Solving Chronic Building System Problems with an Effective Five Phase Retro–Commissioning Plan

For many of us employed within the building engineering profession, there is nothing more frustrating than dealing with chronic building system complaints. In most cases, these problem building systems have never performed as desired and likely were never adequately commissioned prior to acceptance. And because we often don't have the luxury of dedicating the time and budget necessary to seriously diagnose and correct these problems at the root cause, we too often look for "quick-fixes" that just get us by for the time being.

The building systems that typically plague us the most are those related to heating, ventilation and air conditioning (HVAC). With the advent of modern direct digital control (DDC) systems, and the nearly constant addition of new features, the complexity of your typical HVAC system has increased dramatically over the past twenty years. Add to this the unfortunate fact that many designers, contractors and building operators have not kept pace with the world of technical HVAC advances, and you have a guaranteed recipe for disaster.

For those Building Engineers who end up with the responsibility for operating and maintaining one of these "disaster" building systems, I can offer my sincerest sympathies, and I can also offer a reasonable solution. That solution is called a retro-commissioning (RCx) plan, and it can be applied to any chronically failing building system.

Phase I – Planning

The first phase of any retro-commissioning project needs to be the development of an appropriate and achievable plan. The success of any project is most often dependent on the selection of your project team members and a clear definition of the project objectives. You need to have people familiar with (and supportive of) the retro-commissioning process on your team and you need to know where it is you are going so that you will know when you get there. So start your plan and organize that first meeting!

Major Planning Phase Elements:

- Designate the Project Leader (in-house or consultant)
- Designate other desired project team members
- Define the desired scope, objectives and deliverables (work products)
- Develop the RCx Plan with the following components:
    1. Brief Building and Systems Description
    2. Project Scope and Objectives
    3. Team Roles and Responsibilities
    4. Work & Communication Protocols
    5. Documentation Requirements
    6. Schedule
    7. Functional Testing Plan Outlines

8. List of Expected Deliverables

- Organize and conduct a project "Kick-Off Meeting" with the following purposes:
    1. To discuss and understand the Retro-Commissioning Plan
    2. To impart the owner's objectives for the project
    3. To clarify the key roles and responsibilities of commissioning team members
    4. To establish the desired communication and general work protocols
    5. To identify and agree to a schedule

Phase II – System Investigation

During this phase of the project, the initial goal is to clearly identify all the components of the system you are retro-commissioning and to clearly define the system design intent. By "design intent" we mean: "how was this system intended to work as defined by the original designer?" Operational sequence narratives are often provided as part of the original design documents and seasoned building engineers with experience on similar systems can also provide invaluable assistance with determining how systems were intended to operate. In some cases it will be determined that the original design intent was never appropriate or is no longer appropriate for the current use and/or configuration of the building. In any case, it is important to develop an operational design intent that is endorsed by the project team regardless of whether it is based on the original or revised design intent. This design intent document becomes the standard for all the repairs and improvements that will follow.

In addition to defining the desired system design intent, the system investigation phase must also include a general inspection of the physical condition of each system component and some functional testing to determine where operational issues may exist. Interviews with building occupants and the building maintenance staff can also yield valuable clues regarding chronic issues and previously attempted remedies.

The final step of this phase is to compile a list of recommended repairs and improvements based on the "evidence" you have thus far collected. In most cases it is prudent to prioritize these recommendations, and it may also be helpful to assign some range of anticipated cost impact to each item.

Major Investigative Phase Elements:

- Gather and review all pertinent building documentation.
- Define current desired design intent.
- Perform the O&M Physical Condition Assessment.
- Perform limited functional testing to identify performance issues.
- Identify and document critical issues and desired improvements.
- Prioritize list of repairs and improvements.
- Establish budget estimates.
- Review list of proposed repairs and improvements with the RCx team.
- Decide which repairs and improvements to implement.

Note: If no repairs or improvements are desired, the next phase is skipped and you can go directly to Phase IV – Comprehensive Functional Testing.

Phase III – Repairs and Improvements

During this phase the agreed upon repairs and improvements are completed. In some cases in-house staff will complete these repairs and improvements. In some cases the work is contracted out. In all cases, when the work is complete, the RCx team is notified and at least one team member must be responsible for verifying the work is complete and the systems are ready to be functionally tested.

Repairs and Improvements Phase Elements

- Designate repairs and improvements as either in-house or contracted.
- (In-House) Assign responsible persons for work and establish completion schedules.
- (Contracted) Establish contracts and completion schedules.
- Verify completion of all work and operational condition of all system components.

Phase IV – Comprehensive Functional Testing

Once all repairs and improvements are verified as complete and functional, it then becomes time to complete a fairly comprehensive functional testing of all system components. The RCx team must develop and conduct documented functional testing routines designed to verify the correct operation of the system through all potential modes of operation. In the case of the HVAC system, this might include tests appropriate to verify the warm-up mode, economizer mode, mechanical cooling mode, mechanical heating mode, etc. All issues identified during these tests are documented and tracked until resolved.

Comprehensive Functional Testing Phase Elements

- Develop final versions of testing procedures and expected performance criteria
- Complete and document functional tests
- Document and report on all issues discovered during the FT process

Phase V – Final Issues Resolution

When the functional testing phase is complete, a number of issues will undoubtedly remain unresolved. It is critical that the RCx team meet at this time and reach consensus on who will be responsible for shepherding these issues to resolution. Additional meetings can be scheduled to review progress and at some point the RCx team will hopefully reach an agreement that the process is complete and the system is now functioning reasonably in compliance with the desired design intent. A commissioning consultant company would typically then package all the documentation thus far generated in the form of review reports, test reports and the final version of the issues log. This documentation would be presented to the RCx team as the Final Retro-Commissioning Project Report.

Final Issues Resolution Phase Elements

- Review remaining un-resolved issues with RCx team.
- Determine and assign responsible party for resolution of all remaining issues.
- Verify resolution of all issues to the satisfaction of the RCx team.
- Complete and submit final report detailing RCx procedures and results.

The Hardest Part – Getting Started!

Like so many things in life, the hardest part is getting started. Once you have gotten the RCx ball rolling you will find it to be a rewarding albeit challenging endeavor. If you participate actively in the process, you will become on expert on your building system and diagnosing future similar issues will be made all the easier. I can tell you honestly that I have learned more about systems through the RCx process than I ever learned in the many technical classes I have attended over the years. And there is a great amount of satisfaction to be found in discovering why that particular building system has always been a problem, coming up with a way to fix it and then proving it can actually work as intended.

Case Study – Park Lodge Elementary School, Tacoma, Washington

This successful retro-commissioning project was initiated through the Washington State Office of General Administration's Retro-Commissioning Program (Roger Wigfield). Our project building (like many we see!) had a history of chronic occupant complaints related to temperature control and poor ventilation. The mechanical system at this facility consists of eight separate air handling units, with one large unit (AHU-1) serving multiple fan powered VAV units in the classroom wing. The air handling units were provided with gas heating sections and economizer cooling capability. In addition, each individual zone (including the VAV zones) was provided with a dedicated return air fan. In the classroom wing, these return air fans returned all the air from the classrooms into a central attic plenum where it was then either returned to AHU1 or exhausted outside through a central two-speed relief air fan.

After our general review of all related documentation, a tour of all related equipment, discussions with the M&O staff and some cursory functional testing, we had a list of issues and made several recommendations for system changes and repairs. These included the following:

- Control code changes to allow AHU-1 to better match supply air temperature to actual current load in the classrooms.
- Control code changes to lock-out AHU-1 in the un-occupied night low-limit mode and allow the individual fan powered VAV boxes to maintain un-occupied low limit setpoints as necessary.
- Control code changes to stage the two-speed AHU-1 relief fan based on AHU-1 economizer damper position rather than building static pressure (the building static pressure sensor was found to be un-reliable for this purpose).

- A number of the classroom return-air fans were failed (bad motors) and not operating. Suggest repairing all fans.
- The CO2 sensors on the AHU return air ducts had failed and were not controlling minimum air position as desired. Suggest replacing with new and more reliable sensors.
- Several room temperature sensors were inappropriately located. Suggested moving to better locations.
- Several AHU mixed air sensors were inappropriately located. Suggested moving to better locations.
- EF-4 (exhaust fan for gym) was found to be running backwards. Suggested investigation and repair.
- Return air grilles (located low on interior walls) were blocked in a number of classrooms. Suggested working with teachers to keep this area clear.
- Digital point to start one exhaust fan was found to be mislocated. Suggested changing wiring to the correct location.
- Economizer OSA temperature lock-out setpoints were set too low for a system without mechanical cooling. Suggested setting up.

The final list of repairs and improvements was submitted to the project team and we worked with the school district M&O staff to assign responsibility for the resolution of each issue. The school district M&O staff actually completed several of the repairs with in-house staff. In addition, we contracted out some of the control code changes to the control system contractor, and a number of the recommended changes/repairs were completed by our commissioning firm with an extension to our original contract budget.

Once all the repairs and improvements had been completed, we then conducted a final comprehensive testing of all HVAC zones to confirm compliance with our new design intent. While a few smaller repair-related issues were generated, we managed to confirm that the system was now operating to provide a vastly improved level temperature control and ventilation for the occupants.

Ultimately, commissioning costs for the project were $21,720 ($0.48 per square foot). The first year cost benefit was $8,410, with subsequent annual energy savings estimated to be $6,460 so that the project payback period was less than three years. More importantly though, the retro-commissioning process improved the environment for students and staff, as well as reducing the number of service calls, saving money and aggravation.

About the Author:

Peter Keithly has over 18 years of experience as a Building Operating Engineer. He is currently a Principal in the Seattle based firm of Keithly Barber Associates Inc. and has been a practicing Commissioning Authority for over nine years. His company has now completed formal building commissioning procedures on over two hundred building projects. Pete was a founding board member of the Building Commissioning Association and he is also a LEED Accredited Professional. You can email Pete at pete@keithlybarber.com.