EXPLORING THE IMPACT OF TECHNOLOGY ON HVAC COMMISSIONING PRACTICES

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Abstract
The primary method to ensure that systems are operating as designed is heating, venting and air conditioning (HVAC) commissioning, painstakingly stepping through a sophisticated process of running, testing, and verifying that the various components move, react, and respond in a way that fully utilizes the equipment and meets the environmental needs of the building occupants. The significant positive impact of technology on HVAC Commissioning is undisputed. Little research exists, however, on the field challenges and resource implications of rapid changes to HVAC components and control software for owners and contractors. This research explores solutions to the challenges that arise when advanced HVAC controls technology becomes burdensome and disadvantageous. The role of HVAC Commissioning within the very real constraints of federal mandates for energy use and the trend to convert from fossil fuels to “clean” fuels cannot be overlooked. The “trade-offs” encountered are substantial when highly sophisticated control sequences are utilized with HVAC equipment in the private sector and government facilities. The consequence of the lack of skilled technicians clearly has the opposite effect on utility savings. This research validates the effect of the practices of skilled professionals that make up the commissioning team to ensure that building HVAC systems perform as intended by the designer and building owner. Data was collected from commission professionals in construction, research and design fields. Qualitative data analysis yielded six primary themes that represent sub-themes that were repeatedly described as challenges, positive benefits or obstacles to progress. Thematic analysis of the primary themes peeked beneath the surface of the interview narratives to ask what is the structure that supports the major themes. Looking for broader implications and consequences, interpretation led to three proposed action topics. Recommendations are offered to improve commissioning practices by solving the implications of technology on human resources and developing partnerships with the industry that promote HVAC systems’ efficiency. Finally, a compilation of industry experts’ perspectives is laid out for re-aligning HVAC equipment, software, and controls technology to fully utilize the vast opportunities for utility savings, equipment longevity, and occupant comfort.

Keywords: HVAC, Commissioning, Cx, ASHRAE, Energy Efficiency, DDC

1. Introduction
Commissioning (Cx) is a plan (road map) consisting of steps and procedures to increase the reliability of any building system by designing, testing, and checking interfacing components to ensure the systems operates as intended by the designer and as requested by the owner. A commissioning process may be applied to any system -- electrical, mechanical or the building as a whole system. While it is most common for commissioning to be performed during new construction, it can be done at any point in a building’s life. Existing building commissioning (recommissioning) is a type of commissioning that is not done during new construction. Rather, recommissioning is done after the building or system has been functioning for years and seeks to ensure energy savings and operational improvements last over time. It may be initiated as part of a preventative maintenance plan or when the building function changes or as a diagnostic tool to identify causes of excessive energy usage or a need to investigate that minimum ventilation standards are met in a medical facility.
Retro-commissioning process involves investigating a building's equipment and systems together after the facility HVAC equipment has been functional for months to years to understand and improve their operation. The facility owner/manager may have reported systemic operational problems since first occupation or issues that developed over the life of the building. A successful retro-commissioning means improved building performance with the addition of or fine-tuning of operations and maintenance procedures (O&M). Commissioning existing building systems has nearly unlimited potential for reducing the owner's energy consumption and increasing equipment life because it is a systematic process for improving an existing building's performance. The process will identify and allow implementation of relatively low-cost operational and maintenance improvements before an expensive loss of equipment occurs [1]. Ongoing commissioning combines continuous commissioning and monitoring-based commissioning (MBCx) and uses retro-commissioning techniques but adds the requirement for ongoing monitoring. Continuous and MBCx employ monitoring devices that collect energy use data based on equipment operation including hourly, daily, and seasonal energy use for the building. A departure from the energy use baseline then alerts the facility manager that the change might be an opportunity for improvements or repairs.

Monitoring-Based Commissioning or MBCX, is the newest technology for keeping buildings fit and equipment running as intended as an ongoing process. “MBCX leverages technology and innovative commissioning techniques to integrate energy management in a continuous fashion. Think of it as an ongoing process, wherein Monitor-Based Commissioning allows the commissioning agent to take a real-time look into building systems and operations, to fine-tune the system operations and identify areas that need improvement.” [2]. This research focuses on commissioning of Heating, Ventilating, Air Conditioning (HVAC) systems and explores HVAC commissioning as it has evolved with recent technological innovations in HVAC equipment as well as control/monitoring capability. The ability to remotely view and operate HVAC systems will be explored to establish the impact of HVAC Commissioning during initial construction and functional operation of buildings. Interactive access to HVAC equipment that allows visual real-time systems status, environmental setpoints, and trend reporting ability of remote creating lessons learned and recommendations from which corrective action and process revision can be implemented [3].

2. Literature Review

HVAC commissioning is a process that ensures that heating, ventilation, and air conditioning systems are designed, installed, and operated properly. It is a critical step in ensuring the energy efficiency, comfort, and durability of HVAC systems [4]. The commissioning process typically begins during the design phase of a project. The commissioning agent works with the architect, engineer, and contractor to develop a commissioning plan. The plan outlines the steps that will be taken to ensure that the HVAC system meets the owner's requirements. Commissioning of the HVAC systems often uncovers faulty equipment and mistakes that waste energy and adversely impact indoor air quality and comfort. Performance studies of schools' HVAC systems found a short payback of 1–3 year payback from the investment of thorough commissioning of HVAC systems often due to correcting faults associated with the HVAC equipment and control [4].

Once the HVAC system is installed, the commissioning agent conducts a series of tests to verify that the system is operating as designed. These tests may include checking the system's energy efficiency, verifying that the system provides the desired level of comfort and ensuring that the system is operating safely. If any problems are found during the commissioning process, the commissioning agent works with the contractor to correct them. Once the system is operating properly, the commissioning agent prepares a commissioning report. The report documents the commissioning process and the results of the tests. HVAC commissioning can provide several benefits to building owners, including reduced energy costs, improved comfort, increased system reliability, extended system life and reduced maintenance costs [5]. The cost of HVAC commissioning varies depending on the size and complexity of the project. However, the benefits of commissioning can far outweigh the costs. HVAC commissioning
is a wise investment that can help building owners save money, improve comfort, and extend the life of their HVAC systems [5].

In the connected information age, buildings are capable to be remotely monitored through connected devices and monitoring equipment [6]. With the rapid expansion of the Internet of Things (IoT), a plethora of new devices have been introduced, tested, and integrated into building and HVAC applications. These devices include low-cost and versatile sensors, smart thermostats, and occupancy sensors [6]. Studies have shown that use of connected buildings can potentially save building owners savings in energy costs [7]. Commissioning of these connected buildings requires a new forms of expertise to maximize the potential energy savings and performance efficiency [3]. This research explores the evolution of these new technologies and their impact on the commissioning process.

3. Research Methodology

HVAC commissioning experts and construction professionals were individually interviewed to capture the state of play, and the future of HVAC Commissioning by asking the following questions to reach the objective of the study:

- Gain an understanding of the challenges and benefits presented with innovative HVAC equipment commissioning processes to all the stakeholders in the construction lifecycle.

- Develop specific recommendations from research data to portray the present value and future benefit of online monitoring and control of Monitoring-Based Commissioning or MBCX.

The qualitative research method of conducting semi-structured interviews allows for discussion and follow up questions for a more thorough and nuanced understanding of the interviewees’ experiences [8]. The insights developed from these interviews will be used to better understand HVAC commissioning as it relates to the design, construction, and occupancy of a building’s life cycle. The literature review did not reveal information about the difficulties and high cost of the HVAC commissioning process. Nor did the literature speak to the common pitfall of HVAC commissioning delaying construction projects prior to building turnover. Interviews are important and vastly different than surveys. Surveys are predetermined questions that have minimal freedom and space for the surveyor to answer. While interviews usually have predetermined questions as a guide, the interviewer can change and adapt to the interviewee which allows them to continue with more detailed answers or to follow through on a topic that was not presented in the questions. The transcribed interviews were analyzed to find common themes that support valid recommendations for HVAC commissioning processes refinement.

3.1. Interview Questions

Interview questions were developed to gain a better understanding of the interviewees’ experiences with HVAC Commissioning. Areas of special interest include determining the interviewees roles, experience levels and observations about the development of HVAC Commissioning practices from 1990’s to present as well as their vision for the future. Each interviewee was asked to describe their experiences/roles with HVAC commissioning and number of years’ experience in the industry so that a broad base of perspectives would be represented in the research data. After the introductions, the interviewer asked for general personal observations about the evolution of HVAC commissioning in their experience. The questions become more focused on the aims and objectives of the research topic with the follow-on questions about what primary technology advances in equipment or controls have expanded/affected HVAC Commissioning. Questions were formulated to find out if and why technology is helpful and probe into the challenges and potential solutions to technology problems encountered. The interviewer questioned how HVAC commissioning affects facility energy efficiency and whether there are negative impacts to owners. One of the final questions is intentionally open-ended inquiring as to the interviewee’s opinion about the biggest challenge with HVAC commissioning. Lastly, participants were asked to share their thoughts about benefits and challenges of ongoing and re-
commissioning. Participants were selected based on their past and current roles in the HVAC Commissioning Industry and was invited by e-mail with a follow up phone call to describe the focus of the research questions. Survey participants will each be provided the same format with the same questions for consistency and transparency. This study interviewed 12 professionals to ensure adequate data collections can be used as this section for qualitative analysis.

4. Results

Content analysis and thematic analysis of the data was performed to understand the feedback from interview data. In this paper, only thematic analysis of the interview data that was performed to identify the main themes in the is presented, due to space restrictions. During the effort of reading, coding, and grouping the data, three unique themes emerged. These main themes and related issues are presented in a pictorial form and further discussed.

4.1. Build Work Force

A recurring pattern in the interviews described the lack of skilled work force within the members of the commissioning team. The participants responses included the roles of commissioning specialist, general contractor, mechanical and electrical subcontractors, controls technicians, facility managers and operators. The positions for these vital workers go unfilled for assorted reasons. The bottom line, though, is that people are not compelled to gain the skills for these trades nor pursue these types of vocations in sufficient numbers.

4.2. Prioritize through Education

Currently in the U.S., there is an emphasis to lower carbon emissions, conserving natural resources, and improved air quality by moving away from fossil fuel consumption. Considering that well-reported reality, one would surmise that most people in the U.S. possess a broad understanding of the role that HVAC systems play. However, the challenges of HVAC commissioning supported by the research data proves otherwise. Several participants observed that the HVAC commissioning is viewed as a misunderstood yet immense task that must be hurriedly accomplished before buildings can be occupied. The necessary end-of-project timing of the task does not motivate the contractor nor anyone on the commissioning team to be proactive about first rate installation and quick remedy of field problems. Even the owner is eager to cut corners during commissioning so they can get moved in. The education piece
is supported by a respondent who stated, “They’re HVAC techs, and they have an aversion, to the control system, the electronic side. They want everything to be manual so they can go out there and flip a switch and turn a wrench and make it work. So, educating, teaching our technicians is still an issue.”

4.3. Incentive Programs

A primary topic of interviewees was that federal or other government mandates for energy reduction focus on equipment energy ratings and annual energy reduction percentages for HVAC equipment. But the fact that facilities need to staff to check, adjust and repair the components that vibrate out of adjustment or fail because of wear is overlooked.

Commissioning is completed (poorly or well) and the assumption seems to be that the automation will take care of everything afterwards. Participants recommended that for buildings to work efficiently in terms of energy use of HVAC equipment, they must be regularly monitored and recommissioned. The general contractor can play a key role in ensuring that new buildings are properly commissioned by
allocating sufficient time for the Cx process. It is well-known that profit is a motivating force for most people. If the energy mandates get the ball rolling toward energy efficiency, using creating monetary incentives that engage the commissioning process may keep it rolling along toward the goal. It was also recommended that incentives be included in the contracts to motivate all key participants in the construction process to get it right the first time.

5. Conclusions

Technical experts, construction managers, and owners provided insights into pitfalls in schedule progress during commissioning and noted that the inherent focus on moving to the next project encourages parties to forego important last steps in the process such as second season testing and facility occupancy scheduling. Valuable lessons were shared and recommendations with high potential for success were brought forward in the interview dialogue. The participants responses offered a comparison of pros and cons about the merit and relevancy of ongoing and re-commissioning. The review of the history and progress of HVAC Commissioning verified that technology advances such as direct digital controls, Wi-Fi-enabled remote monitoring and software that diagnoses mechanical system problems has a significant effect on building systems’ energy efficiency. Literature review presented the previous and current state of HVAC Commissioning to allow a comparison of differences, benefits, and disadvantages. The interview dialogue with industry installers, contractors, owners, and designers provided an understanding of the reality of the challenges with and potential of innovative HVAC equipment, controls, and in the facility lifecycle.

By objective examination of common themes and parallel perspectives, the research presents an image of the HVAC commissioning industry highly impacted by technology but struggling to overcome a critical gap of people with the skills and incentive to meet the intent of the commissioning process. The impact of technology on HVAC Commissioning is direct and simple if one merely looks at direct digital controls and computer advances. Participants widely agreed that the onset of digital components and electronic communication was an incredible boost to the ability to commission HVAC systems. However, complexity and human factors are variables that complicate full utilization. Technology is not the problem, but its implications must be considered. Some salient recommendations of this research include the following:

- Develop programs to encourage students to learn a trade that supports HVAC Commissioning.
- Develop creative ways to incentivize high quality HVAC installation, Commissioning to ensure facility utility savings are a reality.
- Establish an educational campaign focused on increasing awareness about the pivotal role of HVAC Commissioning in advancing the goal of enhancing HVAC system efficiency by minimizing energy use.

References