ANALYSIS 1: CHILLED BEAM SYSTEM

Critical Issue Research Method and Mechanical Breadth

Background

The first analysis deals with the chilled beam system being installed. This is the largest system being installed in the United States and provides an area to gain knowledge to a system that may become widely used in future buildings. This analysis also provides an area for a critical industry research and a mechanical breadth. Both of these topics will deal with the commissioning requirements for Constitution Center.

Problem / Opportunity Statement

The chilled beam system being installed in Constitution Center started as a construction management issue due to the size of the plenum space. This system was then redesigned in order to fit into the space and utilize a system that is widely used in Europe. The chilled beams provide an opportunity for research in a field that is increasing in the United States. This research will allow for increased knowledge of the system, along with an understanding on why the project team decided upon the system. The chilled beam system also allows for the evaluation of how the system affects cost, schedule, and site logistics. Finally, this system presents a construction management issue that can be incorporated into a mechanical breadth.

Mechanical Breadth

While analyzing the chilled beam system, the chance to evaluate the commissioning requirements for the mechanical systems will provide an opportunity for a mechanical breadth as well as a critical industry issue. With a project the size of Constitution Center, the commissioning requirements are very detailed. After evaluating the requirements, if necessary an updated or new system of tracking the commissioning will be proposed.

Research Steps

1. Travel to Atlanta, Georgia to TROX USA, Inc. in order to see firsthand how the chilled beam systems, both passive and active, work. The CEO & President has activities planned to provide me with an understanding of how the system works in order to continue my research.
2. Evaluate publications on the chilled beams.
3. Interview the DAVIS project team in order to see how the schedule, cost, and site logistics were affected by the chilled beam systems.
4. Interview SmithGroup to find out why they chose the chilled beam system and if the design of the building has changed because of their use.
5. Interview Pierce Associates to determine how they have familiarized themselves with the system in order to properly install it.
6. Research the typical costs of an HVAC system that would be installed in a building similar to Constitution Center and compare the costs.
7. Interview DAVIS for commissioning requirements
8. Research current commissioning systems
9. Send out interview/survey questions to industry members
10. Compile interview/survey questions and analyze
11. Finalize Chilled Beam Research

Interview/Survey Questions

1. How many employees does your company employ?
2. What market(s) does you company typically work in?
3. Does your company utilize commissioning?
4. Does your company have full time staff that completes commissioning?
5. Does your company use a specific program for commissioning?
   a. If so, what program(s)?
6. What is one suggestion to make commissioning easier?

Expected Outcome

The expected outcome of this research is to become familiar with the chilled beam system. Also, the goal is to understand why the system was chosen to be utilized at Constitution Center. Finally, the impacts that the system will have on the cost, schedule, and site logistics will be outlined.

Analysis

Traveling to Atlanta Georgia, to the TROX Technik Inc. factory, provided the opportunity to increase the knowledge of the chilled beams air handling system. Heinrich Trox founded the TROX Company in 1951. Since then, the company has grown to over 2,700 employees worldwide and 12 production plants in 10 countries. The company has completed work in numerous types of buildings, such as:

- Office Buildings
- Hotels
- Concert and Theatre Halls
- Shopping Centers
- Recreation Centers
- Hospitals
- Exhibition and Congress Halls
- Sports Facilities
- Universities
- Airports
- Train Stations
- Tunnels
- Ships
- Laboratories
- Clean Rooms
- Data Centers
- Automotive Sites
- Oil Production
- Food Processing Industry
- Power Stations
- Chemical and Pharmaceutical Industry

Through their research and development, TROX was able to create chilled beams. These beams are not actually beams, however they are "finned chilled water heat exchanger cooling coils. These coils are capable of providing 200 to 900 BTUH of sensible cooling per foot of length and are designed to take advantage of the significantly higher cooling efficiencies of water."[3] Figure 8 shows the comparison of a typical air duct size to a water pipe used in chilled beams. As one can see, this will provide much more free space to work with if a water pipe was used instead of an air duct. "(Chris) Lawrence says the system can use a 1-inch-diameter water pipe to transport the same cooling energy as an 18-square-ince air duct."[4]

[3] (TROX Technik)
[4] (Washington Contractor)

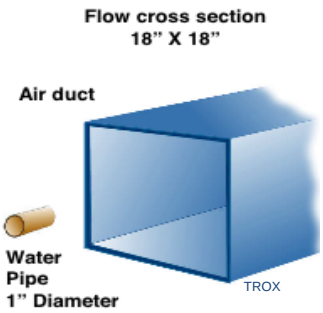


Figure 8: Comparison of Air Duct to Water Pipe

Through their work in a variety of buildings, TROX was able to create two specific types of chilled beams. The first is a passive chilled beam. Passive chilled beams do not use fans or other components, instead they re-circulate air. Figure 9 represents how the passive beam functions. Here one can see that the warm air naturally rises into the plenum space, causing it to flow through the coils. As it does, the heat is removed, causing it to fall back into the space since cool air is less buoyant then warm air.

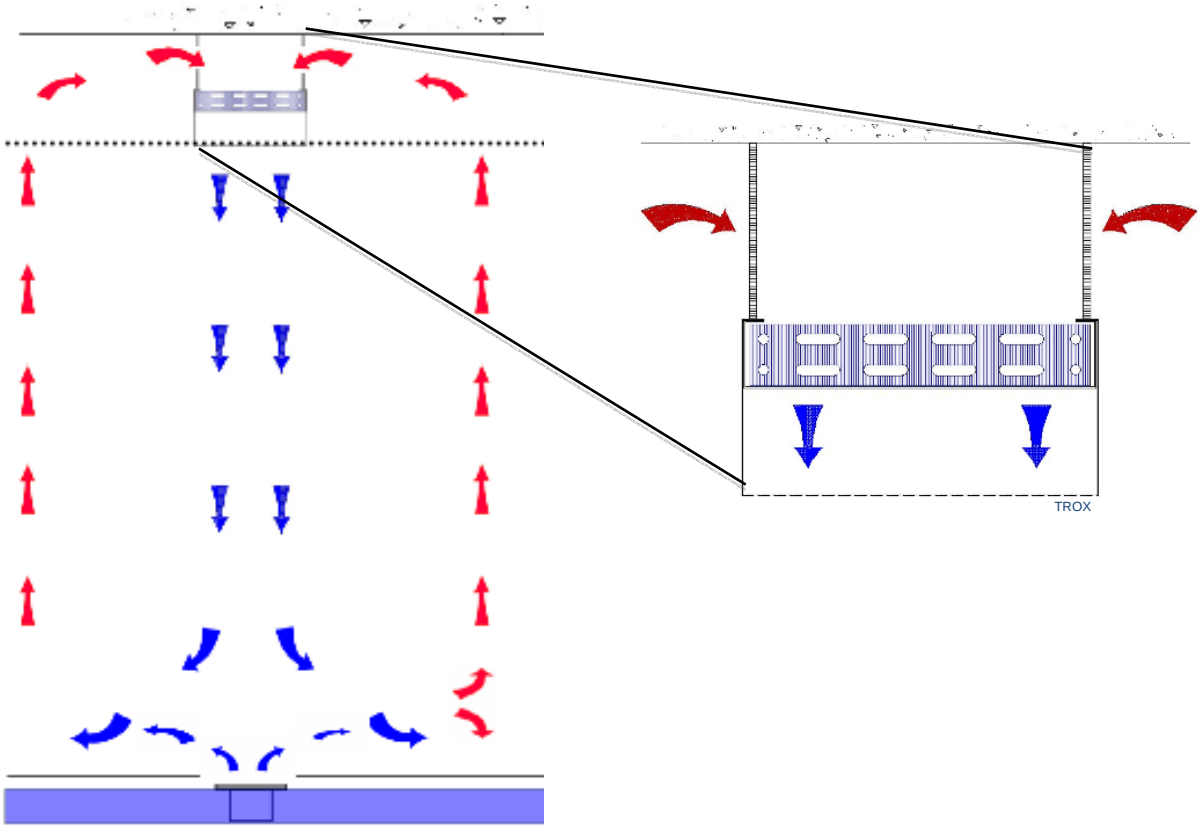


Figure 9: Representation of Passive Chilled Beams

The second type of chilled beams that TROX manufactures is called the active chilled beam. These beams are similar to the passive; however, they utilize a ducted air supply. This supply air is pretreated from a central air-handling unit and typically is injected through

nozzles inside the beams. As one can see from Figure 10, the nozzles supply the air, which then circulates throughout the space. After it heats up, just like the passive beams, the hot air raises and passes through the coils to be cooled and sent back into the space. "Because the active introduction of ventilation air magnifies the natural induction effect, active chilled beams are also commonly referred to as induction diffusers. This induction effect gives active chilled beams much higher cooling or heating capacities than pass chilled beams."[5]

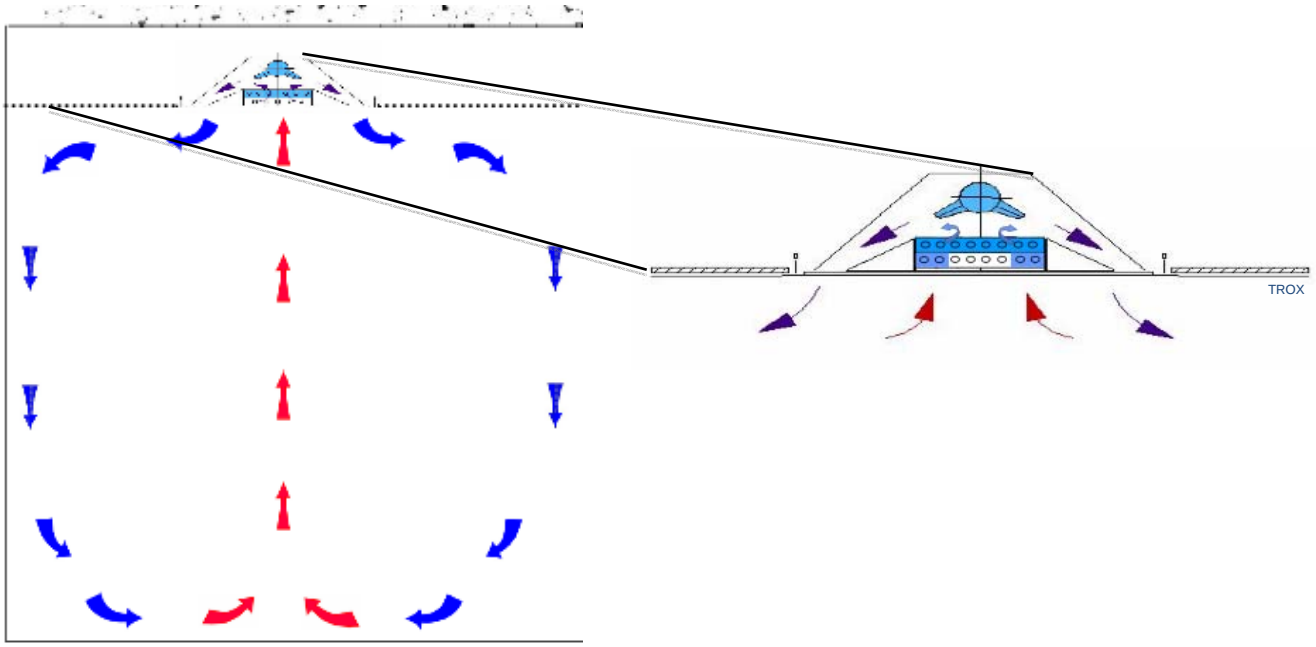


Figure 10: Representation of Active Chilled Beams

Similar to both passive and active chilled beams, TROX has incorporated building features in an integrated system known as multi-service chilled beams. These beams have numerous services built into them at the factory in order to arrive at the site in a "just-in-time" fashion. Figure 11 illustrates some of the services that can be included in the system including:

- Lighting fixtures and control circuits
  - Direct and/or indirect
- Public address speakers
- Occupancy sensors
- Fire and smoke sensors and alarms
- Passive infra-red detectors
- Acoustic insulation
- Sprinklers
- Fresh air supply
- Cooling and heating

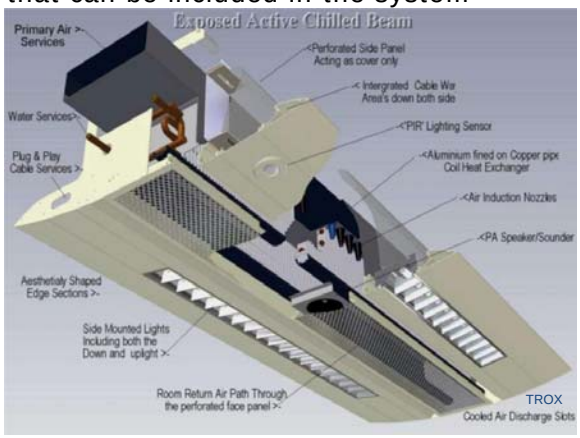


Figure 11: Diagram showing some of the services of a Multi Service Chilled Beam

One special feature about these beams is that the exterior frames can be customized in order to meet the owners' desires. Additionally, the services can be customized in order to meet the requirements that are in the design specifications. After these features are installed at the factory, the final steps are to ship them to the site, mount them, and connect all of the systems.

[5] (TROX Technik)

Since the services are factory installed, testing can be completed prior to the arrival on the site. Additionally, the coordination between trades can be reduced onsite since most of the services will be installed. Also, the units provide a common system for all the services and allow for easy maintenance and commissioning. Since the architects and engineers will be needed to decide the appropriate services, coordination will be established early in the design process. Figure 12 illustrates some of the multi-service chilled beams that have been implemented into numerous buildings.

Throughout research of the multi-service beams used in the United Kingdom, it was determined that "building construction time has been reduced by 25 to 30 percent."[6] Also, it is documented that "construction schedule reductions of ten to fifteen percent result in significant cost savings."[7] These savings have been found in the communication and utility services, sanitation services, equipment rentals, and insurance costs.

Figure 12: Examples of Multi-Service Chilled Beams

After the visit to TROX, Inc., further research was conducted. DAVIS, SmithGroup, and TROX provided publications that featured chilled beams. One outlined the advantages of having chilled beams installed in the building, the advantages are the following:

Advantages
Shorter construction periods
Reduced ceiling void heights
Easier installation (plug and play)
Quicker amortization of investments
Clear reduction of interfaces
Less maintenance and operating costs
Energy savings
More flexible refurbishment
Intelligent control through the connection to building BMS
Lower wiring costs
Higher operational security
Maximum flexibility of configuration and technology

Table 5: Advantages of using Trox air handling systems.[8]

[6] (TROX Technik)
[7] (TROX Technik)
[8] (TROX Technik)

After becoming familiar with what chilled beams were, David Varner from SmithGroup was interviewed in order to determine why they chose to use the new system in Constitution Center. The primary reason was because of the limited ceiling plenum. As one can see from Figure 13, they wanted to achieve an 8'-4" ceiling height, which would only give them 2'-0" to work with, which included the 1'-0" waffle slab. TROX worked with SmithGroup in order to customize the chilled beams to only be 7.5" high and 2' wide by 8' long. With this customization, they were able to give the owner's exactly what they were looking to be "consistent with what our commercial office market in downtown Washington prefers for Class-A space."[9]

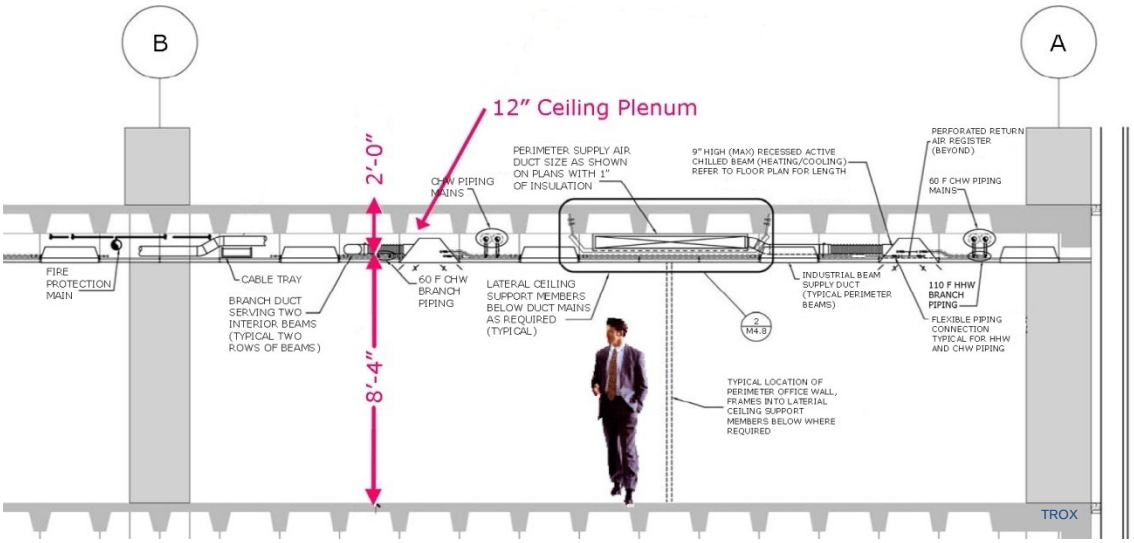


Figure 13: Diagram showing how the plenum space is utilized.

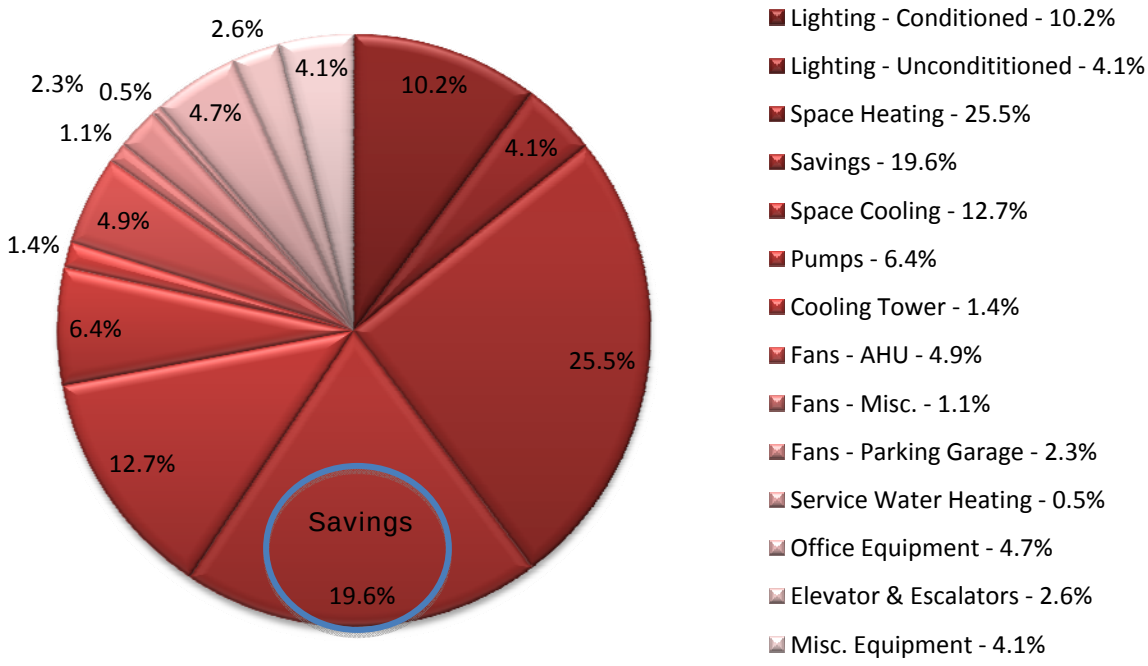
Another reason why SmithGroup chose to utilize chilled beams is because they "had the least impact to the usable office space on typical office floors."[10] Since the beams reduce the size of the ductwork, they are able to provide more area for the tenants in case they need to change the formation of their office space. Additionally, until they find a tenant, the chilled beams will not be installed in order to make sure they meet the tenants' needs.

Although there is a higher initial cost, the lower operating costs quickly offset them. While completing the design for Constitution Center, SmithGroup completed research on the energy usage of the building. This research was to show how much of a saving there would be if the chilled beam system was implemented into the building. As one can see from the graph below, there is a saving of 19.6% on energy usage.

[9] (Varner)
[10] (Varner)

Constitution Center Energy Usage

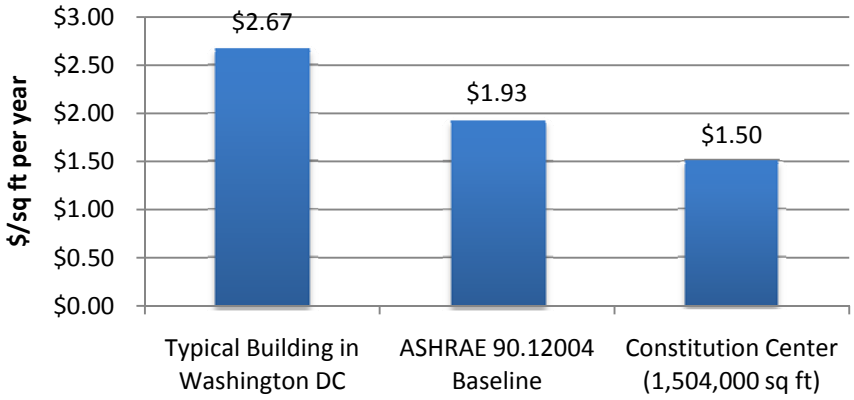
(according to SmithGroup's Research)



SmithGroup also did a comparison on the Energy Cost. The graph below shows how the cost per square foot per year would be $0.49 lower than the ASHREA standard and $1.17 cheaper than a standard Washington, DC office building because of the installation of the chilled beams.

Energy Cost Comparison

(according to SmithGroup's Research)



The fact that chilled beams are attractive and do not detract from the appearance is another reason for their installation into Constitution Center. These beams were designed to fit into the drywall ceiling; therefore will more than likely not stand out and be noticeable. Figure 14 shows the numerous configurations that chilled beams can come in.

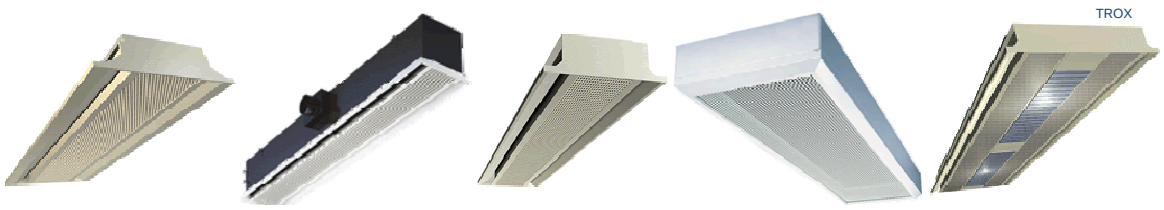


Figure 14: Examples of chilled beams

A concern of the ownership was that the finished office space "not be unduly compromised by innovative technology."[11] Working with TROX, they were able to design a product of high quality and that blends very well with the ceiling. Figure 15 is a rendering from SmithGroup that shows how the chilled beams will be incorporated into the ceiling grid and will not stand out very much. Another benefit of chilled beams was their superior acoustical performance. The reason for this performance is because they are not fan-powered making them very quiet. The "ownership believed that this might be one factor in attracting a major tenant to the building."[12]

Figure 15: Rendering showing how the chilled beams will be incorporated into the ceiling grid.

[11] (Varner)
[12] (Varner)

Although the chilled beams will not be installed into Constitution Center until a tenant is established, Pierce has familiarized themselves with them. Pierce Associates is the mechanical contractor on Constitution Center. During the bidding process, they initially familiarized themselves through information provided by both SmithGroup and DAVIS. They also used "the three beams referenced in the contract drawings as leaping off points to contact various manufacturer representatives on their beams and pricing…"[13] As they compared pricing, they learned the differences between them and were able to supply this information to the design team. Since the ownership wanted to use the chilled beams, Pierce was invited into the design discussion, which allowed them to have "a comprehensive understanding of the beams and their variety of capacities."[14] With this knowledge they have had the opportunity to pursue future work using the chilled beam technology. Additionally, they were able "to build an in-shop chilled beam mock-up to promote the product, and they have developed in-house information packets to assist in educating other members of the industry in acclimating to the beams emergence in our market."[15]

Specifically, Pierce used the following steps to familiarize themselves with the chilled beam technology:[16]

1. Worked with vendors to introduce ourselves to the products and to review sample beams
2. Met with Ownership and designers to assist in desired customization
3. Provided pricing from multiple vendors with differences clearly delineated
4. Attended Chilled Beam Symposium offered by Trox and Nassif
5. Finalized customized beam order and requested samples for inspection
6. Traveled to England to inspect Trox's production and storage activities

Along with the installation of the chilled beams, the mechanical system commissioning plays a large part in the construction. Commissioning is also a critical industry issue since most companies are now incorporating it into the construction process. According to ASHRAE, commissioning is "a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria."[17] There are several benefits in utilizing commissioning. First, the facility is both safe and helpful. Also, it optimizes energy use and the operating costs are reduced. Additionally, it ensures the operation and maintenance staff has proper orientation and training. Finally, commissioning is said to improve the documentation of the installed building systems.

Since Constitution Center is striving for a LEED Gold rating, it is required to have Fundamental Commissioning of the Building Energy Systems for the Energy & Atmosphere LEED points. In order to achieve this point, the project team must:

1. Designate an individual as the Commissioning Authority (CxA) to lead, review and oversee the completion of the commissioning process activities.
    a. The CxA shall have documented commissioning authority experience in at least two building projects.
    b. The individual serving as the CxA shall be independent of the project's design and construction

Figure 16: LEED Gold Award

[13] (Donaghy)
[14] (Donaghy)
[15] (Donaghy)
[16] (Donaghy)
[17] (WBDG Project Management Committee)

management, though they may be employees of the firms providing those services. The CxA may be a qualified employee or consultant of the Owner.
   c. The CxA shall report results, findings and recommendations directly to the Owner.
2. The Owner shall document the Owner's Project Requirements (OPR). The design team shall develop the Basis of Design (BOD). The CxA shall review these documents for clarity and completeness. The Owner and design team shall be responsible for updates to their respective documents.
3. Develop and incorporate commissioning requirements into the construction documents.
4. Develop and implement a commissioning plan.
5. Verify the installation and performance of the systems to be commissioned.
6. Complete a summary commissioning report.

In order to meet these requirements, DAVIS has divided Constitution Center into four phases for the commissioning:

- Phase 1 - Hot Water System
- Phase 2- CHW/CW & North AHU system
- Phase 3 - SW AHU System, Fuel Oil System, Emergency Power System, and Power Monitoring System
- Phase 4- SE AHU System, FA System, BMS System, and conclude with Endurance Period

Although the chilled beams are not being installed until a tenant is selected, research was conducted on what needs to occur for the commissioning process. First, the pipe work needs to be cleared of all the air that may be trapped in the water circuit. This can be done by pushing water through the system, using vents that are located on the header of the coils inside the beams. After this is complete, measuring and balancing valves will be adjusted in order for the chilled water flow rate to be at the designed valve. Another way to test the system is by checking the airflow rate by measuring the static pressure of the pressurized entry plenum. After this, it needs to be compared with calibration charts provided by the manufacturer. The final step is to connect a measuring gauge to the integral pressure tap in order to get a final reading.

While the commissioning of the chilled beams is fairly straight forward, other parts of the building systems will take more time. For Constitution Center, there are numerous steps that must be followed before each system is signed off. First, a factory representative performs equipment start-ups. Then they "continue with Testing & Balancing of the water, and air sides, then the controls subcontractor will put the system under control and check the sequence of operation for the equipment in the system"[18] Once these steps are finished, functional testing is completed by the commissioning agent, Facility Dynamics. During this testing, they verify that the equipment is operating properly and complete several other tests. Additionally, the review all of the completed paperwork is preformed to ensure that everything was documented properly. After this, if all of the equipment passes the test, then the system is signed off.

After the systems are signed off, the final functional testing is preformed. For this testing, the building management system controls the entire building. This testing typically takes about two weeks to test, once this is completed and it is approved, the final step can occur. The final phase is called the endurance period. The ownership has 30 days to operate the

[18] (Santos)

equipment and verify that it operates properly. Once this is proved to be successful, the commissioning of the building is complete.

In order to aid in the commissioning process, DAVIS uses a computer portal called ComIT. This program is used to "track deficiency items, post information such as schedules, submittals, and start-up forms."[19] Additionally, all of the functional tests are documented on the portal.

Although the survey that was sent to industry members did not have very many people complete it, several things were learned from performing the research. The first is that all of the companies utilize commissioning on their projects. Additionally, that only half of them have full time staff that completes the commissioning. When asked what specific programs are used for commissioning the only response was that they used formats from the Building Commissioning Association. In order to make commissioning easier, two topics were discussed. First, "identify the commissioning needs and program requirements early in the design stage so all team members can understand and set their strategies to meet the project goals." Additionally, "Make sure all parties know what is required for commissioning as soon in the project as possible (Communications is key)."

Outcome

After completing the research on chilled beams, it is recommended that a multi-service chilled beam be used in Constitution Center. The reason for this recommendation is because it has been proven that both the construction costs and schedules can be reduced with the additional of multi-service chilled beams.

Additionally, it was learned that if there is a full time staff member on site assisting with commissioning it is easier to stay organized in order to meet the requirements. Also, it reiterated that communication is the key to having commissioning successfully be completed.

[19] (Santos)