"Data Center Commissioning and Integrated Systems Testing"

9th Annual SERBCA Technical Summit

Presented by: Craig A. Hawkins, CCP

Integrated Systems Testing
  IST: Definition, Purpose & Goals
  IST Process; Planning, Writing and Reviewing
  Implementing the IST
  IST Challenges
  Those IST "Ah-ha" moments

DataCenter Cx – New Construction
  Perceived change in Cx focus
  Importance of Facilities Staff in Design Development & Reviews
  Site Observations & Functional Testing
  Planning and implementing the IST

DataCenter Cx – Existing Building
  Existing Documentation Search
  Site walks, Investigations & Analysis
  FIM Implementation
  Component & Systems Testing
  Planning and implementing the IST

Wrap-Up Comments & Questions

Did you know….

Powerful Facts

- Major power outages have been doubling every 5 yrs for the last 15 years**.
  - 44…100…200
- Electrical causes (failures, shorts, surges), Weather, vandalism, physical attacks, stress/demand, aging grid area all factors
- Every facility everywhere WILL LOSE POWER at least once, not an "If we lose power" it's "When we lose power". Plan for it!
- Electrical Inspections and Generator tests alone do not protect you in a loss of power event.

This is NOT what we want!

INTEGRATED SYSTEMS TESTING

IST Overview
- o Definition
- o Purpose
- o Goals

- o IST versus FPT
- o Pre-Planning
- o Planning
- o Creating IST Documents
- o Getting Approval for IST

AKA: "Pull The Plug" Test

Defining Integrated Systems Testing

Definitions of IST:

o **Integrated Systems <u>Test</u>** (Loss of Power Test) is the simulated (controlled) loss of utility power and the verification of anticipated correct systems performance of all building systems under that loss of normal power, as well as the verification of those systems automatic return to designed function upon restoration of normal power.

o **An IST <u>Program</u>** (Regularly scheduled repeats of the IST) will ensure continuous assurance of the facilities reliability.

Purpose and Goals of Integrated Systems Testing

Purposes of an IST:

o Bridges gaps between electrical inspections, generator load bank testing, and routine generator testing.

o Verifies that <u>all</u> powered equipment and systems have been tested under load, with power cut as close to the main utility feed as safety and best practices allow.

o Identifies issues occurring at all powered systems while on emergency power as well as any issues upon return to normal power.

o Verification of automatic control under all emergency conditions without human intervention or assistance.

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Purpose and **Goals** of Integrated Systems Testing

Goals of an IST:

o   Verifies all intended system responses and conditions, including staff response.

o   Verifies that emergency contacts and emergency response team is accessible and ready (to handle any unintended system or occupant responses).

o   As a final step, includes corrective actions and a MOP response plan that includes signage, instructions and feedback from the IST test.

o   Proven confidence in systems reliability under all conditions, manned or not.

o   Verification of all automatic emergency call-out procedures.

Functional Performance Testing

Versus

Integrated Systems Testing

Object Under Test

- o **FPT:** Single pieces of equipment or dependent pieces of a sub-system.
- o **IST:** All building systems and all pieces of MEP equipment all at once.

Test Procedure

- o **FPT:** Simplified test steps to verify mostly control or functionality of each piece of equipment, individually, under all modes of operation. Basically; Verification of BMS "control" and individual performance of each piece of equipment. Repeatable.
- o **IST:** Complex step-by-step process with checks and an "Exit Plan" at each step. Written as an MOP. Repeatable.

Test Participants

- o **FPT:** Usually just BMS contractor and CxP, with aid of installing contractors, often O&M Staff (if available).
- o **IST:** A large, organized, focused troop of 3rd party individuals who understand all operational aspects of the entire facility and it's functioning MEP systems.

Condition of Facility at Time of Test

- o **FPT:** Unfinished, under construction
- o **IST:** Facility completed, all construction completed.

Integrated Systems Test

Pre-Planning

Prepare for the Planning Sessions:

o Put your IST Planning Team together, which should include:
   o O&M Staff Members (at a minimum, the Chief Operating Engineer, but better with all operators).
   o Engineers of Record (Mech & Elec)
   o Key member of GC Team, usually the MEP Coordinator.
   o Key equipment vendor reps, usually Generator, UPS & Switchgear.

o Create a "Planning Plan" that describes, in detail, the planning process, purpose, goals, IST planning meeting schedule, timeline with critical milestones and a Roles & Responsibilities matrix. KEEP IN MIND; MOST, IF NOT ALL, OF THE IST TEAM MEMBERS HAVE NEVER BEEN THOUGH AN IST. THEY ARE COUNTING ON YOU TO LEAD THEM. IN THEIR MIND, THIS IS "YOUR" TEST.

o Schedule at least 4 IST planning meetings, usually 2 weeks apart, to allow team members to complete their IST planning assignments AND manage their normal workloads. Agree on dates and times AND DO NOT MOVE THEM!

o Prepare yourself to lead the meetings. You are in charge of the flow, so be in the know (**about everything IST!**)

o Gather all info needed for a Systems Manual BEFORE the IST Planning Meetings. **This is a huge change from the "normal NCCx Process"** Build the Systems Manual from the design documents prior to start of construction. It will change, but having a DRAFT version will be of tremendous help in planning the IST.

Integrated Systems Test

Planning #1

Plan, plan and more planning:

o   Start with a detailed, quality Systems Manual to understand how building systems function and are related/dependent on each other.

o   Clarify procedure for safely interrupting utility service connections at switchgear.

o   Confirm all transfer timings via FPT's. Document, document, document.

o   When testing UPS batteries under individual FPT's pay particular attention to battery draw-down duration under load. When planning OST, do not run UPS batteries down more than 60%. If gen start, sync and transfer takes longer than 60% timing, stop test and re-evaluate.

o   Consider creating a detailed flow-chart as a planning tool to capture expected reaction to each step and to help illustrate fast, safe, exit plans for each and every step. At a minimum, create a Memo of Understanding that outlines goals what is to be tested. Once approved, roll into MOP type test form

and....

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Integrated Systems Test

Planning #2

Plan, plan and more planning:

o   IST's are written in a format of an Method Of Procedure (MOP) where there is one AND ONLY one action per step, with clear indication of acceptable action (Pass/Fail) for each step and a clearly thought out, and agreed upon "Exit Procedure" for each step for when something comes wrong (and it will).

o   Include all Pre-Test Tasks as a checkoff list, verified by 2 independent parties.

o   Consider making the IST a condition of successful turnover, include language supporting the IST in EVERY project contract and include allotted time on GC's Master Build Schedule (including allowance for IST "Issues").

o   Secure load banks if facility has no load (yet).

o   Verify amount of stored fuel and have procedures for procuring more in place.

and….

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Integrated Systems Test

Planning #3

Plan, plan and more planning:

- Create an "IST Team Organizational Chart" so that everyone on the team knows their roles and responsibilities, and everyone else's too.

- Senior CxP is the IST Team Leader. The CxP alone directs the action and has ultimate "Go/No-Go" authority.

- Fellow CxP's and O&M Staff carry out step-by-step actions, project engineers are witnesses and contractors are "runners" as need be, equipment vendors are on standby for informational support as necessary.

- Make it clear from the very beginning, and reiterate as necessary, the IST must be run from start to finish without interruption to be considered a success. Any failure of any step, no matter how small or seemingly insignificant, requires the IST to stop, the exit plan at that step initiated and utility power restored until repairs are made and then the IST starts over AT THE BEGINNING.

and….

Integrated Systems Test

Planning #4

Plan, plan and more planning:

- Plan not only the actual IST but also the Assigned Witness Plan:
  - Who is assigned each observation zone.
  - What they are expected to see at each step (usually nothing at most zones).
  - What their Radio Number is (usually same as Zone Number).
  - Who is their backup in case they cannot be at the scheduled test date and time.
  - If the zone is large enough, consider adding at least one or two "runners" to assist.
  - Select witnesses according to their level/area of expertise and make sure they all understand the critical nature of the IST. Ensure they know how to properly use the radios and are able to remain calm and quiet throughout the test. In most cases, most witnesses will have little to nothing to report after each test step, which means they need to stay sharp for hours of inactivity.
  - Consider a "dress rehearsal" at least 2 days prior to the scheduled IST to do a radio check with the actual witnesses assigned.

Writing an Integrated Systems Test

o **Writing an IST**
  o Writing an IST Procedure is a little like writing out a cooking recipe; you start with a list of ingredients, then move into the actual preparations steps, then "serving" instructions.

o **IST Deliverables (List of Ingredients):**
  o IST Goal & Task Overview (for team approval)
  o IST Flow Diagram (for IST Script Planning)
  o IST Communications Plan (for team approval)

  o IST Pre-Test Checklist (for 1-week look ahead)
  o IST Test-Day Checklist (for day before)
  o IST Script (for test day use)

  o IST Corrective Action List (Post IST)
  o IST Final Report (Post IST)

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Creating Integrated Systems Test Documents

- **IST Flow Diagram:**
  - For planning only
  - Electronic whiteboarding
  - A method to graphically illustrate the "flow" of the test
  - Allows for capturing ideas for safe test stoppage (exit plan)

- **IST Communications Plan:**
  - Communications Overview
  - Equipment to be used
  - Acceptable communications procedures
  - Unacceptable communications methods (list of "No-No's")
  - Back-Up plans (for when Mr. Murphy shows up)
  - Single Command Authority (Hint: CxP)
  - Signature lines for approval by **ALL** IST Team Members

Creating Integrated Systems Test Documents

- **IST Script:**
- Written as a "Method Of Procedure" where each step includes:
  - Timing of Step
    - Time period (hour/minute) of when test step should occur (WHEN)
    - Duration of time to complete step including all-call
  - Action of Step
    - Description of actual test step (WHAT)
  - Team Member Assignments
    - Team Member to initiate test step & Team Members who report on reaction (WHO)
  - Anticipated Reaction to Step
    - "Correct" automatic reaction of system(s) to test step (SYSTEM RESPONSE)
  - Safe "Step-Stoppage" procedure
    - "SAFE STOP – EXIT PLAN)

Creating Integrated Systems Test Documents

- **IST Pre-Test Checklist (up to a week ahead of IST)**
  - Checklist of things that must be in place prior to IST, including:
    - Verification of Generator Fuel level
    - Verification of all FPT's completed
    - Verification of all Issues resolved
    - Sign-off by all IST Team Members of IST Procedure Script
    - Sign-off by IST Team members of their specific IST Equipment responsibilities

- **IST Test-Day Checklist (day before):**
  - Last minute check of all IST Team Member's readiness for IST
  - Last minute Pre-Test Check-In arrangements (time, location)
  - Verification of radios (quantity, full-battery charge)
  - Verification of Comm-Check (radio coverage, channel strength)
  - Verification of back-up representatives in case of last-minute personnel "issues"
  - Verification of "Notice to Test" to local FD, local utility, security firm, all on-site personnel.
  - T-Minus 24 site verification

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Creating Integrated Systems Test Documents

o **IST Corrective Action List:**
  o Formal name for "IST Only Issues Log"

o **IST Final Report:**
  o Summary of IST disposition (Pass/Fail)
  o Summary of all IST activities (History)
  o Copies of all IST Deliverables
  o List of recommendations for future (repeat of IST, more training, etc.)

Reviewing and approving an Integrated Systems Test procedure

Reviewing the IST Plan

o   Prior to implementation of the IST, the IST Procedure MUST be **unanimously** approved by all Team Members and the Owner (Reps).

o   Even though the Team met (several times) to generate the IST Procedure, each IST Team Member should be given time to review the procedure with their own "in-house" teams.

o   Included with the actual IST Procedure, attached to the front, should be a "Cover Sheet" that outlines:

   o   Purpose and goals of the IST.

   o   List of IST Planning Members, including space for their wet-ink initials approving the final version.

   o   Timeline for the test.

   o   The IST Communications Plan.

   o   The Pre-IST Checklist.

   o   List of all required equipment for IST and who is responsible for each item.

o   The critical nature of the IST mandates that time for review and approval is just as, if not more so, important as all the planning. Review and approval sets the IST into final motion and everyone involved must be "on-board" with the Final IST Procedure.

DATA CENTER Cx – NEW CONSTRUCTION

DCCx – New Construction Overview

o Change in Focus

o Involving O&M Staff Early

o Site Observations & Functional Testing

o Planning and Implementing the IST

NCCx for Data Centers

A slight change in focus

1. Reliability (Uptime) trumps all.

2. "Creature Comfort" not really an issue.

3. Focus on understanding, documenting and getting FULL TEAM approval on the "Critical Path" (what's on emergency generator load).

4. Pay attention to how redundant (+1) equipment operates:
   a. Off, on standby?
   b. On, sharing load? ….Pro's & Con's?

5. Protocols? PM's? How organized are they? What will they use in the future (SOP)?

NCCx for Data Centers

A different kind of Cx Design Review

1. Focus on power, normal and emergency

2. Focus on redundancies

3. Start with a Systems Manual (normally at the end)

4. Include Facilities and IT Teams in Design Development and Design Reviews

5. Identify "Single Points of Failure"

6. Focus: "It's all about **Uptime**".

Why NCCx Design Reviews?
Just because it can be drawn, doesn't mean it can be built!

NCCx Design Reviews

General Notes

TRICHOTOMETRIC INDICATOR SUPPORT

0.0833 FT

AMBIHELICAL HEXNUT (3.1416 REQUIRED)

RECTABULAR EXRUSION BRACKET

10.16 CM
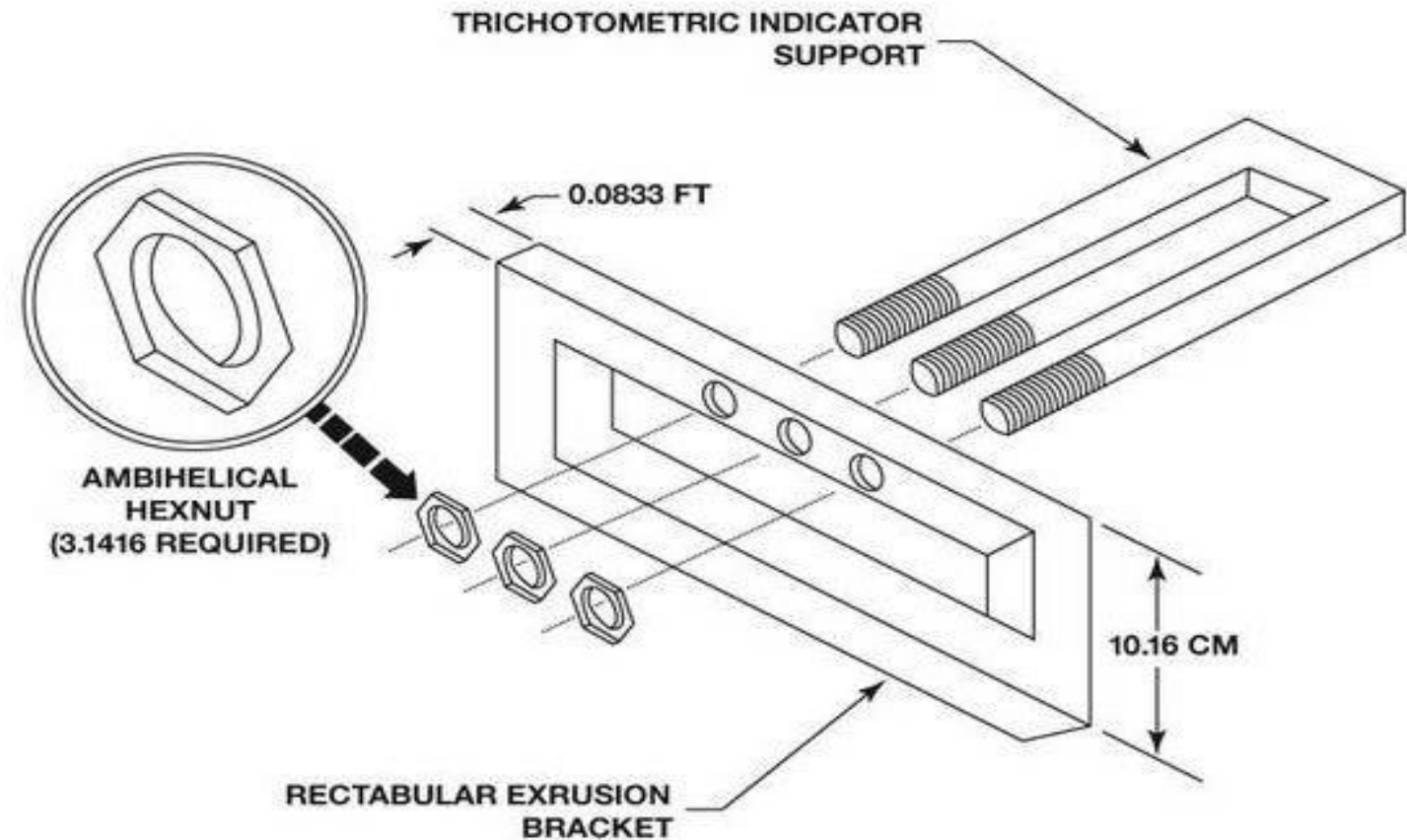
NCCx Design Reviews

Data Centers

Design Reviews specific to Data Centers
a. Electrical System
   i. Single points of failure
   ii. Documented Critical Path
   iii. UPS (Duration without Generator)

b. Generators & Emergency Fuel System
   i. Size of generator
   ii. Types of fuel
   iii. Location, location, location
   iv. Fuel Storage & Delivery

c. Mechanical-HVAC
   i. White Space operating temperature
   ii. Hot Aisle/Cold Aisle containment
   iii. UFAD
   iv. Rack Coolers
   v. CRAC Units
   vi. +1

NCCx for Data Centers

Managing Cx Issues as a Team

1. Review and solve each Cx noted issue as a team (Owner, O&M Staff, IT, GC & CxP at a minimum).
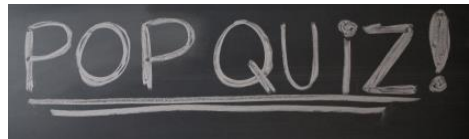
….Why is this "Team Concept" critical for DC's?

NCCx for Data Centers

Functional Performance Testing

1. Start on smallest component level and work up through sub-systems then systems.

2. We all try to resolve all Cx Issues on every project, but there are usually a few that linger past Occupancy date, however…….. When commissioning a DC (or any other Mission Critical facility) ALL ISSUES MUST BE RESOLVED BEFORE THE IST!!! And if Occupancy is dependent on the IST being finished prior to Move-In, then solve issues ASAP, do not let the team put them off (typical).

NCCx for Data Centers

Facilities Staff Training

1. Start with a Training Plan months ahead of the actual training sessions

2. Focus on the quality and experience of the trainers

3. Spend time reviewing documentation (As-Builts, Systems Manual, O&M's)

4. Help facilitate PM if necessary

5. Verify training effectiveness at the end of each session

6. Develop a transitional phase program (training wheels) for the first year

NCCx for Data Centers

Finish with the IST

1. Schedule IST immediately following Training

2. Use the IST as a final verification of Operator Training (dry run on handling emergency operation)

DATA CENTER Cx – EXISTING BUILDINGS

EBCx – Existing Building Overview

o Existing Documentation Search

o Involving O&M Staff in CFR

o Site Walks, Investigating, & Data Analysis

o Implementing FIM's

o Planning and Implementing the IST
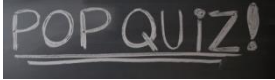
EBCx for Data Centers

Working in a completed and operating facility

1. Always, ALWAYS, remember "You are the visitor, the alien in their foreign land". You work around their schedules, you respect their "rules". Be non-obtrusive and respectful at all times to everyone.

2. When you meet with the Owner, before you walk the facility, ask how you should respond when the occupants ask *"What are you doing and why?"* (and they will ask!) <u>Work out an acceptable response BEFORE you start the inspection.</u>

3. When walking the facility and talking to people, always ask permission first *("Excuse me, can I ask you a quick questions...?")* and be ready when they say *"No, sorry, I'm too busy".* Keep the conversations with them as brief as possible. THEY HAVE WORK TO DO (and so do you).

4. DO NOT EVER voice a critical opinion. You might round a corner and want to blurt out *"WTF were they thinking!?!"* but don't!

5. Specifically ask the Owner and IT Lead about their 1 year, 5 year and 10 year plans. Expansions, changes to racks, changes to servers, etc. Get to know their current operation AND their future plans.

6. Ask first if photography is allowed within the white space. Many CoLo's don't allow photography of their tenants cages.

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Understanding the facilities operation....

....and operators!

1. As with any EBCx Project, start with creating a CFR, however, with operating DC's, get the Owner together with key members of the O&M Staff and interview both together to establish how the facility "really" operates.

2. In the first meeting with the Owner, ask how they want to see the FIM's list (ROM, Certified Estimates, etc.??)

3. During the CFR interview, try to get an idea of where the trouble spots are (and if you can, why are there trouble spots).

4. Remember...everyone has their own personal agenda, so take everything you hear with a grain of salt. Listen, then verify.

5. S. O. A. P. POP QUIZ! ....What's S O A P?

6. Once you finish with the CFR and start your investigation, don't forget that you are investigating the facility, the MEP Systems AND <u>the Operators</u>:
   a. What is their level of expertise?
   b. How do they document maintenance?
   c. What is the condition of their tools and working spaces?
   d. What is their working relationship with the Owner?
   e. Do they employ "band-aid" quick fixes or do they try to do the right thing?

7. A common FIM is "O&M Staff need more training" so don't be shocked, you'll see.

EBCx for Data Centers

Investigation Phase

...be ready for anything....

.....especially the Good, the Bad and the Ugly!

.....or worse than ugly)....
......yep, it's out there,
....waiting for you!

1. Start at Central Plant and then walk distribution systems.

2. As you are walking through a facility, use almost(**) all your senses:

   a. Look
   b. Listen
   c. Smell
   d. Touch

   (** Just don't go around licking air handlers and CRAC units!)

3. Keep in mind; you are in an operating DC, sometimes 10 – 15 years old, so you will run into spaces so cold you can hang meat inside. Many older IT teams still think "the colder, the better". Be nice! They know not what they should!

4. Try to visualize airflow and once you understand the flow, go verify it.

5. Q=The #1 Key to doing a High Quality Site Investigation of an operating facility?

   A=Always ask "WHY?" Why is that doing that? Why isn't that working? Why? Why?

......and once you ask "Why" be ready for the answer......be ready for anything!

EBCx for Data Centers

Investigation Phase

The **Good**, the Bad, the Ugly........

When you ask the Facilities Director of a 5 year old datacenter "Can you show me your "Central Plant?" and he walks you up to the roof and this is what you see……

you know it's going to be a good day!

EBCx for Data Centers

Investigation Phase

The Good, the Bad, the Ugly........

When you are walking around the rooftop air-cooled chillers and ask the Facilities Director "What's with the Jobboxes and the storage sheds up here?" and he shows you his "Cleaning Sheds" and tells you about the "Service Parts & Tools Jobboxes"...........
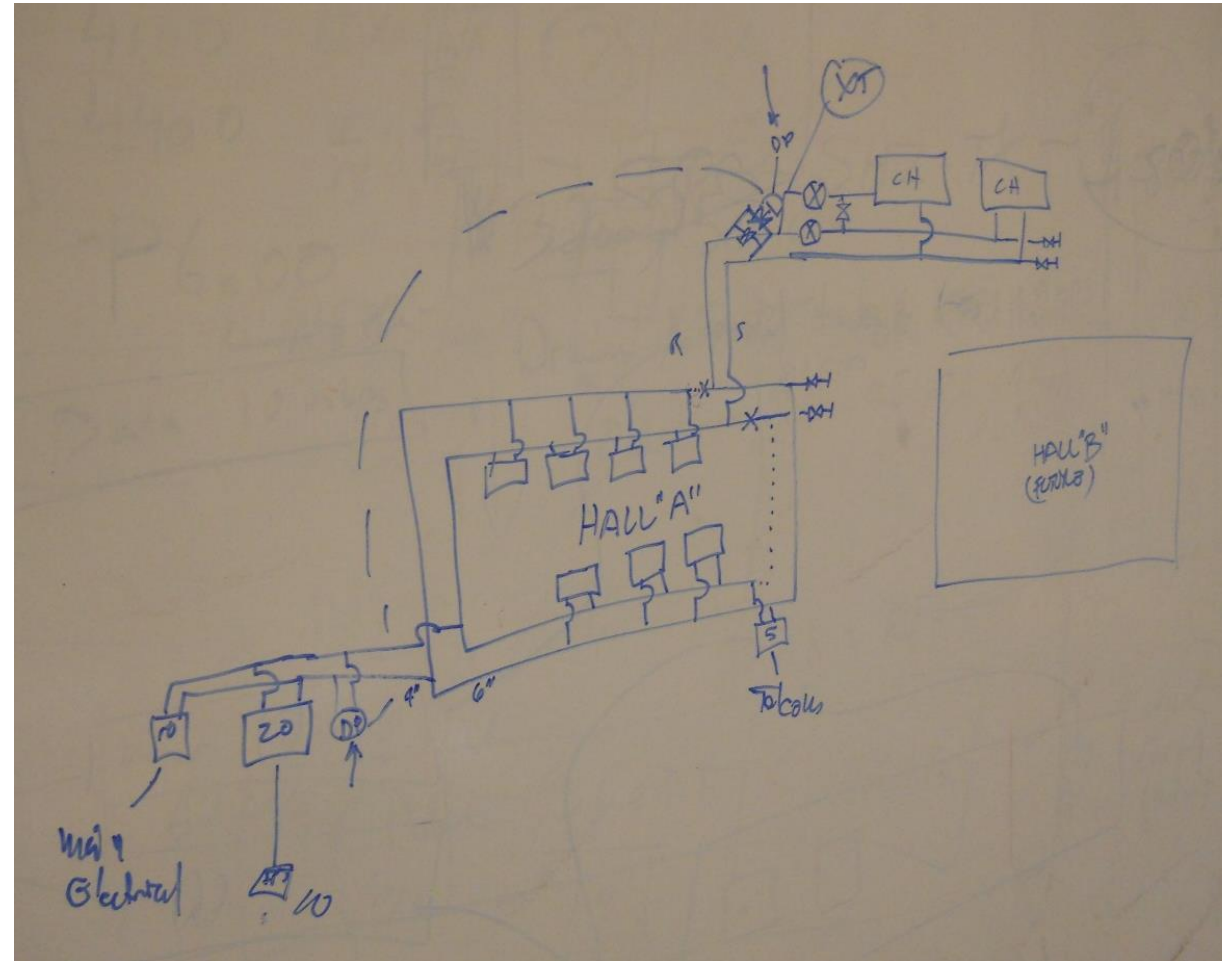
you know it's going to be a good day!

....and the built-in equipment lift...that's just a bonus!

EBCx for Data Centers

Investigation Phase

The Good,
the **Bad**,
the Ugly........

When you ask the Facilities Director of a 7 year old datacenter "How does your CHW System work?" and instead of pulling out an As-Built, a Systems Manual or even showing you the CD's Flow Diagram.......

he goes to the whiteboard and starts drawing.......

you know it's going to be a long day!

EBCx for Data Centers

Investigation Phase

The Good,
the Bad,
the Ugly.......

When you ask the Facilities Director of a 7 year old datacenter "How's your UFAD working for you".....he then asks "What's UFAD?" and then you pull tiles and find a "rats nest".......

you know it's going to be a long day!

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Investigation Phase

The Good,
the Bad,
the Ugly........

When you ask "What's your biggest issue with the mechanical system?" and the O&M Staff all say "We just can't seem to hold pressure in our UFAD system"...........

You walk the white space and see this (all in one facility).

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Investigation Phase

The Good,
the Bad,
the Ugly……..

The O&M Staff just couldn't figure out why the airflow in this room was "less than what they expected". The just couldn't figure it out.

Maybe if you didn't put the floor vents under a desk…….
or cover another with a desktop PC tower…….
I don't know, just a suggestion……..

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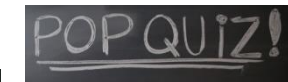**EBCx for Data Centers**

Investigation Phase

**The Good,
the Bad,
the Ugly........**

So, let's just put floor diffusers anywhere we want them, regardless of the fact that the closest racks are 10 feet away!

This is one of my favorite DC photos. A little hard to see, but look just behind the CRAC unit (on the right), on the floor.

POP QUIZ!

....What's the issue here?

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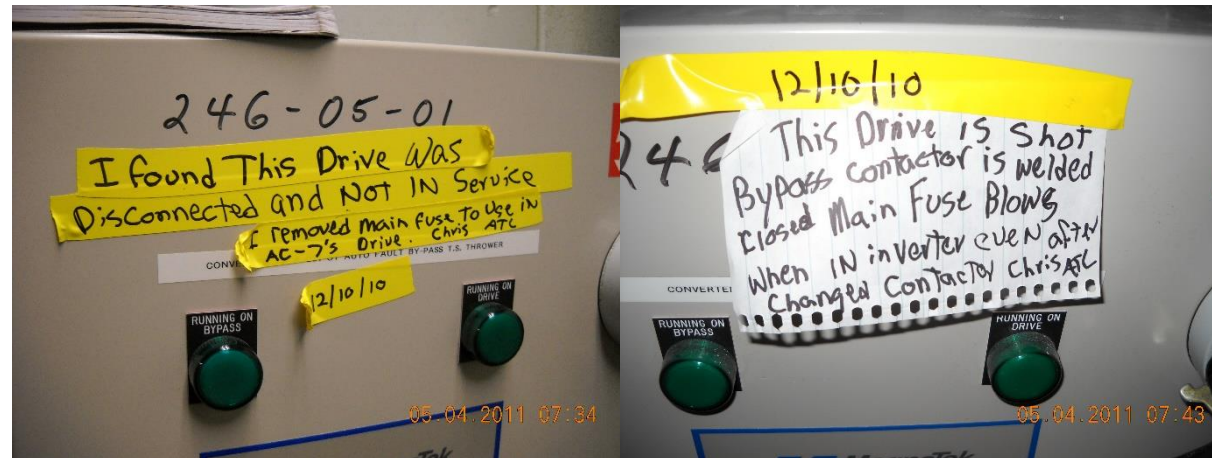## Investigation Phase

The Good, the Bad, the Ugly........ .....the WTF?

....wooden ductwork? Really?

....So that's where that noise was coming from!

First, they leave a note and walk away (what was more important?), secondly, they discovered these issues on December 10, 2010 (see stickers in photo) and we found this on our walkthrough on May 5, 2011......

5 months of ignored service/maintenance. Wish I could say this was unusual, but it isn't.

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Investigation Phase

The Good, the Bad, the Ugly……… ………OMG!!

They couldn't figure out why they couldn't hold the UFAD pressure and why their chiller was working so hard.

I found 4 holes through the outside wall, under the raised floor,
…………all 10" wide x 15" tall!

As I was walking through the white space of a 4 year old Data Center in Dallas, I kept hearing a "popping" sound.

I started pulling tiles and found thousands of crickets coming into the raised floor from cracks in the exterior walls! Crickets in a DC!

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Investigation Data Analysis & FIM Report

1. Ask for help if you need it to:
   a. Calculate operational costs
   b. Calculate energy savings
   c. Estimate demo and implementation costs

Know your limitations and "stay in your swim lanes". Find an Energy Engineer to help with operational and savings costs, partner with a good GC or Estimating Firm for implementation estimates.

Heads Up!! Remember (at the beginning) when you asked the Owner how he wanted to see the FIM's (ROM, Guesstimates, Certified, etc.?) Well, here is where it becomes important….present the FIM's and costs AS THEY REQUESTED!

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Implementing FIM's

Once the FIM's have been selected by the Owner, the implementation "looks like" a normal NCCx effort:

a. Design & Design Reviews

b. Submittal Reviews

c. Site Observation & Issue Management

d. Start-up & TAB Review

e. Functional Testing

f. Training & Systems Manual

Except it isn't a "normal NCCx effort"……..
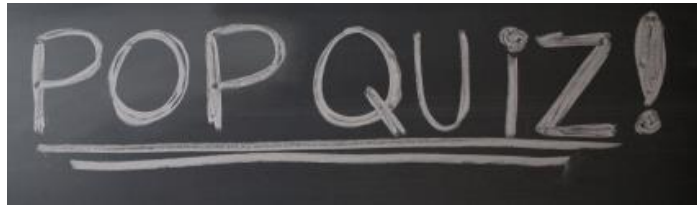
….Why isn't it a normal NCCx effort?

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Functional Performance Testing & Trending

1. Functionally test all new equipment, same as you would test under a NCCx contract.

2. Functionally test all systems that were modified (not just the modifications themselves). Understand that the further you go "back" into a system, the greater the risk for operational issues with equipment/systems you connected to (discuss w/Owner.....negotiate).

3. Be very careful testing in an operating facility. Coordinate, communicate, and be ready to shut the test down at any point if there is an issue that will effect facility operations.

4. Trends (history) are usually more informational that the FPT's (snapshot). Always setup trending (of multiple, related equipment/systems) to start at same time, record same snapshot (every 5 minutes, every 15 minutes, etc.) and always ALWAYS trend outdoor air temperature.

EBCx for Data Centers

Facilities Staff Training

1. Start with a Training Plan months ahead of the actual training sessions

2. Focus on the quality and experience of the trainers during planning

3. Focus on training needs of the O&M Staff

4. Train on all new equipment, modifications to existing AND overall operation of the facility (remember why you were asked here to begin with)

5. Spend time reviewing documentation (As-Builts, Systems Manual, O&M's)

6. Help facilitate PM if necessary

7. Verify training effectiveness at the end of each session

8. Develop a transitional phase program (training wheels) for the first year

EBCx for Data Centers

Finish with an IST

1. Schedule IST immediately following Training

2. Use the IST as a final verification of Operator Training (dry run on handling emergency operation)

3. Be very aware of resistance to "cut" utility power in an operating facility. Work the issue and don't back-down on the necessity of an IST

THE FINISH LINE! WRAP-UP COMMENTS & QUESTIONS

Thank You

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