

BENEFITS OF PROSPECTIVE COMMISSIONING FOR CONDOMINIUMS IN CHICAGO

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Summary Building commissioning certifies that a building performs as it was designed and intended; ensuring that systems, both static and dynamic, work together in an efficient manner. If it is not completed as part of the construction process, mechanical equipment problems can occur, such as the need to replace hot water boilers because of improper operation, and of pumps due to bearing failure. By commissioning condominiums prospectively as part of the building process, rather than retrospectively or not at all, many building performance and maintenance issues can be identified and resolved before occupancy; safety and comfort can be maintained, and litigious action can be avoided.

Keywords: prospective commissioning, condominiums, case study

INTRODUCTION

Building Commissioning ensures that a building performs as it was designed and intended, meeting the operational and occupant needs, through verification of procedures, testing of performance, and training in equipment operation. This commissioning can be prospective or retrospective depending on the timing of the involvement of a commissioning agent. There has been a boom in condominium construction projects in the Chicago and other major metropolitan cities due to empty nesters and young professionals moving to the city. Often construction booms, with quick turn-around projects, short time lines, and limited first costs result in lack of commissioning involvement at an optimum stage in the construction process. Currently, less than 5 percent of multi-family (5 or more) residential buildings are commissioned [1]. Although the least amount of construction dollars are spent on the residential market, it also has the least amount spent on commissioning, as shown in Table 1. Commissioning costs for buildings can range from 0.5-2 percent for new construction, and 3-5 percent for existing construction [1], and encompasses many building systems, including building envelope, cooling equipment, air distribution, indoor air quality, combustion appliances, controls, and other electrical equipment such as lighting and pumps [2]. By taking a proactive approach, such as prospective commissioning of condominium complexes rather than a reactive approach, costly repair and replacement of poorly functioning equipment can be prevented

and cash outlay from tenants post occupancy for such repairs can be mitigated.

Table 1. Commissioned Construction as Percentage of Construction Dollars [1]

	Residential	Institutional	Industrial	Commercial
% Commissioned	4.8%	12.2%	9.5%	8.0%

BACKGROUND

The assessed Condominium Complex (CC) was designed, rehabilitated, and constructed between 1996 and 1999. The CC is made up of a Loft Building (LB), comprised of three buildings six stories in height, originally built in 1910 of heavy timber construction with full basements; and a Tower Building (TB), built in 1999 of reinforced concrete and twenty-four stories in height. The CC consists of 232 condominium units: 108 in the Loft Building and 124 in the TB. The LB includes a basement containing parking, storage, and mechanical rooms; first floor retail space, lobbies and building support areas; and five residential floors. The TB first floor encompasses lobbies, retail space, storage, garage space, mechanical and electrical rooms and a loading dock; five floors of additional garage space; seventeen residential floors; and exercise, meeting, and mechanical rooms on the top floor. Each building, the LB and TB, are conditioned by two separate systems and system types. The LB has decentralized heating, ventilation and air-conditioning (HVAC) equipment that is the responsibility of the condominium owner, while the TB has a centralized HVAC system for the entire building.

Approximately one year after the building was turned over to the Homeowners Association (HA), many issues related to the design, construction, and maintainability of the CC were questioned by management staff and the residents. The management staff of the building had no “as-built” drawing to consult as they addressed resident complaints, which limited their effectiveness. Design issues that surfaced included the tower building HVAC system not meeting heating and cooling loads during the shoulder months (April through May, and September through October), and water from an adjacent alley channeling water regularly into the offices and hallways in the building. Perhaps the most egregious design issue was the failure of the domestic water boilers due to tube fouling. The fouling was caused principally by back-drafting within the boilers themselves; not only a mechanical equipment maintenance issue but one that affected the life safety of the residents.

The HA tried to negotiate with the developer to try to recoup costs due to the poor design and construction practices of the general contractor and subcontractors. The developer was resistant to negotiation, therefore the HA built a case against the developer. To that end, they required third party documentation of design compliance issues before entering into litigation. After

an unsuccessful experience with HVAC contractors who repaired the TB chillers, the HA decided to hire professional engineers. Commissioning of the TB water boilers ensued, which included a retrospective facility needs assessment of the remaining mechanical and electrical systems.

INITIAL CONDITIONS

As there are no as-built drawings or specifications for equipment, it is unclear specifically how the systems were designed to operate or are controlled, including the humidifiers, exhaust fans, and carbon monoxide (CO) sensors for the garage makeup air handling units in both buildings. Several drawing sets and partial sets were provided, which detailed some of the piping, heating, air-conditioning, and ventilation specifications for the TB. Although there were limited drawings available for the TB, there were no drawings available for evaluating the LB. This made the process of assessing and maintaining the CC more difficult and evaluating the maintenance and operation of the building more complicated.

The common areas of the LB are conditioned by residential grade gas furnaces with cooling coils and remote air-cooled condensing units, while two sidewall exhaust fans and a direct-fired gas make-up air unit with override CO detectors controls take care of the garage ventilation. The residential floors are heated by a gas-fired furnace with supply air ducted to each room; air-conditioning is provided through remote air-cooled condensing units located on the roof, with direct-expansion cooling coils located within the furnaces, and humidification is provided by a duct-mounted humidifier. The roof houses the condensing units for the condominium units, furnace flues, and exhaust fan discharge ducts for kitchen, bathroom, and clothes dryers. Additionally, three-combination gas heating and electric cooling make-up air units (one 7.5 ton, two 8.5 ton) to condition the common corridors, and a fire pump and controller for fire suppression, are located on the roof of the LB.

The common areas of the TB on the first floor are conditioned by incremental electric heaters and a direct expansion fan-coil unit. The garage levels are ventilated with wall mounted exhaust fans and outside air intake louvers, and incorporate CO sensor override controls, while heat is provided by hot water unit heaters to keep water piping systems from freezing. The residential units are heated and cooled by vertical fan coil units located around the perimeter of the units and building. A fourpipe system, using two independent water distribution systems, one dedicated to hot water and one to chilled water, allow heating and cooling year-round, controlled by a thermostat. A make-up air unit supplies air to the building to replace air exhausted from various exhaust systems (kitchen, toilet, and clothing dryers) at each floor level through a supply riser adjacent to the common corridor. The top floor meeting and exercise rooms are conditioned by the same type of four-pipe fan coil unit, while air is ducted to supply air

diffusers located throughout these spaces. The mechanical room contains the main heating and cooling equipment, including water boilers, hot water pumps, chilled water pumps, make-up air unit, and domestic water heaters. The water boiler provides hot water for the heating loop, circulated by hot water pumps, while two air-cooled chillers provide chilled water for the cooling loop, circulated by chilled water pumps. The air-cooled chillers, combustion air intakes for the boilers and domestic water heaters, and flues for the boiler (four) and water heater (one) are located on the roof of the TB.

ISSUES, IMPROVEMENTS, PROACTIVE MAINTENANCE

The main areas of concern for the CC were the domestic hot water system, pump applications, chillers and boilers, though there were several other areas of concern that were identified. These recognized problems ranged from current maintenance practices, to improper installation and operation of equipment, and city code and safety issues. Table 2 provides a summary of the types of problems identified.

During the retro-commissioning of the domestic water heating system in the TB, it was discovered that the air intake area required by the City of Chicago Building Code and the National Fuel Gas Code (NFPA 54) was 840 square inches, while the installed air intakes only measured 650 square inches. In addition, this intake was ducted up through the mechanical room roof to a curb mounted intake hood. This hood was located tight to the parapet wall on the backside, tight to the boiler combustion air intake duct on the right side, and the bottom of the opening 12 inches above the roof. With this installation, during the winter months this area can quite easily fill up with snow, burying the intake and not provide any combustion air for the domestic water heaters or the water boilers used for heating the building. Raising the outdoor air intakes above the parapet wall was not approved by the HA for aesthetic reasons. Therefore, the domestic water heaters were retro-commissioned to use an induction fan on the heater exhaust stack to maintain flow throughout the boilers. The pumps associated with the domestic water pumps failed in the TB within the first two years of operation. In both the TB and LB, the fire pumps failed within the first two years due to bearing failure. Both of these issues were a direct result of improper maintenance on the pumps, effecting the safety and comfort of the condominium owners and occupants.

The TB chillers were retrofitted with a “low ambient kit with heat trace” to allow operation of the chillers at low loads (winter months). This was required as residents on the south and west sides of the building required cooling to meet their comfort requirements during shoulder months. This was not addressed during the design of the system or the selection of the equipment. One of the two chilled water pumps (40 HP) must be operational full time to eliminate the chance

freezing the chilled water piping, which is a waste of energy. The HA opted for this alternative rather than using a chilled water loop with glycol.

The two central plant water boilers in the TB were operated at the highest set point for three heating seasons. At the end of the third heating season, both boilers needed re-tubing. The water heater room in the LB did not contain auxiliary room heaters or have a system of motorized dampers installed, interlocked with the hot water heater burners. Therefore, when the water heaters are not operational, or in the event of an extended power outage, cold air can infiltrate the mechanical room and freeze water piping. In addition to dampers, a unit heater was recommended to be installed to protect equipment and piping from freezing and maintaining the room temperature during the winter months.

The standard package rooftop cooling units were not constructed or intended for 100% outside air (make-up air) applications. The HVAC equipment, comprised of these rooftop units, installed for meeting the conditioning and ventilation requirements of the common areas in the LB was not optimal for the intended use. Furthermore, it was discovered that there was heat stratification between the upper and lower floors. The thermostats for these units were located on the sixth floor of their respective buildings. However, visual inspection indicated that there were no air-balancing dampers located at the branch take offs at each floor. Without these dampers, adequate air balancing cannot be achieved resulting in the temperature differential between floors. Design modifications to these issues that were recommended to the HA include: replacing units with more appropriate models, redesigning the duct system to incorporating return air into the systems and/or modifying the control strategy to maximize comfort within the building.

Other design and construction issues discovered in the TB included: a make-up air unit that was designed for 21,600 CFM had actual measured airflow of 23,607 CFM, wasting energy; a fan coil unit serving the hospitality and exercise rooms was designed for 3,000 CFM, although actual conditions indicated 2,457 CFM, 20 percent short of capacity; at least two exhaust fans were not balanced; and design flow for several pumps documented as 130 GPM, had balance reports indicating that these pumps were flowing from 200 to 210 GPM, an excess of approximately 58 percent. There were no hydronic test and balance reports for the chilled water pumps, chillers, or piping. Additionally, emergency egress lighting was missing from both the LB and the TB. This is against local codes and is a safety issue. It was estimated that the HA required at least twenty fixtures to bring the building up to code.

In addition, the HA should have received documents with respect to the operations, control, and maintenance of the building's mechanical systems prior

to occupying the buildings. These documents are important in understanding the building systemically and holistically. The following is a list of documents owed to the HA: a complete set of “As-Built Drawings” from each contractor who participated in the construction of the building; an explanation of the controls currently used for the HVAC, domestic hot water and fan coil systems; a “Sequence of Operations” for all equipment; and a valve tag list from the HVAC contractor to locate all riser shut off valves to fan coil units (maintenance issue). In addition, the plumbing contractor should provide a valve tag list for all domestic hot and cold water.

Miscellaneous design and construction issues discovered while assessing the LB included: a 24 X 8 exhaust duct in the LB, providing the code required exhaust air for the sales room, was capped within the garage area; outside air intake duct providing cooling/make-up air for the electrical switchgear room was capped within one of the garage areas[3]. Several combustion flues (water heating and residential furnace) have not been installed in accordance with the City of Chicago Building Code and the National Fuel Gas Code (NFPA 54), requiring that all chimney termination adjacent to walls, extend a minimum of two feet above the top of the wall. Residential furnace flues and duct furnace flues in the LB are located as close as 3 feet from the outside air intakes for the three make-up air units for the LB, which is not in compliance with the City of Chicago Building Code requiring all intakes to be a minimum of fifteen feet from any flue or exhaust air outlet. Additionally, visual observation of the pipe portals on the LB roof, which have been installed for the piping and electrical conduits for the air conditioning equipment appear to be in poor condition and a number of openings have the counter-flashings askew, and in need of repair and caulking.

Table 2. Summary of Issues, Costs and Solutions

Building	Identified Problem Type	Retrofit Cost	Avoidable	Solution
TB	DHW Combustion Issues	High	Yes	Commissioning
TB	Failed DHW Pumps	High	Yes	O & M Training
TB	Failed Fire Pumps	Medium	Yes	O & M Training
TB	Chiller Retrofit	High	Yes	Commissioning
TB	Premature Boiler Failure	High	Yes	O & M Training
TB	DHW Freeze Protection	Low	Yes	Commissioning
LB	Failed Fire Pumps	Medium	Yes	O & M Training
LB	HVAC Balance/Controls	High	Yes	Commissioning
TB & LB	Missing Emergency Lighting	Medium	Yes	Commissioning
TB & LB	Air and Water Balancing	Medium	Yes	Commissioning
TB & LB	As-Built Drawings	n/a	Yes	Commissioning
TB & LB	Operator Training	Low	Yes	Commissioning
TB & LB	Code Issues	Medium	Yes	Commissioning

RECOMMENDATIONS AND CONCLUSIONS

Numerous operations and maintenance issues including a few life safety issues were discovered at the CC as a direct result of the lack of coordination or cooperation between the HA and the property developer during the final phases of construction. Many of these issues potentially could have been alleviated through prospectively commissioning of the building, by identifying and addressing the potential issues and incorporating maintenance-related recommendations into an operation and maintenance (O & M) manual to be used by the HA and associated building management firms hired by the HA during the life of the building. A summary table of the issues identified, their retrofit cost, the ability to avoid the cost and the solutions are identified in **Table 2** Prospectively commissioning the buildings such as the CC has the potential to reduce operating costs, improve operation, address local code and safety issues and increase the overall efficiency of the building.

However, since commissioning was not employed and nobody was protecting the rights of the residents of the CC, all of the costs associated with retro-commissioning mechanical equipment, repairs due to poor or no equipment maintenance and bringing the building up to local code compliance were incurred by the residents of the CC through frequent increases to the monthly association fees. The total predicted cost to rectify all the issues identified in this report was approximately \$260,000 (2001 dollars). The actual cash outlays in the first year following the study were \$120,000. This course of events angered the residents and litigation ensued. As of the writing of this paper, the litigation between the developer and the HA has not been settled.

In this case, the developer had little involvement with members of the condominium association, and the condominium association had little to no consistent contact with the developer prior to or post-occupancy. As often a condominium association cannot be formed until a certain percentage of condominiums are sold, some issues arise from this situation. This is problematic because the rights of the HA should be protected throughout the process of turning over the CC to the HA and property management. It is recommended that in order to alleviate this issue, a representative of the condominium association or management agent working on their behalf be retained to protect the interests of the CC residents.

What should have been part of the prospective commissioning of the building, but was completed as part of this retro-commissioning and facility condition assessment, an operations and maintenance manual was developed for the maintenance staff. This manual was designed to provide information and training

to whoever would be maintaining the systems with the building. Included in the manual were all gathered information from the contractors and developer, and information gathered during the facility assessment. As equipment is replaced, repaired, or controls and operation altered, the manual should be updated as the equipment within the CC changes during the lifetime of the building.

SUMMARY AND LESSONS LEARNED

The commissioning process should assist in determining how to optimally operate the building to improve overall performance, system specific operation, and life cycle, while also addressing compliance and maintenance issues. In assessing the CC, many of these items were attended to, an operation and maintenance manual created, and a plan of action for repairing and improving building system operations created. By taking a proactive approach and incorporating prospective commissioning condominiums as part of the building process or retro-commissioning existing buildings, many building performance and maintenance issues, as well as litigious action, can be avoided. Training of the management and maintenance staff and developing an operations and maintenance manual are key aspects of a proactive approach, and the amount of money required to operate and maintain the building can be alleviated while maximizing the life cycle costs of all the mechanical and electrical equipment within the building and ensuring tenant comfort.

Further work includes the investigation of how condominium complexes can be constructed, where the risk is mitigated to the owners and the onus is on the developer to construct and hand over a working building that has included commissioning throughout the design and construction process. This issue becomes particularly important when management groups and/or occupants of these condominium complexes have a higher turn over rate.

REFERENCES

1. **National Energy Management Institute (NEMI) and FMI.** Building Commissioning Market Analysis. November, 2001.
2. **Wray, C.P., Piette, M.A., et al.** Residential Commissioning: A Review of Related Literature. Lawrence Berkeley National Laboratory, Energy Performance of Buildings Group. March, 2000.
3. **Boland & Associates, Inc.** Conversation with Engineer. August, 2002.