PURPOSES AT THE FRONT END. THE VFDs SHALL ALSO BE HARD WIRED TO THE DDC SYSTEM FOR THE FOLLOWING FUNCTIONS: START/STOP, SPEED CONTROL INPUT, SPEED CONTROL OUTPUT, RUN INDICATION AND FAULT ALARM. CONSTANT SPEED PUMPS SHALL BE MONITORED VIA THEIR RESPECTIVE CURRENT SWITCH (CS). THE CONTROL SYSTEM SHALL SEND AN ALARM ANYTIME AFTER A 30 SECOND DELAY, THE CONTROL SYSTEM SENSES NO STATUS AFTER A PUMP IS ENERGIZED.

O. PROVIDE ADEQUATE DAMPING OF ALL MODULATING CONTROL LOOPS TO PREVENT HUNTING. MAXIMUM RESPONSE TIME SHALL BE 30 SECONDS.

P. WHENEVER A UNIT IS SHUT DOWN BECAUSE OF A SAFETY DEVICE, THE BAS SHALL RETAIN IN MEMORY THE READING AND SETPOINT OF EACH ASSOCIATED DEVICE TO HELP THE OPERATOR IN ISOLATING THE CAUSE OF THE SHUT DOWN.

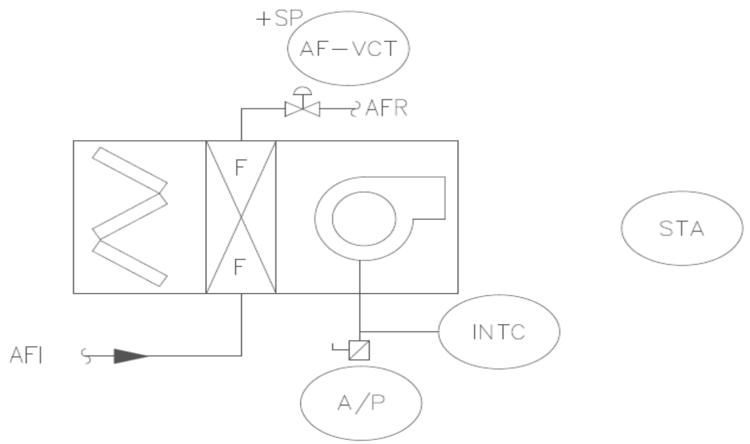
Q. WHENEVER AN ALARM IS INITIATED, THE BAS SHALL RETAIN IN MEMORY THE READING AND SETPOINT OF EACH ASSOCIATED DEVICE TO HELP THE OPERATOR IN ISOLATING THE CAUSE OF THE ALARM.

R. GROUP REMOTE DAMPER ACTUATORS FOR VIVARIUM VOLUME DAMPERS ALONG THE VIVARIUM INTERSTITIAL CATWALK OR IN ADJACENT ACCESSIBLE CEILINGS. FINAL QUANTITY OF OPERATOR PANELS IS LEFT TO THE DESCRECTION OF THE CONTRACTOR. ROOM NUMBER AND DAMPER SERVICE TO BE INDENTIFIED NEXT TO THE OPERATOR ON THE PANEL. REMOTE OPERATING DAMPERS ARE REQUIRED DOWNSTREAM/UPSTREAM OF SUPPLY/EXHAUST BOXES THAT HAVE MORE THAN ONE BRANCH AND ARE ABOVE INACCESSIBLE CEILINGS.

GENERAL (MASTER LIST) CONTROL NOTES

TESTING SHOULD ADDRESS ALL NARRATIVES AND/OR SYSTEM NEEDS

Fan coil unit (2 pipe) working with other systems (chiller and BMS system, for example)

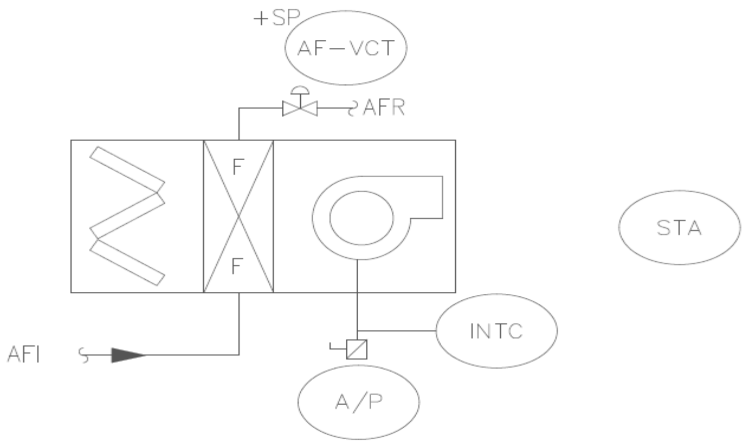


Measurements

	CHECK		DESIGN	REAL	Obs
CHECK THE AIR FLOW OF EACH FAN-COIL AT PROJECT SPEED	YES	NO			
OUTSIDE TEMPERATURE [°C]					
SUPPLY TEMPERATURE [°C]					
RETURN TEMPERATURE [°C]					
FRESH AIR TEMPERATURE [°C]					
AIR FLOW [m/s]					
FAN SPEED [NUMBER]					
CHECK THE COLD WATER (AND HOT WATER) FLOW RATES WITH THE VALVE OPEN 100% OF EACH FAN-COIL					
COLD WATER FLOW [m^3/h]					
SUPPLY TEMPERATURE [°C]					
RETURN TEMPERATURE [°C]					

TESTING SHOULD ADDRESS ALL INSTRUCTIONS AND/OR SYSTEM NEEDS

Fan coil unit (2 pipe)



Control check

Control	Check ?	
	Yes	No
THE FAN-COIL (POWERED) AND ON/OFF BY THE CONTROL SYSTEM.		
THERE IS A DEAD BAND OF 2.5 °C BETWEEN THE SETPOINT OF HEATING AND COOLING.		
THE FAN-COIL FAN WORKS TO KEEP THE TEMPERATURE SETPOINT IN SPACE.		
THE COLD WATER VALVE (AF-VCT) OR THE HOT WATER VALVE (AQ-VCT) MODELS TO KEEP THE DESIRED TEMPERATURE SET-POINT AS INDICATED BY THE STA		

Safety and Log

LOGS	Check ?	
	Yes	No
SYSTEM SHUTS DOWN WITH FIRE ALARM?		
WHEN ANY ALARM IS EMITTED, THE SYSTEM RETAINS THE LAST VALUES OF ALL READINGS, COMMANDS AND SETPOINTS ASSOCIATED WITH IT, IN ORDER TO BE CHECKED THE CAUSE OF IT.		

HOW TO DO IT ? PRATICAL EXAMPLES

Fan coil unit (2 pipe). Just showing specific sequences. For duct systems with multiple diffusers more analysis is required. Not showing filter, or damper analysis.

DATA POINT	MEASUREMENT	ACTION
SYSTEM SHUTS DOWN WITH FIRE ALARM?		TEST BMS SIGNAL TEST TELEROUPTOR CONNECTION SHUNT THE "FIRE" CONTACT
WHEN ANY ALARM IS EMITTED, THE SYSTEM RETAINS THE LAST VALUES OF ALL READINGS, COMMANDS AND SETPOINTS ASSOCIATED WITH IT, IN ORDER TO BE CHECKED THE CAUSE OF IT.		CHECK HOW THE SYSTEMA STARTS AGAIN AFTER STOP CHECK HOW IT STOPS
THE FAN-COIL (POWERED) AND ON/OFF BY THE CONTROL SYSTEM.		ON OFF SIGNAL FORM THERMOSTAT OR BMS
THERE IS A DEAD BAND OF 2.5 °C BETWEEN THE SETPOINT OF HEATING AND COOLING.		BMS ORDER)OR THERMOSTAT) , VS VALVE COMMAND SIGNAL
THE FAN-COIL FAN WORKS TO KEEP THE TEMPERATURE SETPOINT IN SPACE.	ROOM TERMSOTST OUTPUT VALVE COMMAND WATER TEMERATURE FLOW TEMPERATURE	FOOL THE THEMROSTAT TO HOT OR COLD AND CHEC VALVE COMMAND SIGNAL (AND CHEACK ACTUAL WATER TEMPERATURE AND SUPPLY FLOW TEMPERATURE)
THE COLD WATER VALVE (AF-VCT) MODELS TO KEEP THE DESIRED TEMPERATURE SET-POINTS INDICATED BY THE STA		MEASURE SEVERAL ROOM CONDITIONS TO CHEGE VALVE COMMAND (AND CHEACK ACTUAL WATER TEMPERATURE AND SUPPLY FLOW TEMPERATURE)

HOW TO DO IT ? PRATICAL EXAMPLES

Fan coil unit (2 pipe). Just showing specific sequences. For duct systems with multiple diffusers more analysis is required. Not showing filter, or damper analysis.

DATA POINT	MEASUREMENT	ACTION
OUTSIDE TEMPERATURE [°C]	AIR TEMPERATURE [°C]	GOOGLE ?
SUPPLY TEMPERATURE [°C]		AIR FLOW THERMOMETER
RETURN TEMPERATURE [°C]		AIR FLOW THERMOMETER
FRESH AIR TEMPERATURE [°C]		DUCT THERMOMETER (NORMALLY DUCT PLACED) BMS INFO FROM AHU
AIR FLOW [M/S]	AIR FLOW [m3/s]	AIR FLOW MESURING DEVICE
FAN SPEED [NUMBER)	FAN SPEED [NUMBER)	LOOK AT FANCOIL WIRING AND CONTROL
COLD WATER FLOW [M^3/H]	COLD WATER FLOW [m^3/H]	METER, INIDRET MESUREMNT (ULTRASONIC) , VALVE (CHECK PRESSURE AYT BALANCING VALVE
WATER TEMPERATURE [°C]	WATER TEMPERATURE [°C]	PIPE THERMOMETER, BMS, OTHER CLEVER PLACED THERMOMETER

ANOTHER EXAMPLE: STAND ALONE BOILER

2st Example Gas fired Boiler: Example Check list for Pre Testing (PHYSICAL CONSTRUCTION, MACHINES AND COMPLIANCE)

EQUIPMENT		CHECK YES	CHECK NO
BOILER	CATALOGUE		
	MODEL		
CONTROL FLOW VALVE	CATOLOGUE		
	MODEL		
CONTROLS	BUILT IN		
	BMS CONNECTION		
CHIMNEY CONNECTION	AIR TIGHT		
	MATERIAL		
	SUPPORTS		
	OTHER		
HIDRAULIC CONNECTION	LEAKS		
	CONDENSATE PUMP AND TRAY)IF CONDENSING)		
	INSULATION		
	MARKS AND SIGNS		
	OTHER		

EQUIPMENT		CHECK YES	CHECK NO
GAS CONNECTION	MATERIAL		
	BUILT		
	REDUCTION VALVE CONNECTION		
	REDUCTION VALVE SET		
	LEAKS		
ELECTRICAL CONNECTION	CABLES AND CONNECTORS		
	CIRCUIT BREAKER SIZE		
	EMERGENCY CONNECTION		
	SENSOR AND CONTROL DEVICES CONNECTED		
	OTHER		
TESTING	TEST POINTS CHIMNEY		
	PRESSURE WATER POINTS		
	GAS METER		

ANOTHER EXAMPLE: STAND ALONE BOILER

2st Example Gas fired Boiler: Example Check list for Pre Testing (POWER UP STAND ALONE)

Power Up

- All items have to be checked for power up and power down sequences
- Simple measuring of electrical consumption Check for power and control cabling
- Check control sequences (power up. Power down, operation and emergency)

Control and Power UP	CHECK	
	YES	NO
ELECTRICAL POWER CONNECTED		
POWER OFF AND POWER DOWN SEQUENCE		
ELETRICAL CONSUMPTION (PER CIRCUIT [A])		
BREAKER SUITS POWER		
EMERGENCY SYSTEM OPERATION		
ON/OFF SWITCH WORKING		
GAS FLOW STOPS WHEN POWER DOWN		

ANOTHER EXAMPLE: STAND ALONE BOILER

2st Example Gas fired Boiler: Example Check list for Performance Testing (WORKING WITH OTHER SYSTEMS)

Test guidelines

- System should be set for design conditions (set point and water flow)
- Measurements should also be made of max and min water flow
- Attention to desired level of service (occupation and consumption) and meteo season
- Boiler efficiency should be calculated for full load and part load

Measurements

AIR FLOW	CHECK		DESIGN	REAL	OBS
FOR DESIGN CONDITIONS	YES	NO			
OUTSIDE AIR TEMPERATURE [ºC]					
SUPPLY AIR TEMPERATURE [ºC]					
FLUE GAS TEMPERATURE [ºC]					
FLUE GAS COMPOSITION [ºC]					
FLUE GAS AIR FLOW [M/S]					

ANOTHER EXAMPLE: STAND ALONE BOILER

2st Example Gas fired Boiler: Example Check list for Performance Testing WORKING WITH OTHER SYSTEMS)

Test guidelines

- Water flow measured through meter, pressure, sonic meter
- Flue gas metering point should be provided
- Water pressure measured with ,manometer
- Efficiency can be BMS calculated if sensors are available

Measurements

WATER FLOW	CHECK		DESIGN	REAL	OBS
	YES	NO			
MAX WATER FLOW [M3/H]					
MIN WATER FLOW [M3/H]					
SERVICE WATER FLOW					
GAS FLOW [M3/H]					
FLUE GAS AIR FLOW [M/S]					
WATER PRESSURE					
EFFICIENCY FOR DESIGN CONDITIONS					

ANOTHER EXAMPLE: STAND ALONE BOILER

2st Example Gas fired Boiler: Example Check list for Performance Testing

Test guidelines

- Control sequences have to be adapted to the particular situation, specially to the outside connections ON systems integration
- Control signal measurements should be made if external controls are available (thought 0-10vcc signalling). Not needed for built in control (closed system)
- Control sequences should be verified if external BMS operates system

Control check

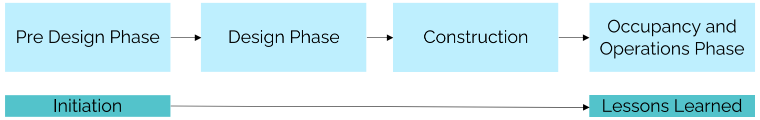
Control	Check ?	
	Yes	No
BOILER FOLLOWS CONTROL SYSTEM. CHECK FOR SEQUENCES)		
SET POINT WORKING FOR WATER SUPPLY, WATER OUT AND EXTERNAL BMS CONNECTION		
PID SEQUENCE FOR SET POINT APPROACH		
CONTROL SEQUENCES FOR POWER DOWN, POWER UP AND OPERATION		

Safety and Log

LOGS	Check ?	
	Yes	No
SYSTEM SHUTS DOWN WITH FIRE ALARM?		
WHEN ANY ALARM IS EMITTED, THE SYSTEM RETAINS THE LAST VALUES OF ALL READINGS, COMMANDS AND SETPOINTS ASSOCIATED WITH IT, IN ORDER TO BE CHECKED THE CAUSE OF IT.		

…AND LETS GO BACK FOR A MINUTE….DESIGN HAS TO TELL WHAT TO DO…

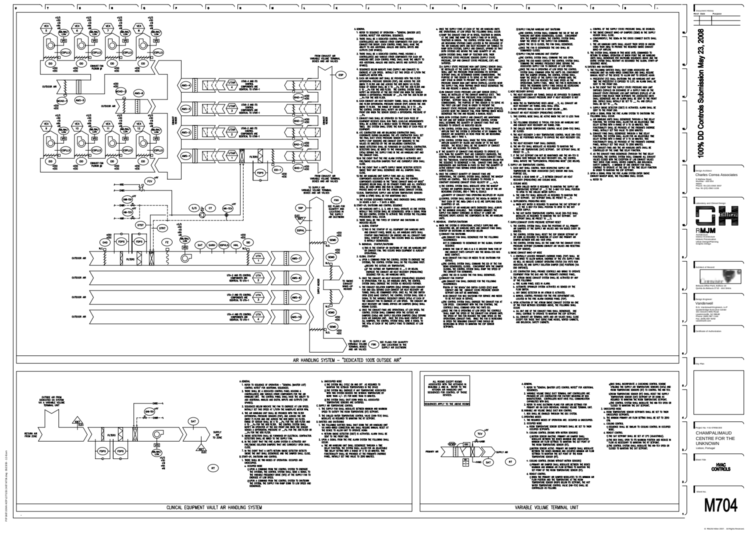
We know that Cx starts in pre design….



…KABEV sometimes does not have pre design…

- Mainly refurbishing
- Level of service already exists
- Infrastructure may not yield output increase
- Not enough time, money, structure, info etc to address the needs

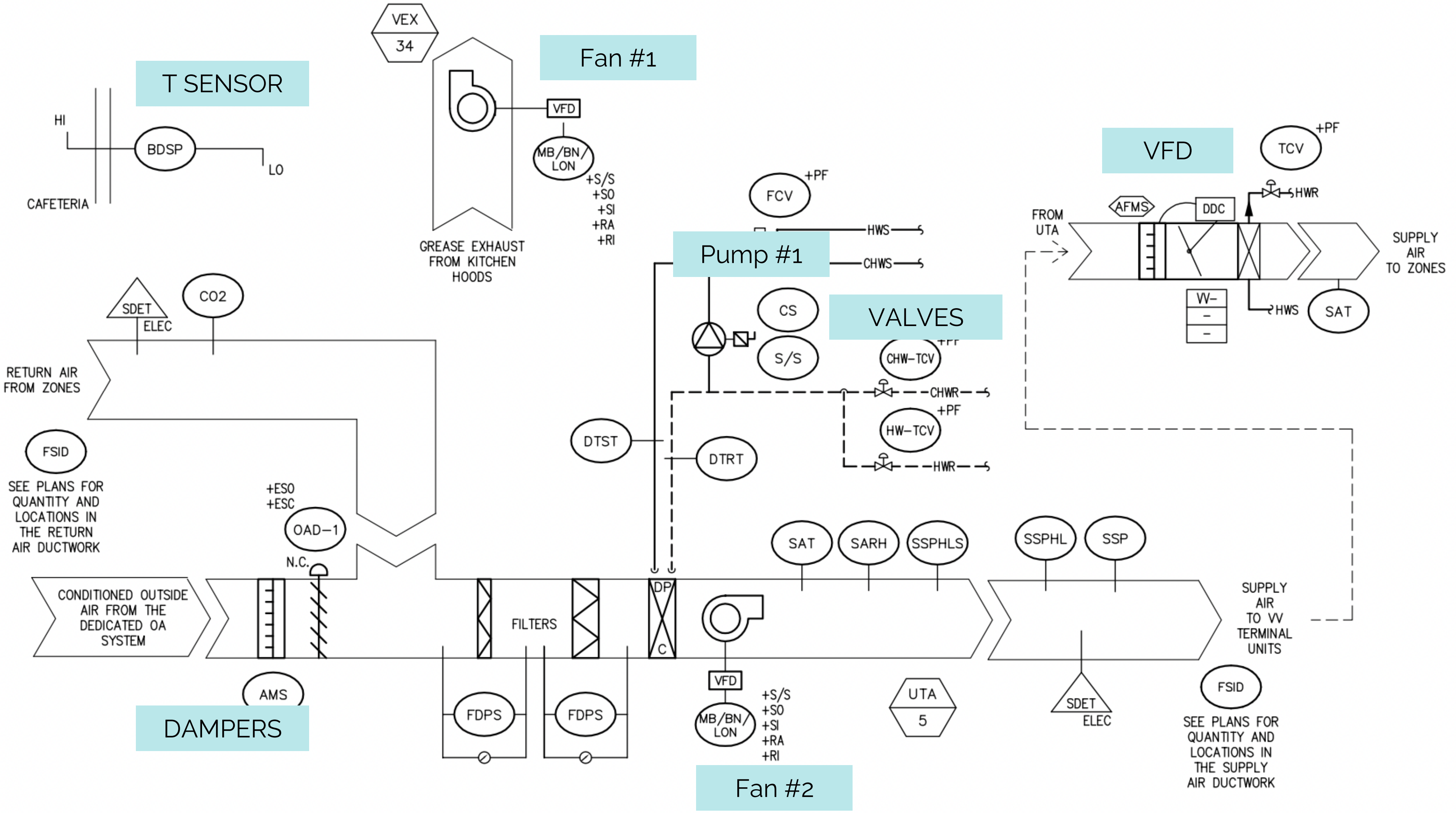
…but narrative output should always exist to lead output quality



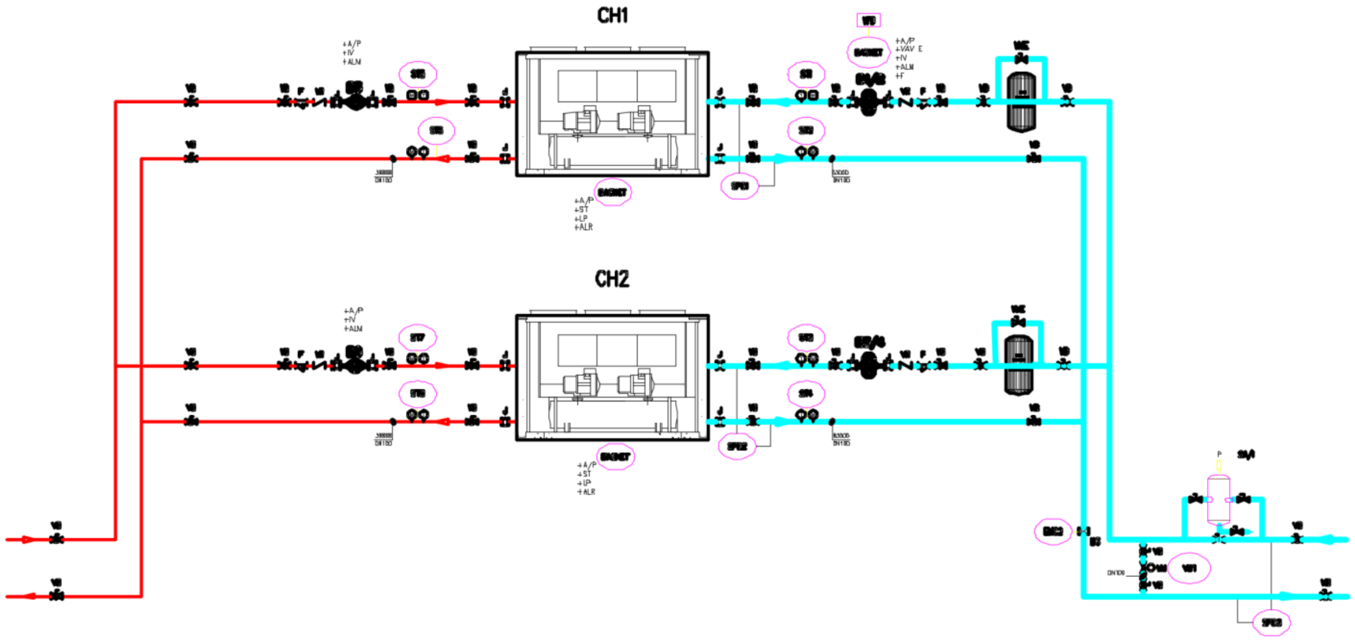
T.C. ÇEVRE, ŞEHİRCİLİK VE İKLİM DEĞİŞİKLİĞİ BAKANLIĞI

escon Altensis Managing Sustainability enve enerji S317 CONSULTING

COMPLEX SYSTEMS ARE MADE OF STAND ALONE EQUIPMENT'S AND SMALL SOCIETIES



LETS ADD COMPLEXITY: CHILLER OPERATION WITH HIDRAULIC PUMPS



A. GERAL

1. O SISTEMA DESCRITO NOS PONTOS SEGUINTES VAI SER LIGADO E DESLIGADO MANUALMENTE, ATRAVÉS DO POSTO DE COMANDO CENTRAL. DEPOIS DO COMANDO INICIAL PARA OPERAR, O SISTEMA DDC, VAI ENCARREGAR-SE DA OPERAÇÃO AUTOMÁTICA, TAL COMO DESCRITO NOS PONTOS SEGUINTES. O SISTEMA VAI OPERAR 24 HORAS POR DIA, 7 DIAS POR SEMANA

■ O CHILLER TERÁ OS SEGUINTES PONTOS CABLADOS PARA A GTC, ON/OFF (+A/P), SETPOINT DE TEMPERATURA (+ST), LIMITE DE DEMANDA (+LD) E ALARME GENÉRICO (+ALM).

■ O CHILLER VAI TER UM HISTÓRICO DOS SEGUINTES PARÂMETROS:
■ SETPOINT DE TEMPERATURA DE SAÍDA DO EVAPORADOR E CONDENSADOR
b. TEMPERATURA DE ÁGUA À ENTRADA DO EVAPORADOR E CONDENSADOR.
■ TEMPERATURA DE ÁGUA À SAÍDA DO EVAPORADOR E CONDENSADOR.

4. AS BOMBAS VÃO SER OPERADAS DE MODO A QUE OS TEMPOS DE FUNCIONAMENTO SEJAM OS MESMOS. O ESQUEMA DE ARRANQUE DEVE SER ALTERADO SEMANALMENTE, DE MANEIRA DESFASADA, DE MODO A OBTER ESTA IGUALDADE DE TEMPO. O SISTEMA DDC VAI ARMAZENAR OS TEMPOS DE FUNCIONAMENTO DE CADA EQUIPAMENTO.

■ O DDC VAI SUBSTITUIR A BOMBA PRINCIPAL PELA DE RESERVA EM CASO DE AVARIA. NESTAS CIRCUNSTÂNCIAS O SISTEMA VAI REFAZER O PROTOCOLO DE ARRANQUE DE MODO A COLOCAR EM FUNCIONAMENTO OS EQUIPAMENTOS EVENTUALMENTE AFETADOS PELA AVARIA DA BOMBA.

■ O SISTEMA VAI SER CHEIO, UTILIZANDO O SISTEMA DE ENCHIMENTO BASEADO NUM POSTO DE TRATAMENTO DE ÁGUA.

■ TODAS AS VÁLVULAS DE CONTROLO DE CADA UNIDADE TERMINAL (UTA'S OU FANCOILS) Vão TER FEEDBACK DE POSIÇÃO (OU DIRETA OU INDIRETA)

B. PRESSÃO DIFERENCIAL

■ O OBJETIVO É TER A MÍNIMA PRESSÃO DIFERENCIAL NO SISTEMA, CAPAZ DE FORNECER O CAUDAL NECESSÁRIO A TODOS OS EQUIPAMENTOS NO LOOP.

■ O SENSOR DE PRESSÃO DIFERENCIAL (SPD1) VAI TER UM SETPOINT QUE SEJA O MÍNIMO NECESSÁRIO PARA MANTER A VÁLVULA DE CONTROLO DO EQUIPAMENTO TERMINAL (AF-VCT) COM MAIOR CARGA EM QUALQUER MOMENTO, UM MÍNIMO DE 90% ABERTA.

b. O SISTEMA VAI VERIFICAR A POSIÇÃO DE TODAS AS AF-VCT (TODOS OS 15 MINUTOS) E AJUSTA O SETPOINT DO SPD DE ACORDO COM O NECESSÁRIO.

■ A EQUIPA DE ARRANQUE E COMISSIONAMENTO VAI DETERMINAR QUAL A PRESSÃO DIFERENCIAL NO CHILLER NAS SEGUINTES SITUAÇÕES E REGISTAR ESTES VALORES NO SISTEMA DDC.

1) PRESSÃO DIFERENCIAL NO SENSOR DE PRESSÃO DIFERENCIAL DO CHILLER (SPD1-2), COM O MÁXIMO CAUDAL DE ÁGUA NO EVAPORADOR.
2) PRESSÃO DIFERENCIAL NO SENSOR DE PRESSÃO DIFERENCIAL DO CHILLER, COM O MÍNIMO CAUDAL DE ÁGUA NO EVAPORADOR.

D. AS LEITURAS ACIMA DESCRITAS VÃO SER UTILIZADAS PARA LIMITAR A MODELAÇÃO DA ÁGUA FRIA.

C. ARRANQUE

1. EM PRIMEIRO LUGAR, A BOMBA RESPETIVA DE UM CHILLER VAI ARRANCAR. SEGUIDAMENTE O SENSOR DE PRESSÃO DIFERENCIAL SPD VAI SINALIZAR O ESTADO DA PRESSÃO NOS CIRCUITOS DE DISTRIBUIÇÃO E VAI ORIENTAR O FECHO PROGRESSIVO DA VÁLVULA VM1, SE MODO A QUE A PRESSÃO DIFERENCIAL ENTRE A IDA E O RETORNO NÃO SEJA MENOR A PRESSÃO REGISTADA NO PONTO ANTERIOR PARA O CAUDAL MÍNIMO.

■ O SISTEMA VAI ESTABILIZAR QUANDO O CAUDAL QUE NÃO PASSA NOS CIRCUITOS TERMINAIS, PORQUE NÃO EXISTE CONSUMO, ESTEJA A SER COLOCADO NA VÁLVULA VM1, DE MODO A QUE O CHILLER POSSUA O SEU CAUDAL MÍNIMO ESTÁVEL.

■ TODOS ESTES PONTOS DE FUNCIONAMENTO TÊM QUE SER AFERIDOS NO ARRANQUE.

D. OPERAÇÃO

1. A VÁLVULA DE BYPASS VM1 VAI MODELAR PARA MANTER O CAUDAL MÍNIMO PARA O EVAPORADOR, SATISFAZENDO OS SETPOINTS DE PRESSÃO DIFERENCIAL NOS SENSORES (SPD1 e 2) PARA O CAUDAL MÍNIMO. TIPICAMENTE A VM1 DEVE SER ATIVADA SOMENTE QUANDO A CARGA DO EDIFÍCIO ESTÁ ABAIXO DOS REQUISITOS MÍNIMOS DE CAUDAL DO CHILLER.

■ OS SETPOINTS DE TEMPERATURA DEVEM SER DE 7°C NA IDA.

■ A ENTRADA DOS COMPRESSORES DEVE SER COMANDADA PELO PRÓPRIO SISTEMA DE CONTROLE DO CHILLER. ESTA ENTRADA/SAÍDA DEVE MANTER OS SETPOINTS DE TEMPERATURA DE SAÍDA DE ÁGUA FRIA.

■ DEPOIS DA ORDEM PARA LIGAR O CHILLER, A BOMBA BF (1 2 3 OU 4) VAI SER LIGADA E VAI FUNCIONAR DA SEGUINTE MANEIRA:

a) A BOMBA BF VAI SUBIR OU DESCER A SUA VELOCIDADE, PARA MANTER A PRESSÃO DIFERENCIAL NO SENSOR SPD, MAS NÃO VAI SUBIR ACIMA DO LIMITE DE DP DEFINIDO PARA O CHILLER, ATÉ QUE A BOMBA TENHA CHEGADO AO SEU CAUDAL MÁXIMO.

■ QUANDO UMA BOMBA TIVER ATINGIDO O SEU CAUDAL MÁXIMO (IE QUANDO O VALOR DE SPD FOR IGUAL AO MÁXIMO MEDIDO NO PONTO ANTERIOR) E O SISTEMA NÃO CONSEGUIR MANTER A PRESSÃO DIFERENCIAL, OUTRO CHILLER ENTRA EM OPERAÇÃO.

■ O SISTEMA DE RECUPERAÇÃO DE CALOR ESTARÁ SEMPRE DISPONÍVEL DESDE QUE O CHILLER ESTEJA EM OPERAÇÃO. AS BOMDAS RESPETIVAS SÃO ENERGIZADAS COM A ENTRADA DAS BOMBAS DE ÁGUA FRIA DO CHILLER RESPETIVO. O CONTROLO DA VÁLVULA DE 3 VIAS É REALIZADO PELO PRÓPRIO CHILLER.

■ QUANDO OS DOIS CHILLERS ESTIVEREM EM OPERAÇÃO, AS BOMBAS VÃO OPERAR PARA MANTER O SET POINT DE PRESSÃO EM SDP3, MANTENDO O OS LIMITES MÁXIMOS DE PRESSÃO DIFERENCIAL EM CADA EVAPORADOR.

■ QUANDO OS DOIS CHILLERS ESTIVEREM EM OPERAÇÃO E A VÁLVULA VMI ABRIR POR DIMINUIÇÃO DA CARGA NECESSÁRIA, UM DOS CHILLERS VAI INICIAR A SEQUÊNCIA DE PARAGEM.

■ PARAGEM

■ QUANDO O SISTEMA ESTIVER EM MANUAL, VAI ESPERAR PELA ACEITAÇÃO DO OPERADOR À JANELA DE PARAGEM. SE ESTIVER EM AUTOMÁTICO, O EQUIPAMENTO VAI PARAR A SUA ATIVIDADE, COMO DESCRITO EM BAIXO.

1) QUANDO UM CHILLER É COMANDADO PARA DESLIGAR, A BOMBA DE ÁGUA FRIA RESPETIVA, VAI DIMINUIR ATÉ SER ATINGIDO O PONTO MÍNIMO DE PRESSÃO DIFERENCIAL NO EVAPORADOR. O TEMPO DESTA REDUÇÃO TEM QUE SER VERIFICADO COM O FORNECEDOR DO EQUIPAMENTO PARA NÃO EXISTIREM ALARMES DE FUNCIONAMENTO.

2) QUANDO OS CAUDAIS MÍNIMOS FOREM ATINGIDOS, O SISTEMA ENVIA UM SINAL DE PARAGEM. QUANDO OS COMPRESSORES ESTIVEM DESLIGADOS, A MESMA ORDEM É DADA ÀS BOMBAS ASSOCIADAS.

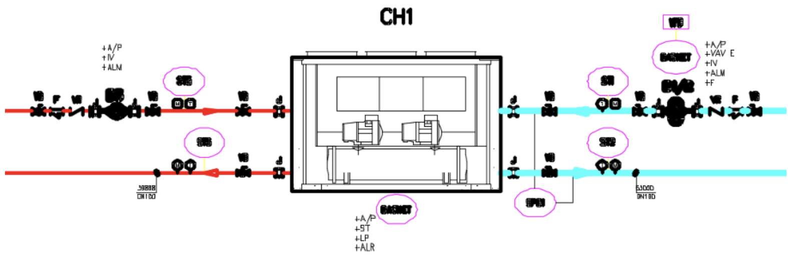
3) STIVEM DESLIGADOS, A MESMA ORDEM É DADA ÀS BOMBAS ASSOCIADAS

ESQUEMA DE PRÍNCIPIO HIDRÁULICO ÁGUA FRIA

THE Cx PROCESS STARTS WITH SIMPLE SYSTEMS.....

2st example Chiller, pumps and differential pressure control

System breakdown



- In this case, the system has several equipment's that work together.
- The Cx process has to start by a system breakdown and an individual analysis before the whole System can be tested
- The pre-functioning test have to be made to the Chiller unit, the pump unit, to the valve system, to the sensor and actuators array and to the BMS integration and schematics

Control narrative

The control narrative of the whole system us divided in main tasks. Normally:

- GENERAL NOTES: Data to be stored, schedules of operation, pre start procedures, hardware and equipment needs
- CONTROL METHOD: How the system is controlled, differential pressure, temperature), initial settings and baseline operation
- START UP: How the system will indicate activity, order for power up, start sequence of individual components
- OPERATION: setpoint definition, how the system is controlled and how reacts to the the sensors view of the output and needs
- POWER DOWN: How the system stops and powers down
- EMERGENCY: Emergency sequences

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS: DIFF PRESSURE CONTROL

2st example Chiller, pumps and differential pressure control

1 Setting the scene

- All individual components were pre tested
- All individual equipment are powered up
- Water is flowing at right pressure
- Pumps are operating at design point
- Chiller has all BMS connections working
- Chiller is keeping the chosen set point

2 Cx task objective

- Set and Check the differential pressure mechanism for hydronic system control
- Requires interaction from the chiller, pumps, terminal equipment's and BMS system
- Process is necessary to make sure that the systema can adapt to half load situations and have the right efficiency
- Only with this process in place the expected efficiency from pumps with VFD and VFD chiller compressors will be achieved

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS: DIFF PRESSURE CONTROL

2st example Chiller, pumps and differential pressure control

Differential Pressure Control narrative

1. THE OBJECTIVE IS TO HAVE THE MINIMUM DIFFERENTIAL PRESSURE IN THE SYSTEM, CAPABLE OF PROVIDING THE NECESSARY FLOW TO ALL EQUIPMENT IN THE LOOP.

2. THE DIFFERENTIAL PRESSURE SENSOR (SPD1) WILL HAVE A SETPOINT THAT IS THE MINIMUM NECESSARY TO KEEP THE TERMINAL EQUIPMENT CONTROL VALVE (AF-VCT) WITH GREATER LOAD AT ANY TIME, A MINIMUM OF 90% OPEN.

3. THE SYSTEM WILL CHECK THE POSITION OF ALL AF-VCT (ALL 15 MINUTES) AND SET The SetPOINT OF The SPD ACCORDING TO WHAT IS NECESSARY.

4. THE START AND COMMISSIONING TEAM WILL DETERMINE THE DIFFERENTIAL PRESSURE IN THE CHILLER IN THE FOLLOWING SITUATIONS AND REGISTER THESE VALUES IN THE DDC SYSTEM.

   a) DIFFERENTIAL PRESSURE IN THE CHILLER DIFFERENTIAL PRESSURE SENSOR (SPD1-2), WITH THE MAXIMUM WATER FLOW IN THE EVAPORATOR.
   b) DIFFERENTIAL PRESSURE IN THE CHILLER DIFFERENTIAL PRESSURE SENSOR, WITH THE MINIMUM WATER FLOW IN THE EVAPORATOR.

5. THE READINGS DESCRIBED ABOVE WILL BE USED TO LIMIT THE MODELING OF COLD WATER

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS: DIFF PRESSURE CONTROL

2st example Chiller, pumps and differential pressure control

What to do ?

INSTRUCTION	EFFECT	NEED
1. THE OBJECTIVE IS TO HAVE THE MINIMUM DIFFERENTIAL PRESSURE IN THE SYSTEM, CAPABLE OF PROVIDING THE NECESSARY FLOW TO ALL EQUIPMENT IN THE LOOP.	PUMPS SHOULD WORK AT MINIMUM VOLUME FLOW	PUMP BMS CONTROLLED BY PRESSURE SENSOR INFORMATION
2. THE DIFFERENTIAL PRESSURE SENSOR (SPD1) WILL HAVE A SETPOINT THAT IS THE MINIMUM NECESSARY TO KEEP THE TERMINAL EQUIPMENT CONTROL VALVE (AF-VCT) WITH GREATER LOAD AT ANY TIME, A MINIMUM OF 90% OPEN.	PRESSURE SENSOR SPD1 WILL COMMAND THE SYSTEM TO HAVE THE MOST DEMANDING TERMINAL VALVE AT LEAST 90% OPEN	PRESSURE SENSOR NEEDS DATA FROM ALL TERMINAL VALVES
3. THE SYSTEM WILL CHECK THE POSITION OF ALL AF-VCT (ALL 15 MINUTES) AND SET THE SETPOINT OF THE SPD ACCORDING TO WHAT IS NECESSARY.		BMS HAS TO REPORT POSITION EVERY 15 MN OF EVERY TERMINAL VALVE
4. THE START AND COMMISSIONING TEAM WILL DETERMINE THE DIFFERENTIAL PRESSURE IN THE CHILLER IN THE FOLLOWING SITUATIONS AND REGISTER THESE VALUES IN THE DDC SYSTEM.		
A) DIFFERENTIAL PRESSURE IN THE CHILLER DIFFERENTIAL PRESSURE SENSOR (SPD1-2), WITH THE MAXIMUM WATER FLOW IN THE EVAPORATOR.	MAXIMUM SYSTEM WATER FLOW IS SET BY THE CHILLER CAPACITY (WILL SET THE DIFFERENTIAL PRESSURE MAX)	OPEN ALL VALVES 100%, PUSH PUMPS TO THE NECESSARY SPEED TO ARCHIVE CHILLER MAX FLOW
B) DIFFERENTIAL PRESSURE IN THE CHILLER DIFFERENTIAL PRESSURE SENSOR, WITH THE MINIMUM WATER FLOW IN THE EVAPORATOR.	MINIMUM SYSTEM WATER FLOW IS SET BY THE CHILLER CAPACITY (WILL SET THE DIFFERENTIAL PRESSURE MIN)	SEQUENTIAL CLOSE VALVES 100%, PUSH PUMPS TO THE NECESSARY SPEED TO ARCHIVE CHILLER MIN FLOW
5. THE READINGS DESCRIBED ABOVE WILL BE USED TO LIMIT THE MODELLING OF COLD WATER	THE LAST MEASUREMENTS WIL BE THE MIN AND MX FLOW. THE PART LOAD WILL BE SET BY THE CONDITION 2	

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS: DIFF PRESSURE CONTROL

2st example Chiller, pumps and differential pressure control

Measurements and pre requisites to set points: check list example

OUTPUT	PRE REQUISITES	ACTION	MEASUREMENT	VALUE	SET POINT
MAX FLOW	MAX EVAPORATOR FLOW [M3/S]	PUMP 100% ALL TERMINAL VALVES (2WAY) OPEN 100%	DIFFERENTIAL PRESSURE (BMS OR MANOMETER)		
MIN FLOW	MIN EVAPORATOR FLOW [M3/S]	PUMP 100% THEN REDUCING 10% AT TIME (10 MN CYCLE) ALL TERMINAL VALVES (2WAY) OPEN 100%	DIFFERENTIAL PRESSURE (BMS OR MANOMETER)		
NORMAL FLOW	TERMINAL VALVES AT LEAT 90% OPEN	CHECK IF BMS SEQUENCE IS CORRECT	DIFFERENTIAL PRESSURE (BMS OR MANOMETHER)		

Measurements and pre requisites to check control sequences: check list example

OUTPUT	PRE REQUISITE	ACTION	MEASUREMENT	VALUE	SET POINT
NORMAL FLOW	TERMINAL VALVES AT LEAST 90% OPEN	CHECK IF BMS SEQUENCE IS CORRECT SET ONE TERMINAL VALVE FOR 90% (BMS CONTROLLED OR THERMOSTAT CONTROL, SEE EFFECT ON DIF PRESSURE AND PUMP CONTROL. CHANGE VALUES 5 MN CYCLE	DIFFERENTIAL PRESSURE (BMS OR MANOMETER)		

Kahve Molasi

PERFORMANCE TESTING CHECKLIST

We already discussed that performance testing is about systems and real part load behaviour…

SYSTEM 1

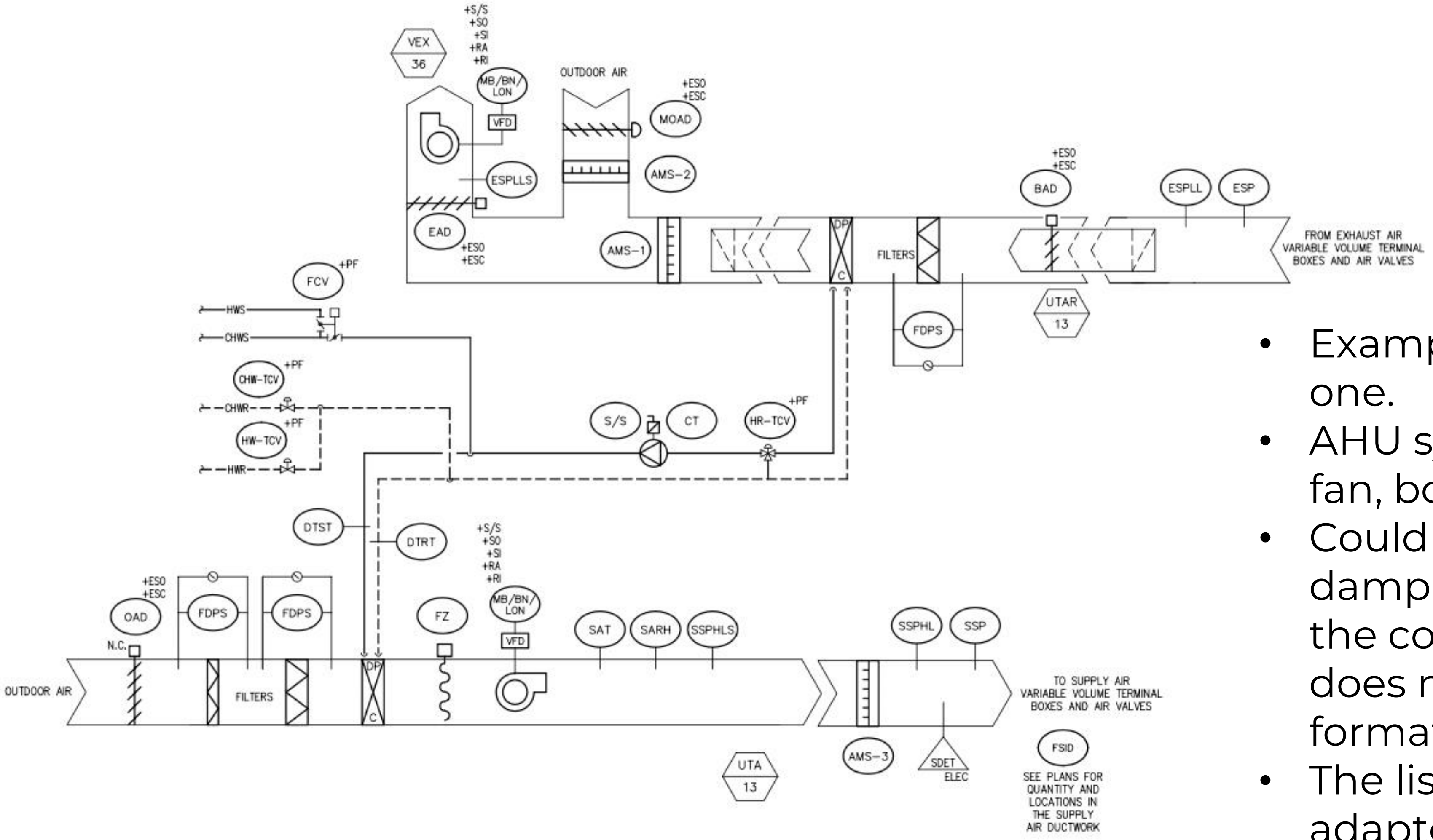
Equipment 1 | Equipment 2

- Control sequences
- Relations btw equipment's
- Ability to achieve outputs
- Setting Set Points and operating schedules
- Part Load consumption
- Testing for several schedules and climate situations

..to do this the process is organized around checklists and rehearsed procedures to analyse real world conditions in a simulated way

- Define scope
- Define team
- Define schedule
- Define reports and checklist format (can be the Cx team, the supervision team…etc)
- Define pre-requisites to follow (normally look for system complexity)
- Define method to achieve forecasted test result

EXAMPLE FOR PERFORMANCE TESTING CHECKLIST



- Example is a system similar to this one.
- AHU system with suppy and return fan, both with VSD, advance BMS.
- Could have also air mixing dampers, heat recovery coils etc. the complexity (ou the simplicity) does not affect idea of the chelist format.
- The list presented next was adapted for workshop format

EXAMPLE FOR PERFORMANCE TESTING CHECKLIST

Altensis
Managing Sustainability

FUNCTIONAL CHECKLIST
AIR HANDLING UNIT

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

Design Compliance and Documentation

- Catalogues and documents
- System composition (equipement, components)
- Test data (location, time, system etc)
- This part sets the scene of the performance testing, and could/should be together with systema plans, narratives, descriptions etc).

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

ITEM/TASK		YES	NO	N/A
A. PREREQUISITES				
A-1	**Contractor QA/QC Testing Reports completed & submitted to CxA.** *Müteahhitin hazırladığı Kalite Kontrol test raporları tamamlanmış ve CxA'ya verilmiştir.*	☐	☐	☐
A-2	**Pre-Functional Checklist completed.** *Pre-Functional (Ön Kontrol) Checklist'i tamamlanmıştır.*	☐	☐	☐
A-3	**Preliminary Test & Balance report submitted to CxA for review.** *Ön Test&Balans raporu CxA'ya kontrolü için sunulmuştur.*	☐	☐	☐
A-4	**O&M Manuals submitted to CxA for review.** *Cihazlara ait işletme kitapçıkları (O&M Manuel) CxA takımına verilmiştir.*	☐	☐	☐

Pre-requisites for Performance Testing

- TAB already performed
- Pre functional tests to each individual equipment
- Hand in of the as-built documentation (and O&M)
- In this case de premilanre TAB was already done (either in on fist part of performance test or in the pre-functional testing)

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

ITEM/TASK					
B. SYSTEM SETPOINTS					
System Setpoint (Sistem Set Noktası)		**Unit (Ölçüm Birimi**	**Setpoint Design Value (Set Noktası Dizayn Değeri)**	**Current Setpoint (Şu andaki Set Noktası)**	**Current Status/ Value (Şu andaki Durum /Değer)**
B-1	Supply Air Temperature *(Üfleme Havası Sıcaklığı)*	°C	N/A	N/A	N/A
B-2	Supply Air Static Pressure *(Üfleme Havası Statik Basıncı)*	Pa	N/A	N/A	N/A
B-3	Return Air Static Pressure *(Dönüş Havası Statik Basıncı)*	Pa	N/A	N/A	N/A
B-4	Outdoor Air Static Pressure *(Taze hava statik basıncı)*	Pa	N/A	N/A	N/A
B-5	Supply Fans Differential Pressure *(Üfleme Fanı Diferansiyel Basıncı)*	Pa	N/A	N/A	N/A
B-6	Return Fans Differential Pressure *Dönüş havası fanları diferansiyel basıncı)*	Pa	N/A	N/A	N/A
B-7	Supply fan VSD speed values (%) *(Üfleme Fanı VSD Hız Değerleri)*	%	%......	....	....
B-8	Exhaust fan VSD speed values (%) *(Egzost Fanı VSD Hız Değerleri)*	%	%......	....	....
B-9	Heating Valve Position (%) *(Isıtma Valfi Pozisyonu)*	%	N/A	N/A	N/A

Standard operation data

- Setpoint data
- Static pressure data from measurements and design
- Air Temperature, valves position etc
- All data from the normal set up operation that was set at pre functional tests power up and design data

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

ITEM/TASK						
C. ALARM LISTING&STATUS						
System Alarm (Sistem Alarmı)		**Unit (Ölçüm Birimi**	**Alarm Design Value (Alarm Dizayn Değeri)**	**Operational Status/Value (Operasyonel Durum/Değer**	**Current Status/ Value (Şu andaki Durum /Değer)**
C-1	Supply Air Temperature Upper Limit *(Üfleme Havası Sıcaklığı Üst Limiti)*	°C	……°C	………	………
C-2	Supply Air Temperature Lower Limit *(Üfleme Havası Sıcaklığı Alt Limiti)*	°C	……°C	………	………
C-3	Supply Air Temperature Upper Limit *(Üfleme Havası Basıncı Üst Limiti)*	%	N/A	N/A	N/A
C-4	Supply Air Temperature Lower Limit *(Üfleme Havası Basıncı Alt Limiti)*	%	N/A	N/A	N/A
C-5	Filter Dirty Alarm Differential Pressure *(Filtre Kirliliği Fark Basıncı Alarmı)*	Pa	…… Pa	………	………
C-6	Freeze Protection Sequence Setpoint *(Donma Koruma Set Değeri)*	°C	……°C	………	………
C-7	Outdoor Air Min. Flow Rate *(Taze Hava Debisi-Min.)*	m^3/h	……m^3/h	………	………
C-8	Return Air Max. CO_2 Alarm Value *(Dönüş Havası Max CO_2 Alarm Değeri)*	ppm	….. ppm	………	………

Alarm setpoints

- All BMS alarm setpoints, and intervals to check for compliance
- This will be found in design data and BMS (equipment) data
- The data will prepare the BMS reporting for the future

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

ITEM/TASK			
D. FUNCTIONAL TEST PROCEDURES			
Pass Y/N	No	Test Procedure (Test Prosedürü)	Expected Results (Beklenen Sonuçlar)
GENERAL SYSTEM READINESS (GENEL SISTEM HAZIRLIĞI)			
☐ Yes ☐ No ☐ N/A	D-1	Verify system has been operating at stable, normal conditions. All test pre-requisites have been satisfied. *(Sistem stabil olarak normal koşullarda çalışmaktadır. Bütün test ön koşulları sağlanmıştır.)*	
		Note:	

☐ Yes ☐ No ☐ N/A	D-2	Verify adequate access is provided to all components that require periodic maintenance. *(Bütün ekipmanların periyodik bakımının sağlanması için yeterli boşluk vardır)*	
		Note:	

General system analysis

- Review of operational status
- Review maintenance access

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

SENSOR VERIFICATION (SENSÖR DOĞRULAMA)			
☐Yes ☐No ☐N/A	D-4	Verify the temperature shown at the BMS workstation for the Supply/Return Air Temperature is within ………°C of the temperature shown on the calibrated test instrument. *(*BMS ekranında *görülen Üfleme/Dönüş havası sıcaklık değeri ile, kalibre edilmiş ölçüm ekipmanı ile ölçülen sıcaklık değeri arasındaki fark değeri………°'dir)* Verify sensor is accessible for future maintenance. *(Sensör, bakımlar için erişilebilir durumdadır). Confirm sensor calibration. (Sensör kalibrasyonu yapılmıştır)*	Supply Air Temp. (BMS): …… °C Instrument: …… °C Return Air Temp. (BMS): …… °C Instrument: …… °C
		Note:	

Sensor Compliance

- Check if sensor values are correct with reality

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

MANUAL MODE OPERATION (MANUEL MOD ÇALIŞMA DURUMU)			
☐Yes ☐ No ☐N/A	D-8	BMS Control is disabled. The unit works free of BMS. *(Otomasyon kapatılır. Ünitelerin otomasyonla ilişkileri kesilir.)*	☐1. Unit starts to work on manual mode *(Ünite manual modda çalışmaya başlar)* ☐2. Supply and Return Fans ramp down and stop working. *(Üfleme ve dönüş fanları yavaşlar ve durur.)*
		VSD'ler üzerindeki Local/Remote anahtarı Local durumuna getirilerek sistemin manuel modda çalışmasına izin verin.	☐3. Exhaust air damper and outdoor air dampers close. *(Egzost damperi ve taze hava damperi kapanır.)* ☐4. CHW/HW valves close. *(Isıtma suyu ve soğutma suyu vanaları kapanır.)* ☐5. Supply and return fans start. *(Üfleme ve Dönüş fanları çalışmaya başlar.)* ☐6. Mixing Damper is positioned %100 open *(Karışım Damperi %100 açık konuma gelir)* ☐7. BMS has no controls over these elements *(BMS'in bu elemanlar üzerinde bir kontrolü kalmaz)*
		Note:	

Control sequences

- Check for all relevant control sequence
- In this case the example is stand alone mode (local control)

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

☐ Yes ☐ No ☐ N/A	D-9	On VSD interface, switch the supply and exhaust fan Local/Remote mode selector to Remote and allow the system to work on Auto mode. BMS Control is enabled. The unit works as connected to BMS. *(VSD arayüzünde üfleme ve egzoz fanı Local/Remote anahtarı remote olarak değiştirilerek sistemin otomatik modda çalışmasına izin verin)* *(Otomasyon açılır. Üniteler otomasyon üzerinden çalışır.)*	☐1. Unit starts to work on auto mode *(Ünite otomatik modda çalışmaya başlar)* ☐2. AHU masterpoint is commanded to start either by the BMS time schedule or by overriding via BMS operator. *(BMS zaman çizelgesi veya BMS operatörünün override işlemi ile AHU Masterpoint'a çalışması için komut gönderilecektir.)* ☐3. Masterpoint will command both supply and exhaust fans to start. *(Masterpoint hem üfleme hem egzozst fanlarına başlaması için komut verir.)* ☐4. When the supply fan and exhaust fans are running the unit is ready for control of BMS logic. *(Üfleme ve egzoz fanları Otomasyon senaryosuna göre çalışmaya başlar.)*
		Note:	

Control sequences

- Check for all relevant control sequence
- In this case the example is Power Up

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

EMERGENCY OPERATION			
☐Yes ☐No ☐N/A	D-25	Utilize aerosol smoke product within duct to verify that the return air smoke detector shuts down the air handling unit when activated. *(Yangın kontağı verilerek test yapılacak. Dönüş havası duman dedektörü aktive olduğunda klima santralini kapattığını doğrulamak için kanal içerisinde aerosol duman ürünü kullanın)*	☐1. Return Air Duct Smoke Detector activates and shuts down unit. *(dönüş havası kanalı duman dedektörü aktive olur ve üniteyi kapatır)* ☐2. Supply fan VSD ramps down and supply fan turns off. *(Üfleme fanı VSD hızı düşer ve ve Üfleme fanı kapanır)* ☐3. Outside air damper modulates closed. *(taze hava damperi kapanır.)* ☐4. CHW/HW valve modulates closed.

Control sequences

- Check for all relevant control sequence
- In this case the example is emergency Operation

T.C. ÇEVRE, ŞEHİRCİLİK VE İKLİM DEĞİŞİKLİĞİ BAKANLIĞI

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

NORMAL OPERATION-OCCUPIED			
☐Yes ☐No ☐N/A	D-31	If the AHU is in cooling mode, do not perform the next two steps. If the AHU is in heating mode, proceed with the next two steps. *(Eğer AHU soğutma modunda ise takip eden iki adımı izlemeyin. Eğer AHU ısıtma modunda ise takip eden iki adımı izleyin)* At the BMS workstation, adjust the return air temperature or supply air temperature setpoint whichever is the control parameter for the BMS to be ….°C above the current return air temperature or supply air temperature whichever applicable. *(BMS ekranında, Dönüş havası sıcaklığı veya üfleme havası ayarnoktasını (BMS tarafından hangisi kontrol ediliyorsa) ,mevcut dönüş havası veya üfleme havası sıcaklığının (BMS tarafından hangisi kontrol ediliyorsa) ……..°C kadar üstünde bir değere ayarlayın)* *Allow system to achieve equilibrium. (Sistemin dengeye gelmesine izin verin)*	☐1. If the unit is mixed air type, exhaust, mixing air and outdoor air dampers modulate to optimize the minimum air quality and return air or supply air temperature whichever is applicable. *(Eğer ünite karışım havalı ise, egzoz-karışım-taze hava damperleri minimum hava kalitesi ve üfleme veya dönüş hava sıcaklığını optimum şekilde sağlamak üzere konumlarını ayarlar.* ☐2.HW valve modulates open to achieve the modified return or supply air temperature setpoint whichever applicable. *(Isıtma suyu vanası, değiştirilen Üfleme havası veya dönüş havası sıcaklığı ayarnoktasına ulaşmak için açık pozisyonuna gelir.)* ☐3. Outside air damper controls to maintain CO_2 level as measured in the return air and the minimum outside airflow setpoint. *(Taze hava damperi, dönüş havasında ölçülen CO_2 seviyesini ve minimum Taze*

Control sequences

- Check for all relevant control sequence
- In this case the example is Standard Operation (occupied Mode)

T.C. ÇEVRE, ŞEHİRCİLİK VE İKLİM DEĞİŞİKLİĞİ BAKANLIĞI

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

			hava debisini ayarlar.)
		Notes: HW return water temperature: …….. °C *(Isıtma dönüş suyu sıcaklığı)* Current supply air temperature: …….. °C *(Mevcut üfleme havası sıcaklığı)* Modified return air temperature setpoint: …….. °C *(Değiştirilen dönüş havası sıcaklığı ayarnoktası)* Initial HW valve position: ……… % *(Isıtma suyu vanası başlangıç pozisyonu)* Modified HW valve position: ……… % *(Değiştirilen Isıtma suyu vanası pozisyonu)* Exhaust damper position before setpoint modification: ……..% *(Ayarnoktası değişikliğinden önceki egzoz damperi açıklığı)* Exhaust damper position after setpoint modification: ……..% *(Ayarnoktası değişikliğinden sonraki egzoz damperi açıklığı)* Mixing damper position before setpoint modification: ……..% *(Ayarnoktası değişikliğinden önceki karışım hava damperi açıklığı)* Mixing damper position after setpoint modification: ……..% *(Ayarnoktası değişikliğinden sonraki karışım hava damperi açıklığı)* Outdoor air damper position before setpoint modification: ……..% *(Ayarnoktası değişikliğinden önceki taze hava damperi açıklığı)* Outdoor air damper position after setpoint modification: ……..% *(Ayarnoktası değişikliğinden sonraki taze hava damperi açıklığı)*	

Control sequences

- Check for all relevant control sequence
- In this case the example is Standard Operation (occupied Mode) (continued)

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

☐Yes ☐No ☐N/A	D-38	At the BMS workstation, adjust the supply flow rate / duct static pressure (whichever is controlled by BMS) setpoint to ….......... m³/h / Pa below the initial setpoint. *(BMS merkezinde üfleme havası debisi / kanal statik basıncı ayarnoktasını başlangıç ayar noktasından .... m³/h / Pa altına ayarlayın)* Allow system to achieve equilibrium. *(Sistemin dengeye ulaşmasına izin verin.)*	☐1. AHU supply fan VSD decreases speed to achieve duct static pressure setpoint. *(Kanal statik basıncı ayarnoktasına erişmek için AHU üfleme fanı VSD hızını düşürür)* ☐2. CHW/HW valve modulates to satisfy the supply air temperature setpoint. *(Üfleme havası sıcaklığı ayarnoktasını karşılamak için ısıtma/soğutma vanaları ayarlanır.)* ☐3. Outside air damper controls to maintain CO_2 level as measured in the return air and the minimum outside airflow setpoint. *(Taze hava damperi, dönüş havasında set edilen CO_2 seviyesini sağlamak için kendini ayarlar.)* ☐4. AHU and EF indicates these status positions on the graphics at the BMS Workstation. *(AHU ve EF, BMS merkezinde bu durumu grafik üzerinde gösterir)*
		Notes: Modified supply flow rate setpoint: ……....... m³/h *(Değiştirilen üfleme hava debisi ayarnoktası)* Modified duct static pressure setpoint: ……...... Pa *(Değiştirilen kanal statik basıncı ayarnoktası)* Supply fan VSD speed: (……….Hz or ……….%) *(Üfleme fanı VSD hızı)*	

Control sequences

- Check for all relevant control sequence
- In this case the example is Standard Operation (occupied Mode) (continued)

EXAMPLE FOR PERFORMANCE TESTING OF COMPLEX SYSTEMS:

“No” Responses	
ITEM	**REASON/CLARIFICATION FOR “NO” RESPONSE**

GENERAL COMMENTS-MISCELLANEOUS

Documentation and lesson learnt

- Explain carefully if some of the objectives were not meet
- Document difficulties or thinks to address in the issues log

Kahve Molasi

KABEV

Energy Efficiency in Public Buildings

(EEPB/DB/MoEU/QCBS-SUBPR-01)