BCxA Building Commissioning Association

Data Center Commissioning

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Precis Commissioning Inc.

AIA Quality Assurance

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

- Data centers are all over the news. New data centers are being designed and built to support the upcoming AI boom. Old data centers are being upgraded or expanded. These facilities are critical and must not have any unexpected down time.

- A loss of any system may cause the loss of servers and data resulting in a large impact of operations and possible loss of revenue. The design of data centers can range from very simple, with single point failures up to data centers with multiple redundant systems, including two or more utility feeds, UPS, generators and support equipment. Commissioning is required to assure the devices, equipment and systems are installed, functional, integrated, and tested for response to failure.

- Early commissioning involvement and continuous commissioning during the project will allow for a smooth transition from design to construction and will confirm that all aspects of the design are met, all systems and equipment operate properly and that the facility is ready to transition day-to-day operations.

Learning Objectives

1. Understanding of the critical nature of the Owner's Project Requirements (OPR) and the Basis of Design (BOD) for Data Centers.
2. Understanding of the roles and responsibilities for the members of the project and commissioning team.
3. Itemize the additional requirements for the project team as it relates to purchasing, installation, start-up and testing of the system and equipment.
4. Explain the functional and integrated testing for data centers.

Pre-Design – Cx Support- Cx Provider

- The commissioning provider should know and understand the general requirements for the electrical and mechanical system, including power and cooling requirements.
- The commissioning provider should be involved in the discussions on any Risk – Reward/Cost vs Impact.
- The commissioning provider should provide insight on why things fail, how they fail, and what mitigation was needed. New technologies due to ”Electrification” or De-Carbonization may lead to the use of unproven technologies or equipment.
- Remember that value engineering never really adds value. Don’t let the owner hurt themselves.
- Provide input to the design, design issues are not resolved by commissioning, a poor design will lead to a poor outcome.
- The commissioning provider may be required to hire the electrical testing firm, manufacturer’s startup and testing staff for start-up and load bank testing. The load bank may be for the generators, UPSs, and cooling systems.
- Commissioning should be completed prior to the installation of the servers or other critical equipment related to the IT side of the project.

Pre-Design – Cx Support - Owner

- The owner should identify any issues with existing facilities, systems or equipment if the Data Center is being constructed in or expanding an existing facility.
- The issues should be addressed or become part of the data center scope.
- The owner should have the required staff ready to support the project, review the installation, provided for punch-lists and be involved with the commissioning process every step of the way.
- The owner should have personnel ready to be trained and to operate the system and equipment at the end of the project or even before the end. This may be required if the project is large and phased.
- If a system or equipment provides “Beneficial Use”, there needs to be an understanding of who owns and operates the systems and equipment. This may also impact warranty.
- The standard Cx support as outlined in “Best Practices” would be expected.

Pre-Design and Early Design - OPR and BOD

- The requirements for the OPR are much more complex and detailed than other OPRs. The Cx Provider should work closely with the owner to develop an OPR that will make a strong BOD and allow for a rigors commissioning of the data center. The use of the BCXA Template is a good place to start.

- The same is true with the BOD, and the commissioning provider should work closely with the A/E, engineering firm and possibly the CM/GC and vendors to assure the quality of the BOD.

- The OPR and BOD should identify minimum capacity of the systems and equipment to assure they meet the needs of the data center in normal and failure scenarios. What is the spare capacity and how much equipment can be added, as the data center develops.

- The OPR and BOD should identify the criticality of the systems and equipment as it relates to redundance and failure scenarios. This must include how the systems and equipment should react to failures, required actions needed to be performed, notification requirements, and expected impacts on facility operations.

- The OPR and BOD should identify the dewpoint, temperatures and humidity control ranges, trending, alert and alarm ranges for the HVAC systems, per area or room.

- The OPR and BOD should identify acceptable response times for the HVAC systems, per area or room. The OPR and BOD should identify how maintenance is to be done, what the expected impacts are and what steps should be taken to avoid unwanted interruptions.

Pre-Design and Early Design - OPR and BOD

- The OPR and BOD should identify the calibration requirements (factory or field) for all devices and sensors. The accuracy of the calibration must be identified.
- The OPR and BOD should identify the pressure relationship between rooms or areas and the minimum acceptable pressures (static or dynamic).
- The OPR and BOD should identify the acceptable noise levels within the spaces. This may impact the type or HVAC equipment required.
- The OPR and BOD should identify acceptable response times for the electrical systems, per system, equipment, area or room.
- The OPR and BOD should identify the requirements for the building, area, and room envelopes as these have impacts on the HVAC and Fire Protection.
- The OPR and BOD should identify the requirements for the building lighting control, interior and exterior (if required).
- The OPR and BOD should contain detailed information on the expected rigor of commissioning. This may include the “Level” of the data center as outlined by the Uptime Institute.

Pre-Design and Early Design - OPR and BOD

- The BOD should identify the location of key items like, EPO, Clean Gas initiation buttons, fire alarm pull stations, ETC.
- The BOD should identify if there are emissions goals and how they are being addressed, identify if there are sustainability goals and how they are being addressed and identify if there are energy goals and how they are being addressed and the possible effects on the robustness of the data center.
- The BOD should identify the required steps, reactions, responses to items like Fire Alarms, EPO buttons, Clean Gas Activation, loss of HVAC, and Power Loss (partial/complete). Other items will be added based on the owner/A/E/Cx Meetings.
- The OPR and BOD should identify any preferred or required vendors.
- The BOD should address catastrophic events like, Fire, Floods, Earthquakes. What is the expected shutdown, mobilization, recovery, and return to operation plan(s). You may not commission to a “worst case scenario” but it should be documented.
- The OPR and BOD may be close to some other types of facilities but should include as detailed information as possible on the purchase, delivery, maintenance, spare parts for the equipment and systems. Issue like requirements for local service and response times should be included.
- If monitoring based commissioning is to be used for and after the project the requirements, tasks, roles and responsibilities must be documented in the OPR and BOD.

Factory Acceptance Testing – Design Phase

- The project may choose to have the key equipment like generators, ATSs, UPS tested at the factory. The Cx Provider should attend the testing to confirm operation and to use the FAT information that can be leveraged into the site commissioning process.
- An early FAT can save time and cost during the construction by assuring the equipment will arrive on site having been fully checked/tested.
- It should be noted that if the equipment is just coming into the market, or the vendors has made changes to the equipment, a FAT is always recommended. After installation is not the time to find out it won't work. This also has a huge impact on schedule.

Cx Design Review – Design Phase - (BOD/DD/CD)

- The Cx Provider must assure that the BOD has met the requirements outlined in the OPR and has the required detail to allow for an understand of normal and failure scenarios. And that the construction documents meet the BOD, and the level of detail will allow for the generation of checks and tests.
- The Cx Provider should assure that the routes for piping, ductwork, conduits are clearly identified, access requirements/clearances are indicated and that there are no obvious interferences between systems. Items like below floor devices, and above ceiling devices should be reviewed.
- The Cx Provided should review the specifications and assure that calibration, demonstration and testing support and requirements for resolution of issues are identified for all trades.
- The Cx Provided should review (or write) the commissioning specifications to identify all contractual requirements have been identified. This will also include the requirements for installation, functional and integrated testing for the project.
- The Cx Provider should review the approved (Not approved as noted) or Record submittals with a key focus on the BAS submission.
- The BAS should include the sequence of operations with modes of operation, alert and alarm information, trends, failure and safety information.
- The BAS should include the time of restarting or enabling of equipment and systems based on each type of failure mode. This may include load sheading or other energy savings requirements.
- The design must have detailed information on the operation and reaction to failures for all system and equipment and include allowable deviations to during testing. This will include items like timing and automatic and/or manual operations or inputs.
- The Sequence of Operations (SOO) should include expectations for failure scenarios, like what happens during a loss of a sensor, BAS panel, and BAS communications and the SOO should include expectations for failure scenarios, like valves or dampers failing closed, open or in last position.
- The Cx Provider should look at the selected equipment and submittals to assure the equipment does not have a limited life span, like discontinued refrigerant or an equipment vendor that has import issues . If it takes 40 weeks for delivery, can they support the future maintenance requirements? Is there a local representative and vendor technicians local to the site?

Cx Project Plan – Pre-Design and Design Phase

- The Cx plan should include a step-by-step outline of what tests will be completed, how they are to be completed and what should happen if a test fails. This may not be specific to each piece of equipment or system but will provide an understanding of the commissioning process for the data center.
- The Cx plan should include a line of communications and roles and responsibilities for the commissioning process and Cx plan should include who is required for each test. The CM/Owner should assure the required personnel are present per each test/step.
- The Cx plan should include expected impact on data center operation during the commissioning process. This is critical if commissioning an expansion or modification to an existing data center.
- The Cx Plan should include an integrated schedule, based on the CM project schedule, for dates and durations of all Cx activities. If the CP project schedule changes, so too should the Cx Plan schedule.
- The plan will also include the steps/procedures for installation, functional and integrated testing for the project.
- The plan should address lock/out -tag/out procedures as they are required to support the start-up and testing of the equipment. This may be critical in phased projects.
- It should identify any Off-Season and follow up testing that may be required due to project timing.

Cx Project Plan – Design Phase

Division 1 Cx Specs

220800

230800

260800

The specifications should include the requirement for commissioning support from each discipline or trade.

Minimum hours and the skill level of the support person should be identified.

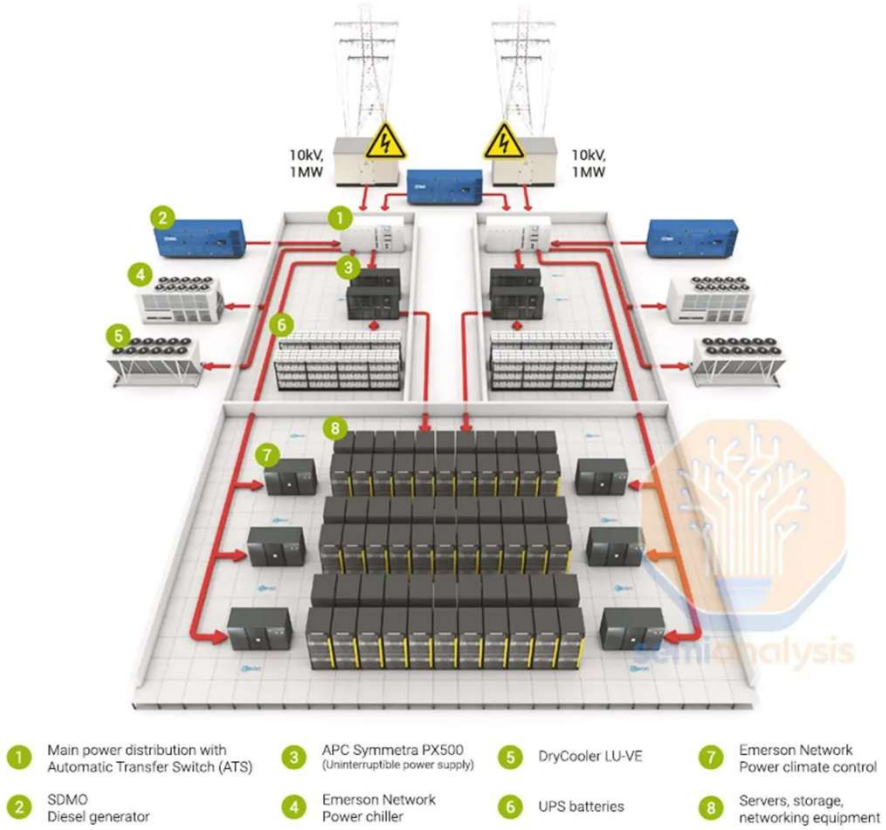
The specifications should include the requirements for Method of Procedure, Receipt Verifications and System Readiness Documents.

The specifications should identify and reference the Commissioning Master (Project) Plan.

Possible Design Phase Issues

No or poor OPR. The Owner must support the development of a strong OPR.
The BOD does not incorporate all the OPR or the level of detail in the BOD does not allow for the development of commissioning checks and tests.
Missing fully developed sequence of operations, not just HVAC, but for all interconnected and interrelated systems.
Misunderstanding of space requirements for all the equipment and system, it's not just about the racks and servers.
Commissioning support not identified, per trade, in the specifications.
The Cx Plan not identified as part of the project documents under design specification requirements.
Equipment interference, duct, piping problems. Can be solved with good 3D modeling. That won't take account of missing or unknown information (like deeper steel, bigger/deeper lights (not so much now with LEDs), incorrect sizes from vendors).
Poor access to equipment due to conflicts, position of equipment, devices and sensors.

Data Center Electrical Service (Emerson)



Buy-Out – Construction Phase

The CM should assure that the buy-out packages include the Cx requirements, including minimum hours and the skill level of the support person and the Method of Procedure, Receipt Verifications and System Readiness Documents.

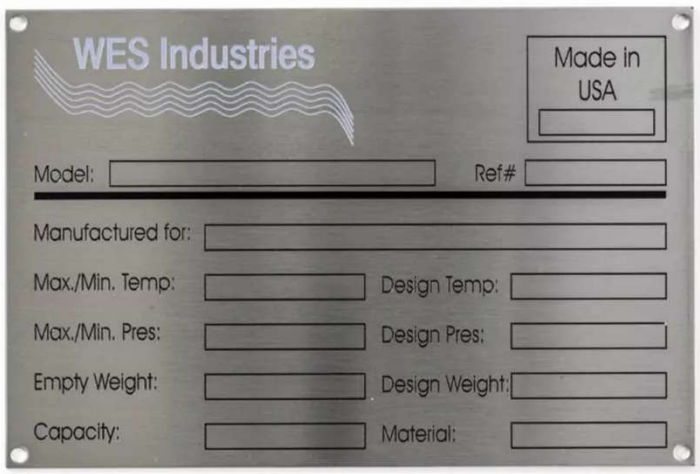
The CM and Cx Provider should meet to review the buy-out packages.

The Cx Provider should meet with subs and vendors after they are selected. An Informal questions and answer session may help with understanding of the Cx Process.

A formal Cx kickoff meeting should follow.

Contractor Receipt Verification – Construction Phase

- The CM should assure that the contractors are installing the devices, equipment, and systems per the approved submittals. Its not just sticks and bricks.
- The sub-contractors should provide a receipt verification, documenting that the have confirmed the make, model, capacity, size, etc. of all devices, equipment, and systems used on the project. No undocumented substitution should be allowed.
- The CM/Subs should provide the completed forms to the Cx provider for review, prior to the start of Cx installation checks.



Metal Marker

Contractor Receipt Verification – Construction Phase

- **EQUIPMENT RECEIPT VERIFICATION (RV) DOCUMENT**

- Contractor has verified that the following items have been purchased in accordance with the approved submittal and/or shop drawings and the items meet the specifications outlined in the approved submittal and/or shop drawings. Generally, one RV is provided for each piece of equipment outlined in the contract documents.

- **System or Equipment Verified:** _____

☐ The system, equipment, or device matches the approved submittal and/or shop drawing.

☐ All accessories outlined in the approved submittals and/or shop drawings have been provided.

☐ The checks should include the following, record the information as required:

- The Make and Model Numbers._____
- The Serial Numbers._____
- The size and capacity of the equipment._____
- The material of construction _____
- The required electrical utilities connection_____
- The required mechanical and/or plumbing connections_____
- The required BAS connection_____
- The Interface with other systems_____
- _____

- ***Attach a list of any known exceptions or outstanding issues related to the above statements.***

- List name, title, company, date: _____

- I have verified that the above statements are true and that the systems and equipment are ready for review by the CxA, except for those items noted as attached. I understand that if it is found that the system or equipment has not been properly checked as listed above, or if an item does not meet the required specifications when reviewed by by the CxA, the Construction Team may be charged by the Owner for the cost of the trip, set at $350/hr including travel time plus travel expenses.

- **Signature:** _____

Cx Installation Checks – Construction Phase

- The CM should provide for dates and duration of the installation checks on the master construction schedule. The Cx provider will review and approve these with the CM. The CM should maintain this schedule based on actual field conditions.
- The Cx provider has developed the checklists using the final design documents and approved submittals and will provide those checklists to the Owner/CM/Subs for review.
- The CM and sub-contractors should provide input to the checklist and confirm that no changes are required due to RFIs or field installation changes.
- The owner should provide input to the checklist and confirm that no changes are required due to owner's updates or changes.
- The A/E may provide for a review if identified in the Cx Project Plan.
- The Cx provider, with help from the contractors will execute the checklists that have been review and approved.
- The Cx provider should work closely with the contractors during installation checks, asking questions and reviewing the progress of the checks and to identify issues as early as possible.
- If any items is found to not meet requirements outlined in the installation checks, the project team must review, approve, or correct those items. The Cx provider should not move forward with additional installation checks, unless directed by the owner.
- All incorrect items, or issues must be documented, and the resolution must also be documented.
- The Cx provider should review the contractors red-line drawings throughout the construction project to assure all (APPRVOVED) changes are well documented.

Typical CRAC Unit - Liebert

Contractor Method of Procedure (MOP) Designed into Construction Phase

Each contractor will have a MOP for their equipment and systems and should coordinate between trades as needed.

The CM should provide a step-by-step Method of Procedure with specific actions and sequence of tasks for the energization, start up, and the required testing to safely bring systems and equipment online.

The MOP should include all safety requirements.

The MOP should include all support requirements.

The MOP should include expected durations.

The MOP should list any “NO-GO” information.

The MOP needs to be review and approved by the project team.

Contractor Certificate of Readiness – Construction Phase

- Prior to startup or energization of the devices, equipment, systems the sub-contractors should provide a Certificate of Readiness, indicating that each device, equipment and system is ready to move to startup, energization, and functional test.
- The BAS vendor should provide the completed point checkout sheets for review.
- The BAS vendor should provide the completed loop check sheets for review, to include valve and damper positions, in all modes.
- The BAS vendor should provide operational schedules (occ/unocc) and a list of setpoints, alert/alarms setpoints/values and ranges.
- Trending should be setup and ready to support functional and integrated testing.
- Provide written and signed conformation that the systems and equipment are ready for commissioning.

Contractor Certificate of Readiness – Construction Phase

- **CERTIFICATE OF READINESS**

- Contractor has verified that the following prerequisite items have been completed in preparation for the functional testing phase of the commissioning process.

- **System to Be Commissioned:** _____

☐ The system to be commissioned, including all equipment, ductwork, piping, electrical, plumbing, and interfaces to other systems is complete, installed per the Contract Documents, and any issues previously identified by the Commissioning Team have been addressed.

☐ All equipment has been properly started up by qualified personnel. Where specified, the startup was conducted by the manufacturer. Startup procedures and reports have been documented and provided to the CxA.

☐ For HVAC Systems, all duct pressure testing, duct cleaning, pipe pressure testing, and pipe flushing has been completed according to the Contract Documents.

☐ For HVAC Systems, the Test and Balance work is complete, all issues have been corrected, and a final (draft) report has been provided to the CxA.

☐ For Building Automation system (BAS), the BAS contractor has completed their own checkout procedures, including but not limited to the following:
- Calibration of all sensors.
- Point-to-Point checks of all sensors and devices.
- Checks of all devices (dampers, control valves, etc.) for proper operation, fail position, and verification of no leakage.
- Programming of all sequences of operations, alarms, and setpoints.
- Completion and check of all graphics.
- Interface with other systems (lighting, plumbing, metering, etc.)

☐ All equipment and systems are online and operating with no restrictions for testing.

☐ All necessary notifications, coordination and scheduling have been considered that might be required for functional testing of this system (e.g. Owner, Fire Marshall, Occupants, etc.)

- ***Attach a list of any known exceptions or outstanding issues related to the above statements.***

- List name, title, company, date: _____

- I have verified that the above statements are true and that the system is ready for functional testing by the CxA, except for those items noted as attached. I understand that if it is found that the system has not been properly prepared as per the above, necessitating one or more return site visits by the CxA, the Construction Team may be charged by the Owner for the cost of the trip, set at $350/hr including travel time plus travel expenses.

- **Signature:** _____

Contractor Start-up Plan, TAB, Calibration– Construction Phase

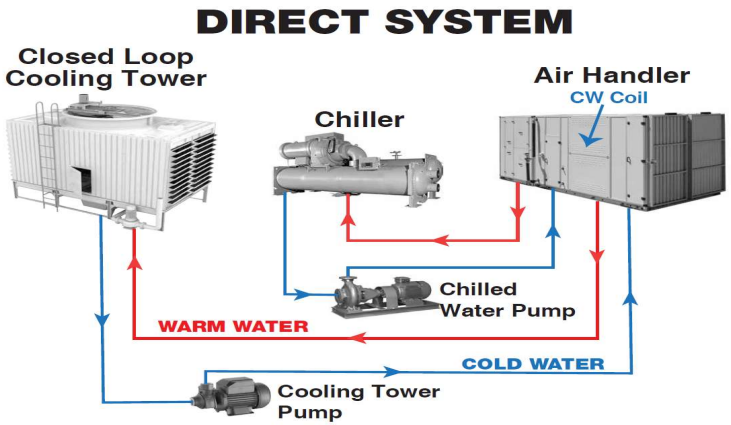
- The CM should provide for dates and duration of the startups on the master construction schedule. The Cx provider will review and approve these with the CM. The CM should maintain this schedule based on actual field conditions.
- Prior to startup the CM/Subs should provide the MOP or startup plan, blank startup sheets and copied sections from the IO&Ms that are related to startup.
- The appropriate vendor should be on site for the startup as well as the supporting contractors.
- The Cx provider shall witness startups based on the contract documents (all/% some/selected).
- The CM should provide for dates and duration of the TAB on the master construction schedule. The Cx provider will review and approve these with the CM. The CM should maintain this schedule based on actual field conditions.
- Prior to TAB the contractor should provide the TAB plan, blank TAB sheets and TAB review of the installed systems to be balanced.
- TAB may require supporting contractors.
- The TAB vendor and the BAS vendor should work to completed calibration of devices and sensors as outlined in the specifications and contract documents. Calibration documents (factory or field) should be provided.
- The TAB vendor should confirm the airflows, air distribution, temperatures, humidity are all within the design parameters and correct or support the correction of any issues.
- Vendor support may be required for “in-rack” cooling system balancing and for future functional testing.

Data Center Commissioning Tests– Construction Phase

Power Tests (NEC/NETA)

- Electrical Distribution Systems
- System grounding
- Generator(s)
- PDU (Power Distribution Units) / or rPDU (Rack Power Distribution Units)
- UPS (Uninterruptable Power System)
- ATS (Automatic Transfer Switches)
- Integrated power system
- EPO (Emergency Power Off)
- Anti-Static Flooring

Data Center Commissioning Tests– Construction Phase



Waterline Controls

HVAC/Cooling Tests

- Chillers
- Chilled water pumps
- Cooling tower
- Condenser water pumps
- Piping
- Heat exchanger
- Ducting / air flow
- Integrated cooling system
- CRAC (Computer Room Air Conditioning)
- Packaged HVAC Equipment (in support areas)
- BAS

Data Center Commissioning Tests– Construction Phase

Fire suppression and Security tests

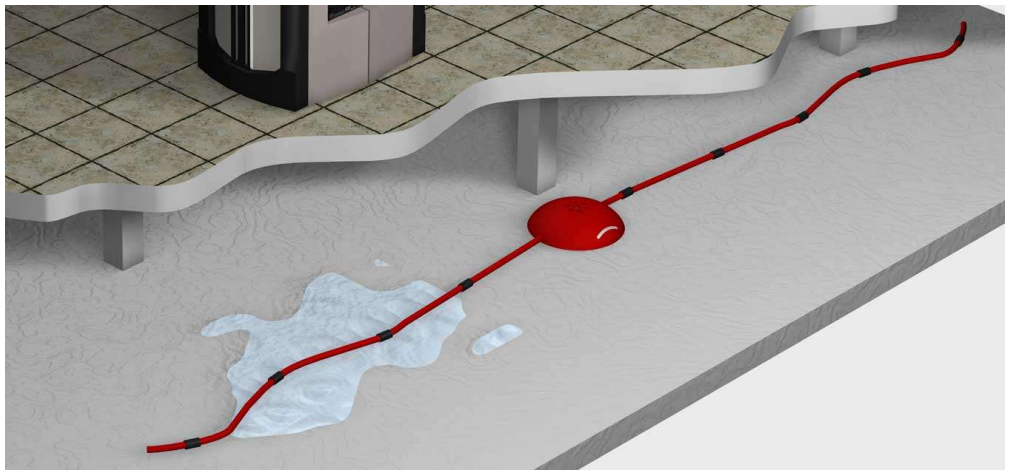
- Pipes
- Sprinkler systems (Wet/Dry(Pre-action)/Clean Agent)
- Valves, Gauges, Meters
- Pumps
- Automatic alarms and Notification
- Smoke detection
- Fire Detection
- Access controls and Man traps
- Door lock system
- Security cameras
- Paging System

Koorsen FP

Data Center Commissioning Tests– Construction Phase

Infrastructure monitoring systems and controls tests

- Power monitoring system
- CRAC monitoring system
- Temperature and Humidity sensors
- Security and Access Controls (Door release)
- Motion Detection Sensors
- Building management system (BMS or BAS)
- Lighting and Controls
- CFMS (critical facility monitoring system)
- Under Floor Leak Detection System



Dorlen Products Inc

Cx Functional Tests – Construction Phase

- The CM should provide for dates and duration of the functional test on the master construction schedule. The Cx provider will review and approve these with the CM.
- The CM should coordinate all activities and personnel required for testing of the devices system and equipment.
- The Cx provider has developed the test using the final design documents and approved submittals, BAS or Vendor, and will provide those tests to the Owner/CM/Subs for review.
- The CM and sub-contractors should provide input to the test and confirm that no changes are required due to RFIs or field installation changes.
- The owner should provide input to the tests and confirm that no changes are required due to owner's updates or changes.
- The A/E may provide for a review if identified in the Cx Project Plan. May not be in the A/E contract.
- The Cx provider will execute the tests that have been review and approved.
- If any items is found to not meet requirements outlined in the functional tests, the project team must review, approve, or correct those items. The Cx provider should not move forward with additional tests, unless directed by the owner.
- All incorrect items, or issues must be documented, and the resolution must also be documented.
- The testing should be completed with the anticipated thermal load within the building, all spaces, and server racks. The requirement for load banks has already been established.
- The mode(s) of operation for the HVAC systems should be tested to include normal, economizer (if required) emergency, or redundancy as outlined in the sequence of operations. This may include additional testing of fire dampers as part of the HVAC system.

Cx Functional Tests – Construction Phase

- System operation, capacity verification, ability to maintain set-points should be tested across all weather conditions, thru simulation, seasonal testing or scheduled follow up testing.
- Trending can be used to verify system operation, capacity verification, ability to maintain set-points (Stability).
- Testing may also include operational tests after the loss of BAS.
- The mode(s) of operation for the electrical systems should be tested to include normal, emergency, and/or redundancy. This will be for electrical services only; integrated testing will be used to test HVAC/FA/FP/Electrical interactions.
- Identify the positions of all valves, dampers, switches, ETC as indicated on the design documents, submittals and BAS Sequences
- The mode(s) of operation for all fire alarm and fire protection systems should be tested to include normal, emergency, and/or redundancy. This will be for FA/FP services only; integrated testing will be used to test HVAC/FA/FP/Electrical interactions.
- If required plumbing checks should be completed. Items like domestic water and sanitary sewer may be part of the project.
- The requirements for training, the training plan, training documents and training schedule should be started in this phase and completed after IST testing.

Cx Functional Tests – Electrical– Construction Phase

- The project team should review the requirements outlined in NETA-ATS.
- The project team may determine that the tests outlined in the NETA-ATS will be purchased thru the CM or EC.
- It should be note that the Cx Provider may be required to hire an independent electrical firm, if they don't have a certified technician, Level 3 or higher, in electrical testing.
- The EC should perform the testing in accordance with the NEC and NETA-ATS. This testing may be developed by the EC or vendor and be reviewed and approved by the Cx Provider.

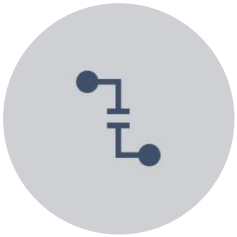
Cx Functional Tests – Electrical– Construction Phase

- **Note: Per NETA-ATS**
- **Summary**
- The guidance of an experienced testing professional should be sought when making decisions concerning the extent of testing. **It is necessary to make an informed judgment for each particular system regarding how extensive a procedure is justified.** The approach taken in these specifications is to present a comprehensive series of tests applicable to most industrial and larger commercial systems. In smaller systems, some of the tests can be deleted. In other cases, a number of the tests indicated as optional should be performed.
- **QUALIFICATIONS OF TESTING ORGANIZATION AND PERSONNEL**
  - **3.1 Testing Organization**
  - The testing organization shall be an independent, third-party entity which can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installers of equipment or systems being evaluated.
  - The testing organization shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.
  - The testing organization shall use technicians who are regularly employed for testing services.
  - The testing organization shall submit appropriate documentation to demonstrate that it satisfactorily complies with these requirements.

Cx Functional Tests – Electrical – Construction Phase

- **3.2 Testing Personnel**
- Technicians performing these electrical tests and inspections shall be trained and experienced concerning the apparatus and systems being evaluated. These individuals shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must evaluate the test data and make a judgment on the serviceability of the specific equipment.
- Technicians shall be certified in accordance with ANSI/NETA ETT, Standard for Certification of Electrical Testing Technicians. Each on site crew leader shall hold a current certification, Level 3 or higher, in electrical testing.
- The mode(s) of operation for the electrical systems should be tested to include normal, emergency, and/or redundancy. This will be for electrical services only; integrated testing will be used to test HVAC/FA/FP/Electrical interactions.

Cx Functional Tests – Electrical – Tests Methods



The tests should be completed simulating actual equipment or device failure by open disconnects or breakers, removing communications, lifting control wires, or moving from auto to hand at VFDs, controllers, ETC.

The tests can be completed simulating equipment failure by changing set points and finally by point override.

Disabling equipment via the BAS may be used, as long as it simulates a failure and not a change in state.

Test can be completed closing valves (simulate loss of flow), closing dampers (simulate loss of airflow) but must not be done unless it has been reviewed by the team and damage to equipment would not be expected.

Cx Functional Tests – Example

The test step should include how the tests are completed, and document the expected operational position, status and set-point.

Record the time and weather conditions prior to testing.

An example would be with the air handler (AHU-1) in normal operation, maintaining the discharge air static pressure or CFM set-point (record the value), in the cooling mode maintaining 55F DAT (record the value) (Record CHW valve position), with the OA damper at minimum position (record the value), fail the DAT sensor by removing the BAS wiring at the field panel.

The tests should include the expected result for each step, including any allowable variations, an example would be after the DAT sensor has failed the unit should maintain the current operational mode, maintain all set-points, maintain the position of all valve and dampers (fail in last position) and alarm at the BAS. Record all previous information after failure.

The tests should include the expected results when the failure is cleared. An example would be upon restoration of the DAT sensor input to the BAS the air handler (AHU-1) should return to normal operation, maintain the discharge air static pressure or CFM set-point (record the value), remain in the cooling mode maintaining 55F DAT (record the value) (Record CHW valve position), with the OA damper at minimum position (record the value). Note, if there is an expected time delay the delay to normal operation should be noted.

Cx Integrated Systems Tests (IST) – Construction Phase

- These tests should be completed with the anticipated thermal load within the building, all spaces, and server racks. The requirement for load banks has already been established.
- The tests are used to challenge the equipment and system and verify the response of the equipment and systems per the design documents and approved submittals.
- The tests should include response time for switchover, enable, disable, alarms and stability for each test.
- The tests should include system operation at various design set-points and conditions. Items like changes in leaving water temperature from the chillers and the effect on the other systems should be confirmed.
- The tests should include recovery times and temperature/humidity checks for equipment after loss of equipment, and switchover when operational time limits are met (run time totals and equalization of run time).
- All equipment and systems should be online, operational, standby, or as identified as normal position.
- No alerts or alarms should be active when starting the testing.
- Tests will include all modes of operation and the interaction between systems as identified per mode.
- Identify the positions of all valves, dampers, switches, ETC as indicated on the design documents, submittals and BAS Sequences prior to the start of IST.
- Interoperability testing should include interactions between Electrical and HVAC, HVAC and Fire Alarm/Fire Protection.

Cx Integrated Systems Tests (IST) Examples

Start the testing by noting the time and weather, the status of all systems and equipment, with as detailed information as possible. BAS data, screenshots and trending information should be used to support the “as found” conditions.

An example might be: With all system and equipment running in a normal state, kill the incoming main power at the utility or main service breaker at the switchgear. Note, there is a lot more detail in the actual test steps.

The interaction between the normal and emergency power, power for the HVAC, power for the lights, interaction with UPS,

The timing for the generator start, load transfer times at the ATS, UPS Power, Restart timing of HVAC are all types of tests to be completed during a power loss test.

Possible Functional and IST Issues

Schedule, sorry but you can't push commissioning into a smaller window due to poor schedule management.
Missing the required support for testing.
Missing components on vendor provided "Package" equipment. Did they provide all the "Bells and Whistles"? Missing components will compromise the equipment and system operations.
Incorrect placement of key sensors and devices.
Closed valves, dampers or utilities not ready to support testing.
Stopping of commissioning due to interference with other building operations.

Closeout Activities, Occupancy & Operations Phase

- Review the required Monitoring Based Commissioning to verify all the required points, data, and trends are being provided and utilized for MBC.
- The Cx Provider will perform the Warranty Phase Cx as outline in the contract documents.
- The Cx Provider will perform the Ongoing Commissioning as outline in the contract documents.
- The Cx Provider will perform the 10-12 month follow up as outline in the contract documents.
  - Provided the owner the 10–12-month performance and maintenance questionnaire.
  - Ask for the maintenance logs, alarm list, and trend logs for review.
  - Meet with the staff and review the questionnaire and the information provided.
  - Confirm that the training provided the required knowledge as identified by the operational staff.
  - Plan a path forward based on the outcome of the review and meeting.

Marketing of Data Center Commissioning - (Not a BCXA Best Practice)

- **Summary of Commissioning Level Phases:**

- **Level 1: Factory Witness Testing (FWT) Summary:**

- Factory witness testing (FWT) consists of Owner/CA/AE-witnessed testing of equipment at the factory, by factory personnel. FWT is not required for this project; however, factory testing and related test reports for factory testing required by the specifications shall be included in the commissioning process.

- **Level 2: Component Quality Assurance (CQA) Summary:**

- Component quality assurance (CQA) includes inspection and verification of individual system components and equipment at the site upon delivery for compliance to the design specifications, drawings, and approved project submittals; it includes inspection of system components and equipment for shipping damage and missing items.

- **Level 3: Startup Verification (SUV) Summary:**

- Startup verification testing (SUV) includes review and conducting startup procedures and testing in accordance with the commissioning plan and manufacturer procedures.

- **Level 4: Functional Performance Testing (FPT) Summary:**

- Functional performance testing (FPT) includes demonstration that each system is operating according to the contract document requirements, manufacturer operational control sequences, and the commissioning plan; it includes bringing the systems from a state of individual substantial installation completion to full dynamic operational completion as individual systems.

- **Level 5: Integrated Systems Testing (IST) Summary**

- Integrated systems testing (IST) includes demonstration that each system is operating seamlessly in an integrated manner coordinated with all other related systems in the project, so that the facility as a whole meets the Owner requirements for reliability and availability; it includes bringing the systems from a state of individual operational completion to full-scale operation of systems as a cohesive integrated system.

Marketing of Data Center Commissioning - (Not a BCXA Best Practice)

- **Summary of Commissioning Level Phases**

- **Level 1 - Red Tag (Factory Testing)**

- Level 1 commissioning, also known as Red Tag, involves conducting factory testing of components and systems before they are delivered to the data center site.

- This level ensures that equipment, such as servers, cooling units, and power distribution systems, undergoes rigorous testing in controlled environments to verify their functionality and performance.

- **Level 2 - Yellow Tag (Pre-Installation)**

- Level 2 commissioning, referred to as Yellow Tag, focuses on the delivery and pre-installation phase of components and systems at the data center site.

- This level includes inspecting the delivered equipment, verifying its compliance with specifications, and preparing it for installation.

- **Level 3 - Green Tag - (Pre-Commissioning)**

- Level 3 commissioning, known as Green Tag, involves pre-commissioning activities to ensure that individual components and systems are ready for operation.

- This level includes functional checks, initial startup, and testing of components and systems to confirm their readiness for integration.

Marketing of Data Center Commissioning - (Not a BCXA Best Practice)

- **Summary of Commissioning Level Phases**

- **Level 4 - Blue Tag - (Functional Performance Testing)**

- Level 4 commissioning, represented by Blue Tag, is the stage where comprehensive functional performance testing of individual components and systems takes place.

- This level focuses on evaluating the performance and capabilities of each component and system according to predefined criteria and specifications.

- **Level 5 - White Tag - System Integrated Testing**

- Level 5 commissioning, denoted by White Tag, involves testing the integrated operation and interoperability of all systems within the data center. Also named Integrated System Testing.

- This level includes comprehensive testing scenarios that evaluate the overall functionality, coordination, and performance of the entire data center system.

- Normal level 5 testing would be to simulate a power failure (blackout test) and see how the backup systems react. This is to ensure that the data center can handle a power failure without going down. For example, if the UPS systems can handle the load and if the generators start up as intended.

Site Infrastructure Tier Standards (Uptime Institute)

1. **Tier I: Basic Site Infrastructure**
    1. The fundamental requirement:
        a) A Tier I basic data center has non-redundant capacity components and a single, non-redundant distribution path serving the critical environment. Tier I infrastructure includes: a dedicated space for IT Systems; a UPS to filter power spikes, sags, and momentary outages; dedicated cooling equipment; and on-site power production (e.g., engine generator, fuel cell) to protect IT functions from extended power outages.
        b) Twelve hours of on-site fuel storage for on-site power production (e.g., engine generator, fuel cell).
    2. The performance confirmation tests:
        a) There is sufficient capacity to meet the needs of the site.
        b) Planned work will require most or all of the site infrastructure systems to be shut down affecting critical environment, systems, and end users.
    3. The operational impacts:
        a) The site is susceptible to disruption from both planned and unplanned activities. Operation (human) errors of site infrastructure components will cause a data center disruption.
        b) An unplanned outage or failure of any capacity system, capacity component, or distribution element will impact the critical environment.
        c) The site infrastructure must be completely shut down on an annual basis to safely perform necessary preventive maintenance and repair work. Urgent situations may require more frequent shutdowns. Failure to regularly perform maintenance significantly increases the risk of unplanned disruption as well as the severity of the consequential failure.

Site Infrastructure Tier Standards (Uptime Institute)

2. Tier II: Redundant Site Infrastructure Capacity Components

1. The fundamental requirement:
    a) A Tier II data center has redundant capacity components and a single, non-redundant distribution path serving the critical environment. The redundant components are extra on-site power production (e.g., engine generator, fuel cell), UPS modules and energy storage, chillers, heat rejection equipment, pumps, cooling units, and fuel tanks.
    b) Twelve hours of on-site fuel storage for 'N' capacity.
2. The performance confirmation tests:
    a) Redundant capacity components can be removed from service on a planned basis without causing any of the critical environment to be shut down.
    b) Removing distribution paths from service for maintenance or other activity requires shutdown of critical environment.
    c) There is sufficient permanently installed capacity to meet the needs of the site when redundant components are removed from service for any reason.
3. The operational impacts:
    a) The site is susceptible to disruption from both planned activities and unplanned events. Operation (human) errors of site infrastructure components may cause a data center disruption.
    b) An unplanned capacity component failure may impact the critical environment. An unplanned outage or failure of any capacity system or distribution element will impact the critical environment.
    c) The site infrastructure must be completely shut down on an annual basis to safely perform preventive maintenance and repair work. Urgent situations may require more frequent shutdowns. Failure to regularly perform maintenance significantly increases the risk of unplanned disruption as well as the severity of the consequential failure.

Site Infrastructure Tier Standards (Uptime Institute)

2. Tier III: Concurrently Maintainable Site Infrastructure

1. The fundamental requirements:
    a) A Concurrently Maintainable data center has redundant capacity components and multiple independent distribution paths serving the critical environment. For the electrical power backbone and mechanical distribution path, only one distribution path is required to serve the critical environment at any time.

- The electrical power backbone is defined as the electrical power distribution path from the output of the on-site power production system (e.g., engine generator, fuel cell) to the input of the IT UPS and the power distribution path that serves the critical mechanical equipment.
- The mechanical distribution path is the distribution path for moving heat from the critical space to the outdoor environment. For example, chilled water piping, condenser water piping, refrigerant piping, etc.

    a) All IT equipment is dual powered and installed properly to be compatible with the topology of the site's architecture. Transfer devices, such as point-of-use switches, must be incorporated for critical environment that does not meet this requirement.
    b) Twelve hours of on-site fuel storage for 'N' capacity.

2. The performance confirmation tests:
    a) Each and every capacity component and element in the distribution paths can be removed from service on a planned basis without impacting any of the critical environment.
    b) There is sufficient permanently installed capacity to meet the needs of the site when redundant components and distribution paths are removed from service for any reason.
3. The operational impacts:
    a) The site is susceptible to disruption from unplanned activities. Operation errors of site infrastructure components may cause a computer disruption.
    b) An unplanned outage or failure of any capacity system may impact the critical environment.
    c) An unplanned outage or failure of a capacity component or distribution element may impact the critical environment.
    d) Planned site infrastructure maintenance can be performed by using the redundant capacity components and distribution paths to safely work on the remaining equipment.
    e) During maintenance activities, the risk of disruption may be elevated. (This maintenance condition does not defeat the Tier rating achieved in normal operations.)

Site Infrastructure Tier Standards (Uptime Institute)

4. Tier IV: Fault Tolerant Site Infrastructure

1. The fundamental requirements:
   a) A Fault Tolerant data center has multiple, independent, physically isolated systems that provide redundant capacity components and multiple, independent, diverse, active distribution paths simultaneously serving the critical environment. The redundant capacity components and diverse distribution paths shall be configured such that 'N' capacity is providing power and cooling to the critical environment after any infrastructure failure.
   b) All IT equipment is dual powered with a Fault Tolerant power design internal to the unit and installed properly to be compatible with the topology of the site's architecture. Transfer devices, such as point-of-use switches, must be incorporated for critical environment that does not meet this specification.
   c) Complementary systems and distribution paths must be physically isolated from one another (Compartmentalized) to prevent any single event from simultaneously impacting both systems or distribution paths.
   d) Continuous Cooling is required. Continuous Cooling provides a stable environment for all critical spaces within the ASHRAE maximum temperature change for IT equipment as defined in *Thermal Guidelines for Data Processing Environments, Third Edition*. Additionally, the Continuous Cooling duration should be such that it provides cooling until the mechanical system is providing rated cooling at the extreme ambient conditions.
   e) Twelve hours of on-site fuel storage for 'N' capacity.
2. The performance confirmation tests:
   a) A single failure of any capacity system, capacity component, or distribution element will not impact the critical environment.
   b) The infrastructure controls system demonstrates autonomous response to a failure while sustaining the critical environment.
   c) Each and every capacity component and element in the distribution paths can be removed from service on a planned basis without impacting any of the critical environment.
   d) There is sufficient capacity to meet the needs of the site when redundant components or distribution paths are removed from service for any reason.
   e) Any potential fault must be capable of being detected. isolated, and contained while maintaining N capacity to the critical load.
3. The operational impacts:
   a) The site is not susceptible to disruption from a single unplanned event.
   b) The site is not susceptible to disruption from any planned work activities.
   c) The site infrastructure maintenance can be performed by using the redundant capacity components and distribution paths to safely work on the remaining equipment.
   d) During maintenance activity where redundant capacity components or a distribution path shut down, the critical environment is exposed to an increased risk of disruption in the event a failure occurs on the remaining path. This maintenance configuration does not defeat the Tier rating achieved in normal operations.
   e) Operation of the fire alarm, fire suppression, or the emergency power off (EPO) feature may cause a data center disruption.

Data Center Commissioning Downtime Time (Uptime Institute)

	Uptime per year	Downtime per year
Tier I Basic Capacity	**99.671%**	**<28.8 hours**
Tier II Redundant Capacity Components	99.741%	<22 hours
Tier III Concurrently Maintainable"	99.982%	<1.6 hours
Tier IV Fault Tolerant"	99.995%	<26.3 minutes

Data Center Commissioning Times (Uptime Institute)

Commissioning to Tier 1 should take 3 Days to 2 weeks to properly commission the data center prior to operations.

Commissioning to Tier 2 should take 3 weeks to 4 weeks to properly commission the data center prior to operations.

Commissioning to Tier 3 should take 5 weeks to 8 weeks to properly commission the data center prior to operations.

Commissioning to Tier 4 should take 8 weeks to 4 months to properly commission the data center prior to operations.

Note: Uptime can help, write scripts, and witness the performance of the facility itself to create documented Operational Procedures and Playbooks

Questions

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