TITLE

Lessons Learned in Commissioning of a High Technology Data Center

INTRIDUCTION

The Stephen P. Teale Data Center is a State of California department within the Business, Transportation and Housing Agency. Teale is a leader in information technology providing quality services enabling State agencies to better serve the people of California. Teale provides 250 public sector organizations with a wide array of information technology services including:

- Support hardware and software for large mainframe systems
- A Statewide telecommunications network
- Specialized services such as Supercomputer and Geographic Information Systems
- LAN and Network design

In March of 1996 Teale issued a Request for Submittal (RFS) to design and construct, per State specifications for a fixed price, a new data center. The center was designed to exclusively house computerized data processing operations with a large central plant; uninterruptible (UPS) and standby power systems, administrations and staff offices. The center consists of 13,935 net usable square meters (150,000 square feet) of space, with 4,645 square meters (50,000 square feet) of access flooring supporting computer systems.

At the start of construction we were retained by the construction manager to commission the electrical and mechanical systems of this data center. The goal of commissioning was to document the design intent and basis, assure equipment was installed correctly, verify equipment and system performance, train the operating staff and institutionalize all documents. Our efforts at the State of California's Stephen P. Teale Data Center proved difficult at times, rewarding at others, but ultimately successful.

AUTHOR NOTE

Richard A. Greco is a principal of Einhorn Yaffee Prescott, Mission Critical Facilities Group, San Francisco, California.

The business and financial impact of a data center outage is enormous. Teale supports many critical activities; one example is the California State Highway Patrol. Consequently, disruption to this client has the potential of placing an officer's life at risk. Hence, the term "mission critical" has been applied to this type of facility. We believe that commissioning should be a fundamental requirement during the construction of facilities such as these. In this particular case, we believe the commissioning process added extraordinarily benefit to the owner and will ultimately contribute to the long-term success of this facility. Additionally, our lessons learned will allow us to refine our process and deliver a better product in the future.

THE COMMISSIONING PROCESS

This project has some interesting design goals established by the owner. Those goals were: (1) the failure of any single component of the mechanical or electrical system could not impact the computer loads; (2) all equipment supporting the computer load must be able to be serviced and/or replaced without interruption to the computer operation; and (3) the central plant must be expandable without interruption of the computer operations. This is truly a 7/24 concept. Our job as commissioning agents was to assure that the installed systems met these design goals.

Our commissioning process was performed by:

- Review of existing documentation
- Meetings with design/build teams on a weekly basis
- Development and execution of prefunctional checklists
- Development and execution of functional checklists
- Development and execution of integrated system tests
- Coordination of staff training by vendors and design professionals
- Delivering a commissioning plan including all documentation to the State

First let's look at the documentation of the design intent and the basis of design. The State had issued their basic design intent in the Request for Submittal (RFS). Initially documenting the design intent was a matter of extracting information from the RFS, clarifying it, and inserting it in the commissioning plan. Many changes were made during the design/build process that needed to be incorporated in the commissioning plan. Additionally, even though the design intent was defines the design/build team often changed the basis of design during the construction process. Practically speaking, these changes where made on a daily basis, but the design/build process did not lend itself to the rigor of detailed documentation in timely fashion. It proved to be very difficult to obtain written substantiation of these changes from the design professionals and vendors. Finally, this information was obtained when the owner threatened to withhold final payment.

Several key design intent and basis of design examples are:

- RFS design intent: "This facility is required to function 24 hours per day, seven days per week. All systems should be provided with redundant components such that the failure of a single component will not inhibit the capability of the mechanical system to support the operation. In addition, redundant components in the system must be designed to eliminate any single point of failure. All equipment must be able to be serviced and/or replaced without interruption of data operations. Central plant systems must be expandable without interruption of data operation."

- During the course of commissioning, the Building Automation System (BAS) and fuel oil delivery system interface failed the criteria established in the RFS (#1. above). Testing disclosed that failure of power and/or data communications to the BMS panel controlling the fuel oil delivery system caused all pumps to stop running. The BMS was reprogrammed and the basis of design was changed to read: " If there is a failure of electrical power or data communication to the Building Automation System (BAS) controlling the fuel oil pumps, all fuel oil pumps will run." Though this might sound innocuous, the end solution, with proper documentation (the letter from the mechanical engineer assuring that running all pumps simultaneously would not be detrimental to the pumps or the system), took many months to obtain.

- Also affecting the basis of design was the elimination of the requirement for input isolation transformers feeding the Variable Frequency Drives (VFD's). Commissioning revealed that the required isolation transformers were not installed. The owner negotiated with the design/build team and accepted the VFD's as installed. Then appropriate documents supporting this agreement had to be obtained and added to the commissioning plan.

The next step in the process was to assure that equipment was installed correctly. Our methodology was to develop, equipment specific, prefunctional test forms and complete those forms during site inspections. There was significant resistance to these inspections. Resistance manifested itself in two ways: (1) refusal to collaborate in the development or review of the test forms, and (2) scheduling of inspections for equipment and systems that were not complete.

Through persistence and owner's pressure, we did however manage to break through this resistance and implement our requirements. The issues discovered during the process confirmed our belief in the need for these requirements. Following are a sampling of items that were identified during the prefunctional inspections:

1. Supply fan VFD's were installed in the fan motor compartment of Heating Units H1 & H2 causing restrictions and turbulence at the fan inlets.

2. Variable Air Volume (VAV) terminal box VAV3 was installed upside down.

3. Incorrect motor heaters installed on fan/coil units FCU1 & FCU2.

4. Input isolation transformers were not installed on any of the VFD's.

5. Condenser water circuit-balancing devices were missing on each cooling tower circuit.

6. Make-up water to cooling towers was installed through a single pressure-regulating valve (PRV), thereby creating a “single point of failure.”

7. BMS Graphic User Interface display does not agree with actual floor layout of Computer Room Air Conditioning Units (CRAC).

8. AH5 chilled water valve installed backwards.

All of the following were corrected, or accepted as installed by the owner. If the commissioning process not taken place, these problems would likely remain today.

The third and most important step was the testing of equipment, systems, and interactions between systems. Virtually all of the items identified had the potential for catastrophic effects on the continuous operation of the data center. Following are major issues discovered during the system tests:

1. AH1 & AH2 did not meet design airflow requirements.
2. AH1 & AH2 Hand-Off-Auto (HOA) switches did not control unit dampers and chilled water valves; they only start and stop the unit fans.
3. CRAC Units 1-4 motor overload relays did not work.
4. Chilled water pumps CHP5 & CHP6, which were wired to UPS power, failed during power transfer because local BMS panel was powered by non-UPS power.
5. Several critical systems failed to operate when power or data communications from BMS panels were lost.

DISCUSSION

We have found that the concept most difficult to understand, and most important to test, is the interaction between the electrical and mechanical systems. For example, a mechanical engineer typically does not understand the maintenance requirements of a circuit breaker. Industry and professional standards recommend that circuit breaker testing be performed every three years. Circuit breaker testing requires the circuit breaker to be removed from service. How does this impact the electrical system? If the circuit breaker provides control power to a BMS, and the BMS control panel's power is "daisy chained," this could have enormous consequences. Since typically during the design process electrical and mechanical engineers don't have detailed discussions on their respective systems interactions, there is a risk element introduced into the process. Someone that is knowledgeable in the interactions of these systems needs to guide this process.

So what were the lessons learned?

1. At the onset of a project everyone will agree in principal that commissioning is a good thing and they intend to cooperate fully.
2. Reality sets in. Everyone has a different vision about his or her roles and obligations during the commissioning process.
3. The engineers and contractors realize they have not budgeted sufficient funds to meet the requirements.
4. The commissioning process is viewed as an impediment to the schedule.
5. Builders hope that you will go away, by benign neglect.

How to improve.

1. The owner should retain the commissioning agent directly.
2. Thoroughly detail the commissioning requirements in the specifications.
3. Discuss the commissioning requirements of all parties, as early in the process as possible.
4. Specify and enforce damages that result from not meeting the commissioning specifications.

5. The commissioning agent should budget enough money to spend a great deal of time at the job site. A minimum of two days a week.
6. The commissioning agent should differentiate between what he has the authority to enforce versus what has value to his client.
7. Be persistent.

And finally, near a project's end, there is great difficulty in retaining the interest of the design and construction team. Their interest now lies with the next project. The institutionalizing of accurate "as built" documents and proper training is essential to the successful operation of any facility; don't walk away with out them.