7 Retrocommissioning in Action

Once the facility manager has obtained the necessary support and funding for the retrocommissioning project, work can begin. The retrocommissioning process can be viewed as consisting of four primary phases:

1. planning,
2. investigation,
3. implementation, and
4. handoff.

Figure 1 is a flow chart presenting these phases, along with the process steps in each. Table 8 summarizes the primary activities and products of each phase. All of the four phases and their related steps are discussed in more detail below.

In reality, the phases and many of the steps overlap and may occur simultaneously; some may be eliminated, depending on the nature of the project. Depending on the budget, in-house expertise and availability, and the scope of the project, the planning phase may be partially if not entirely completed by the owner or the building staff. Of the four phases discussed below, the planning phase is discussed in the most detail because it involves the most input from management. When project planning is well thought out, success generally follows.

The possible deliverables are listed at the end of each phase discussed in this section. However, many of these are not fully completed until the hand-off phase, when they are included in the final project report.

Planning Phase

1. Developing and communicating the objectives

The retrocommissioning process begins by defining in writing the exact objectives for the project and clearly communicating those objectives to the team involved in carrying out the work. Often the main objective for commissioning an existing facility is to obtain cost savings from improving the operation of the building's energy-using equipment, given current operating requirements. Identifying and

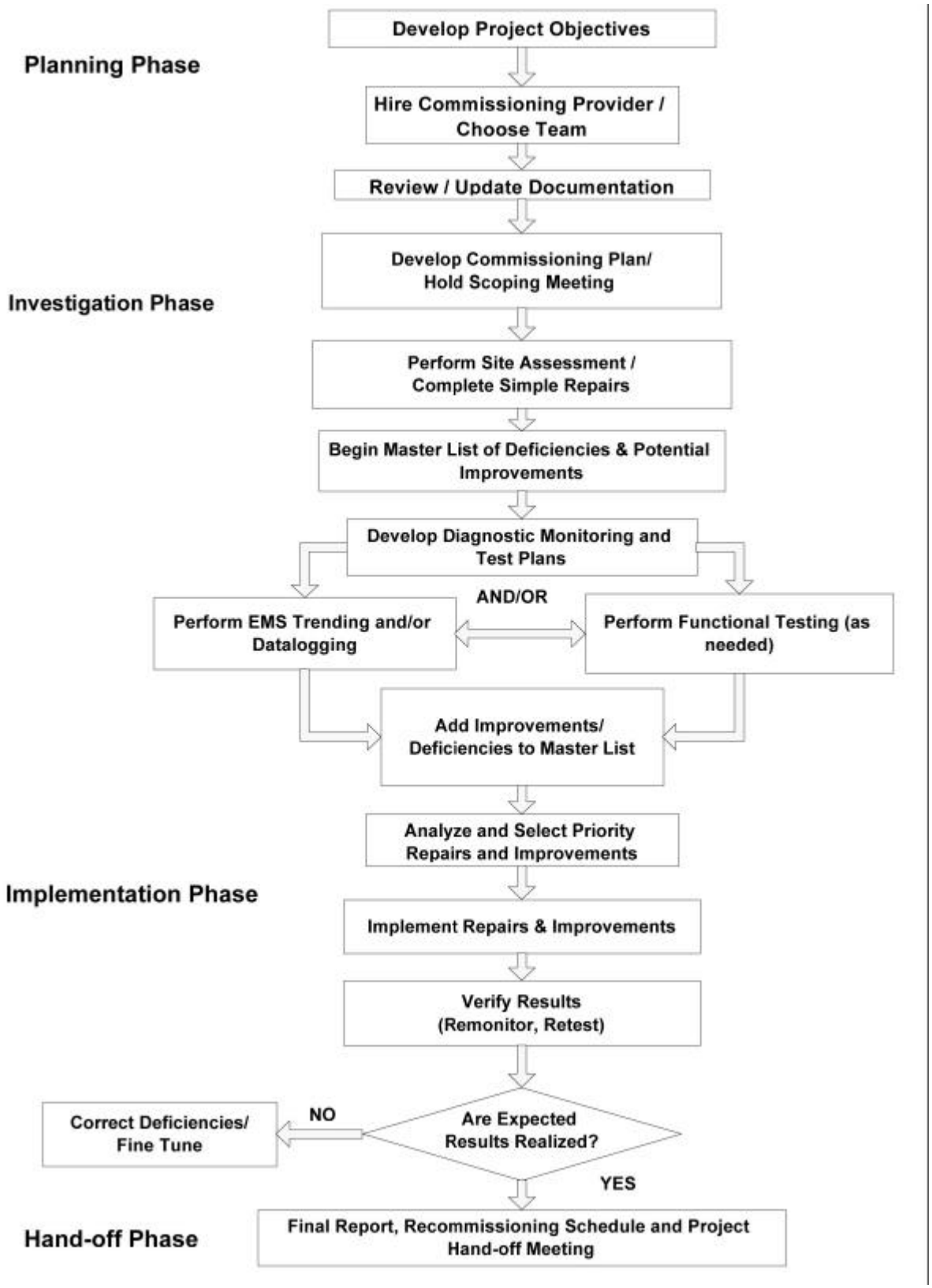


Fig. 1. The phases and activities of the retrocommissioning process.

Table 8. Summary of retrocommissioning activities and products

Phase	Activities	Primary products/deliverables[a]
Planning	1. Developing and communicating objectives 2. Choosing team and hiring commissioning provider 3. Reviewing and updating building documentation and historical utility data 4. Developing retrocommissioning project plan and holding scoping meeting	• Retrocommissioning project plan (including project objectives and scope) • Scoping meeting minutes
Investigation	1. Performing site assessment 2. Developing Master List of deficiencies (repairs) and potential improvements 3. Developing short-term diagnostic monitoring plans 4. Performing functional testing, diagnostics, and trending 5. Selecting most cost-effective opportunities for implementation	• Short-term diagnostic monitoring and functional test plans • Master List of deficiencies and potential improvements (known as the Master List) • Completed assessment forms and diagnostic test results • List of selected improvements for immediate implementation
Implementation	1. Implementing improvements 2. Retesting and remonitoring	• Completed repairs and improvements (noted on revisions to Master List) • Final estimated cost and energy savings calculations for energy efficiency and cost-saving improvements
Handoff	1. Completing final report 2. Maintaining investment by developing recommissioning plan, training, and performance tracking 3. Holding project closeout meeting	• Final report • Recommended capital improvements for future investigation • Revised or upgraded building documentation (if required as part of project) • Recommissioning plan or schedule

[a]All phases should include progress reports and minutes from meetings.

eliminating potential indoor air quality and comfort problems is also often high on the list of retrocommissioning objectives. Figure 2 shows an example of written objectives for a retrocommissioning project in order of priority.

1. Obtain cost-effective energy savings. Verification will require limited performance monitoring of selected building systems.
2. Identify and recommend improvements to operational strategies and maintenance procedures, focusing on those measures that sustain optimal energy performance and reduce operating costs.
3. Identify HVAC-related health and safety issues as they present themselves during the normal course of the commissioning work.
4. Obtain background information for the development of an organization-wide retrocommissioning guideline and plan for inclusion in the organization's energy management program.

Fig. 2. Example of prioritized, written objectives for a commissioning project.

Additional objectives for performing retrocommissioning may include

- reducing comfort complaint calls,
- eliminating targeted indoor environmental quality problems,
- increasing equipment life,
- reducing staff time spent on emergencies and reducing failure rates,
- retaining tenants and solving specific complaints,
- increasing O&M staff skills and improving procedures,
- updating building documentation,
- preparing existing systems and equipment to interface with a new computerized EMCS, and
- benchmarking the operational status of existing systems and equipment.

Also in this first phase, the project team should begin to consider the measurement and verification (M&V) methods needed to evaluate the selected objectives. For many projects, retrocommissioning opportunities are evaluated both before and after implementation. Evaluating the estimated cost and benefit of each recommendation before the implementation phase is used to help prioritize which opportunities will yield the most value. Usually, those estimated to cost the least and produce the most savings are implemented first. Following the implementation phase, evaluation is used to verify whether or not the project objectives have been reasonably met. This usually includes comparing the actual costs and calculated savings for energy-efficient improvements with their estimated cost and savings.

Evaluating results is more easily accomplished and less costly for some objectives than for others. For example, using a simple method such as a written logging system to compare the number of comfort calls occurring before and after the retrocommissioning process is straightforward and inexpensive and can be implemented by in-house staff. On the other hand, understanding the before-and-after energy use or showing indoor air quality improvement are usually more challenging evaluations.[1]

The costs of measurement and verification must be weighed against the need to verify performance or accomplishments.

The costs of M&V must be weighed against the need to verify performance or accomplishments. Owners who are primarily interested in obtaining a building that works well and maintains a comfortable environment for their occupants may be less concerned with knowing exactly how much energy savings should be attributed to the retrocommissioning effort. Some of the recommended improvements resulting from the investigation phase of the project may demonstrate such obvious benefits that owners are willing to implement them without performing any complicated energy analysis. Forgoing extensive analysis reduces the cost of the project.

The methods selected for M&V depend on each objective and the overall project goals. Research and demonstration projects where the major goal is to demonstrate detailed results for particular objectives (such as energy savings or improved indoor air quality) usually require the most rigorous and expensive M&V methods. If retrocommissioning is performed as part of an energy-savings agreement such as an ESPC, the level of rigor for verifying cost and savings may be significant. What is important to remember for typical retrocommissioning projects, where the owner takes the risk and pays the costs, is that the cost for measuring and verifying results should be closely scrutinized before choosing a method. The cost of a rigorous evaluation method can sometimes equal or exceed the cost of identifying and implementing repairs and improvements. For facility or energy managers who need to feel confident about getting value for their investment and are planning to present results to upper management, less expensive methods are usually appropriate.

Owners and managers can gather information for calculating and verifying energy savings by using whole-building metering, end-use metering, or a combination of the two to obtain a before-and-after comparison of energy use and demand. If there is a desire or requirement for this type of verification rigor, the local utility may be willing to help. Some utilities are interested in obtaining data on energy savings through

[1]Most states have an Industrial Commission, a Department of Occupational Safety and Health, a Department of Environmental Quality, or some other similar organization that will perform air quality sampling and testing at little or no cost. In some states, there are tax incentives offered for air-quality-related capital improvements.

retrocommissioning and may be willing to install a pulse meter that will provide 15-minute readings of the whole building's electric use. These readings—in combination with short-term end-use monitoring, which may be accomplished using portable data loggers (discussed in more detail in the section "Investigation Phase")—usually provide an adequate amount of information for acceptable calculation of energy and demand savings. Simply comparing before-and-after energy bills is another method that is easier and less expensive but also less accurate. No matter which method is used, it is sometimes difficult to determine what causes an increase or decrease in energy unless variables such as weather, occupancy, utility rate schedules and changes, and building use are taken into consideration. Facilities that have computerized energy accounting systems should consider using them to help evaluate projects focused on obtaining energy savings. Many of these systems are capable of performing weather adjustments to make annual before-and-after comparisons more accurate. This is especially true for buildings that have both a stable occupancy rate and unchanged building use.

2. Choosing the team and hiring the commissioning provider

A team will be responsible for achieving the objectives defined for the project. Initially, this team will typically require two teams working together: an owner's team and a contractor team. The teams can be small as long as needed skills and authority are represented on each. These two teams must join to become the project team. The skills and authority of the owner's team must be adequate to obtain acceptable contractor services and to interface with the contractor team. Without a reasonable balance between teams, the creation of the project team will be difficult or the project team will be flawed (and potentially not able to manage the project adequately).

Choosing the team

Chapter 6 briefly discusses the roles and responsibilities of all the possible retrocommissioning team members. The important functions of the owner team and the commissioning provider team are clearly evident in that discussion. These two teams must handle many functions, which will drive the ability of the project team to function. Care must be taken that the people assigned to these team positions are able to handle the defined roles and responsibilities.

The owner or owner's representative responsible for the project has the responsibility for bringing the overall team together. The commissioning provider may have varying levels of involvement in this process of bringing the team together, depending on the level of trust and confidence established. The overall team should consist only of those people most critical to accomplishing the work.

For buildings with an in-house staff, one of the most important team members is the building operator assigned to work with the commissioning provider. Ideally, the assigned operator should have historical knowledge of how and why equipment and systems are operated and maintained in the present manner and have a thorough knowledge of the building control systems.

The commissioning provider must bring troubleshooting, problem-solving, diagnostic monitoring, testing, and analysis expertise needed to identify obvious problems and uncover any hidden problems with building systems that must be solved to meet project objectives. The provider must also challenge the use of current equipment, practices, or methods that may be causing problems and identify useful and cost-effective solutions for the problems.

Qualifying the commissioning provider

Currently, there is no universally accepted certification process for commissioning providers. Even if there were, certifications merely indicate that an individual passed a test; they are not guarantees that the person has the experience needed to provide appropriate retrocommissioning services. Appendix E contains two forms that allow the experience of commissioning providers to be described and scoped. These forms are examples and can be modified to meet the information request appropriate to the objectives of a specific project.

Standard approaches should always be used, as appropriate, when seeking commissioning providers:

- evaluate experience;
- request and contact references ;
- evaluate ancillary skills such as diplomacy, negotiation, communications, meeting facilitation, listening, investigation, and reporting abilities.

In addition, the following factors should be considered:

- Is commissioning a core business or a primary business component of a firm?
- Are final commissioning reports available for review?
- Do utilities or state and local government organizations have lists of commissioning providers?

It is important that the skills of the commissioning provider match the objectives and scope of the project. For example, if improving IAQ is the primary objective for the retrocommissioning, then the individual hired for the job must be skilled at investigating and solving IAQ problems.

Hiring the commissioning provider

Initial identification of acceptable commissioning providers may occur through a request for qualifications (RFQ) process. The RFQ allows evaluation of qualifications without detailed definition of the work to be accomplished. In this way, the desired work scope can be developed more fully while a group of qualified firms and their references are being established and contacted.

Small, less complex projects may not require a request for proposal (RFP) process. However, larger and more complex projects will often dictate use of an RFP and an evaluation of submitted proposals from the group of potential providers selected through the RFQ or by another method. Appendix F contains a checklist of factors to consider when putting together an RFP.

As part of the RFP, the owner or manager should provide a list of expected products or deliverables resulting from the retrocommissioning process. The number and type of deliverables depend on the scope of the project. The following list identifies several possible deliverables:

- all required forms according to an agreed-upon time or conditions framework;
- retrocommissioning plan;
- progress reports according to a schedule;
- all major commissioning meeting minutes (scoping meeting, progress meetings, etc.);
- completed assessment forms;
- diagnostic monitoring, trending, and functional test plans;
- completed functional performance tests;
- Master List of deficiencies and potential improvements (a decision-making tool);
- list of recommended improvements for immediate implementation (based on cost-effectiveness);
- final energy saving estimates and calculations;
- list of recommendations for capital improvements for further investigation;

- service contract review findings and recommendations;
- recommissioning schedule ;
- updated/revised building documentation;
- final report (some of the above deliverables may be incorporated into the final report).

The primary deliverables are the retrocommissioning plan, Master List of deficiencies and potential improvements, list of recommended capital improvements for further investigation, and the final report. These primary deliverables are discussed in more detail in the following sections.

If the project is large or complicated, a preproposal meeting, including a site visit to the facilities included in the scope of the project, may be necessary. This approach allows the selected group of commissioning providers a chance to see the facility and ask critical questions they may have concerning the project. It also tends to “level the playing field” so that each party has the same information in developing bids.

3. Reviewing and updating building documentation

Up-to-date, complete building documentation expedites troubleshooting, saving time and money for the building staff.

During the planning phase, the building documentation that was gathered in preparation for the retrocommissioning is passed on to the commissioning provider for review. If this preparatory task has not been done, then the commissioning provider is responsible for obtaining and possibly recreating the documentation needed for the project. This can be an expensive and time-consuming task for the commissioning provider but may be well worth it to the facility manager. Having updated, complete building documentation expedites troubleshooting, saving time and money for the building staff. A comprehensive list of useful documentation is presented in Appendix C.

Accurate, complete, and updated documentation is not only important to the building staff for future use but also immediately important to the commissioning provider, who uses the documentation during the investigation phase of the project for developing the site assessment forms as well as any diagnostic and functional test plans that may be required to verify equipment performance.

When gathering and updating the documentation is a primary task for the commissioning provider, the work is often carried out during the investigation phase rather than in the planning phase of the project.

4. Developing the plan and holding a scoping meeting

The retrocommissioning plan

After reviewing the building documentation package and gaining a clear understanding of the project objectives, the commissioning provider has the primary responsibility for developing the plan, seeking significant input and review from the owner and owner's staff. Including the building operating staff during plan development facilitates their desire to see the process succeed. The plan usually includes the following sections:

- general building information and contact (name, address, phone numbers etc.);
- project objectives;
- building description (brief);
- project scope;
- roles and responsibilities;
- schedule (for primary tasks);
- documentation;
- investigation scope and methods;
- implementation phase;
- project handoff.

The scheduling of project work should coincide with the project objectives. For example, if there is a desire to reduce the number of comfort calls and these calls occur primarily during the cooling season, then the diagnostic testing should be scheduled during peak cooling conditions.

The plan should be viewed as a flexible document that may include some schedule and team member changes during the course of the project. Appendix G contains a sample generic retrocommissioning plan. This plan can be modified as needed to fit the intended project.

The scoping meeting

Generally, the commissioning provider facilitates the scoping meeting with the plan as the primary focus. The scoping meeting brings all of the team members together to review, discuss, and agree to the retrocommissioning plan. The primary role

of the owner or manager is to reiterate the objectives for the project and show support for the retrocommissioning plan. In the meeting, each team member's responsibilities are discussed, and the schedule is agreed to. The scoping meeting sometimes includes others who are invested in the project's success (such as a local utility) but are not directly responsible for performing work on the project.

Work protocols are also conveyed during the scoping meeting. Members of the team must be well informed about what is expected of them when they enter the building to perform work. The following are some examples of work protocol topics:

- restrictions on photos or videos (building-wide or in certain areas),
- restrictions on building keys,
- restrictions on special areas in the building (sensitive tenants, etc.),
- sign-in and sign-out requirements,
- necessary identification,
- parking permits,
- safety and emergency requirements and contacts,
- need for escort while in the building or in special areas of the building and who the escort is, and
- special protocols when entering tenant spaces (e.g., the most acceptable times for performing work in tenant spaces).

Planning phase deliverables

The deliverables that may be expected as part of the planning phase are

- the retrocommissioning project plan (including objectives and scope), and
- scoping meeting minutes (which will become part of the project documentation).

Investigation Phase

Understanding why building systems are operated and maintained the way they are, identifying deficiencies and potential improvements, and selecting the most cost-effective "fixes" are the primary tasks for the investigation phase. In this phase of the project, the team looks at all aspects of the current O&M program and practices as well as the management structures, policies, and user requirements that influence

them. Tasks may include interviewing management as well as building personnel, reviewing current O&M practices and service contracts, spot-testing of equipment and controls, and trending or electronic data-logging of pressures, temperatures, power, flows, and lighting levels and use.

The investigation phase is generally the most time-consuming and expensive part of the retrocommissioning process. The five steps of the investigation phase are discussed below.

1. Performing a site assessment

The goal of the site assessment is to gain an in-depth understanding of how the building systems and equipment are currently operated and maintained, why they are operated in that way, and what building staff and occupants consider to be the most significant problems. Most projects require the commissioning provider to develop a formal site assessment that includes detailed building staff interviews regarding operating strategies and an in-depth site survey of equipment condition. Sample assessment forms are presented in Appendix H. Assigning building operators to the site assessment who have a historical knowledge of the building and expertise in the control systems expedites this task. The site assessment addresses the following major issues:

- overall building energy use and demand and areas of highest energy use and demand;
- current design and operational intent and actual control sequences for each piece of equipment included in the project;
- equipment nameplate information and equipment condition issues (broken dampers, dirty coils, sensor calibration, etc.);
- current schedules (setpoint, time-of-day, holiday, lighting, etc.);
- the most severe control and operational problems;
- location of the most comfort problems or trouble spots in the building;
- current O&M practices.

Depending on the scope of the project, the site assessment can take one day to several days to complete. It is not unusual for many problems and possible corrections to reveal themselves during the site assessment. As noted earlier, it may be cost-effective to have the assigned building operator make minor adjustments and repairs as the site assessment progresses. These “field fixes” should be summarized on the

Master List of deficiencies and improvements (the Master List is discussed below) and documented on the applicable site assessment form. Engineering calculations can often be applied later to determine the value of these adjustments and repairs.

The assessment is meant to uncover where the best opportunities are for optimizing the energy-using systems and improving O&M practices. It provides the starting point from which to evaluate the effectiveness of improvements and O&M activities. It also provides a basis for recommending where more extensive diagnostics and testing may be appropriate to help better pinpoint the causes of problems or to verify that a problem does exist.

A retrocommissioning site assessment differs from an energy audit in that its primary focus is on finding low-cost changes in O&M practices that improve building operation rather than on technology-intensive capital improvements. However, both have the goal of reducing energy waste and improving the building environment. The site assessment can be performed prior to or as part of an energy audit because it offers ways to optimize system operation, possibly reducing the need for expensive technological solutions.

2. Developing the Master List of deficiencies and potential improvements

The Master List ultimately becomes an important decision-making tool for the facility manager and building staff.

Concurrent with the site assessment, the commissioning provider begins to develop a Master List of deficiencies and potential improvements. This Master List ultimately becomes an important decision-making tool for the facility manager and building staff and is a primary product (deliverable) of the commissioning effort. Every finding from the investigation phase is summarized on the Master List, including those adjustments and repairs made during the course of the investigation process. At a minimum, the list should include the name of the system or piece of equipment, a description of the deficiency or problem, and a suggested solution. A sample Master List is provided in Appendix I.

The Master List is a dynamic document and may not be fully completed until after the implementation phase.

To better understand the deficiencies and problems, the owner or manager may require the commissioning provider to categorize them according to type or source. For example, problems may fall into four primary categories: maintenance, operation, design, or installation. Understanding where the more costly problems fall helps management understand where organizational improvements may be needed. For example, several problems in the installation category may indicate a need for the owner to require commissioning for future new construction or new equipment

installation. Such problems may also suggest taking a hard look at who is providing the installation service. If the majority of problems are maintenance-related, additional staff, more training, or a more comprehensive or better-managed service contract may be needed.

3. Developing the diagnostic monitoring and test plans

The information gained from the site assessment may indicate a need to obtain more complete and exact data on when and how systems are actually operating, since the assessment may only identify suspected areas for improvement. If more information is needed, the commissioning provider develops the necessary diagnostic monitoring and test plans.

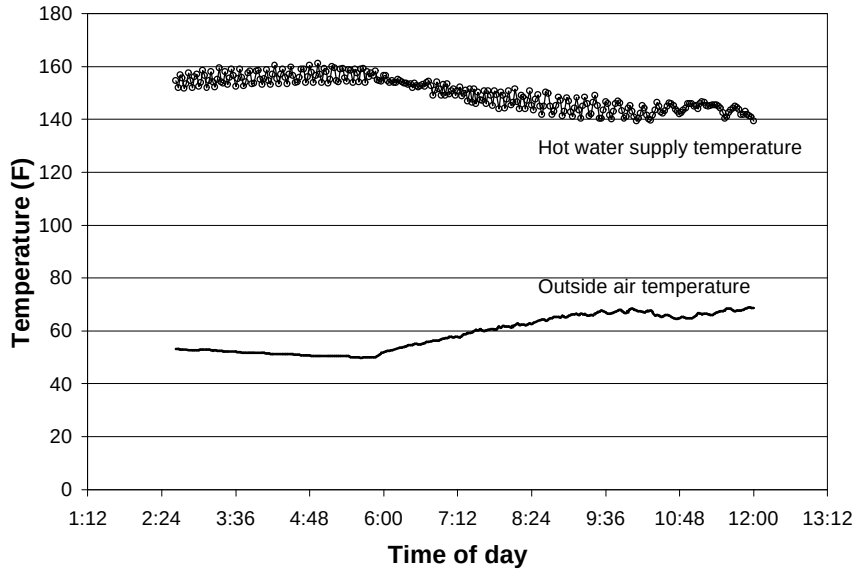
Diagnostic monitoring and testing allows the commissioning provider to observe space and outdoor temperatures along with critical flows, pressures, speeds, currents, and temperatures of the system components under typical operating conditions. By analyzing this information, the commissioning provider determines whether the systems are operating correctly and in the most efficient manner. Three typical diagnostic methods are EMCS trend logging, stand-alone portable data logging, and manual functional testing. Often, a combination of these methods is used. Appendix J contains a sample diagnostic monitoring plan and trend logging plan, and Appendix K contains a sample functional test plan for a centrifugal chiller.

EMCS trend-logging

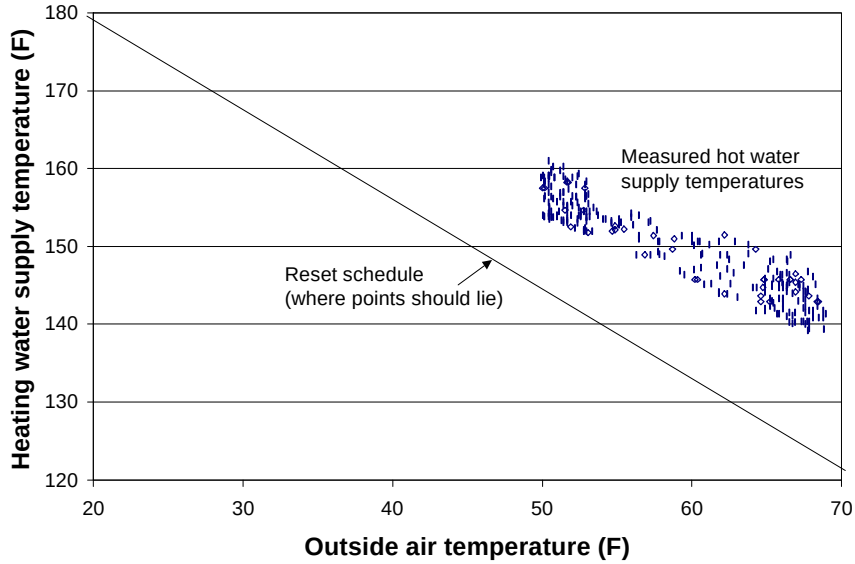
Using the building's EMCS trend-logging capability may be the most cost-effective diagnostic method, as long as the system's sensors have been recently calibrated and team members have high confidence that the system is capable of providing accurate data. However, many systems are limited in their ability to collect, store, and present data. Also, EMCS points (temperature sensors, for example) are permanent, making it impossible to take measurements other than at the location where the points were originally installed. And because it is not unusual for the location of an EMCS sensor be the root of an operational problem, caution should be exercised when using only the EMCS as a diagnostic tool.

Portable data-logging

For buildings lacking an EMCS or for those having an EMCS with limited data points, using portable electronic data loggers is the best method for short-term diagnostic and monitoring activities. Portable data loggers are battery-powered, small, light, and easily installed and removed without disrupting building occupants. Many come with sophisticated software packages so that data can be downloaded and easily graphed and analyzed on a computer in a variety of ways (see Fig. 3). Gathering data in



(a) Investigation of reset schedule via time series plot. In this plot the reset schedule appears to be performing correctly. However, taking the analysis a step further, as shown in (b) below, reveals a problem.



(b) Investigation of reset schedule by plotting one parameter against another. Plotting the heating water supply temperature against the outside air temperature shows that the reset is not performing correctly and needs adjustment. If the reset were performing according to design, the data points would be clustered around the diagonal line.

Fig. 3. Example of data analysis using data derived from a portable data logger.

this manner provides a measure of accuracy that manual testing and spot observations cannot offer. *These data should be trended or logged at a selected frequency (such as every 2 minutes) for a minimum of two weeks, including a typical weekend.*

Short-term diagnostic monitoring serves two purposes: it helps the commissioning team to more accurately locate problems, and it confirms the engineering calculations used to determine which improvements provide the greatest energy savings. During the implementation phase of the project (after the improvements are completed), the original data can be compared against new data to verify that the identified problems are eliminated and that the equipment is operating as expected.

Functional testing

It may be necessary to functionally test a system or piece of equipment during the investigation process. For example, functional testing is sometimes needed because certain conditions never occurred during the diagnostic monitoring period that may be important to understanding whether a system or piece of equipment is functioning properly or efficiently. The condition can be simulated, or the mode (heating, cooling, economizing, etc.) can be forced through functional testing. If functional testing is needed, it is important to perform the test while the data loggers are still installed or the related EMCS trends are initiated so that the results are permanently recorded and can be easily graphed and analyzed using a computer. When the EMCS is used, test responses can often be viewed as they occur.

When data loggers are not available or when the EMCS is inadequate or nonexistent for trending or viewing system responses, *manual* functional testing of the system is the only option for verifying correct operation or pinpointing problems. Under these circumstances, the commissioning provider develops detailed test plans for manually testing the equipment and systems. Manual testing involves putting each system or piece of equipment through a series of tests that check its operation under various modes and conditions. Data are gathered by taking spot measurements using hand-held instruments such as multimeters, ammeters, digital thermometers, and light meters. The data are then used to verify correct operation.

4. Implementing the diagnostic monitoring and test plans

The commissioning provider and the owner's representative schedule the implementation of the diagnostic monitoring, the testing, and the associated preparatory work. Preparations for monitoring and testing may include checking and calibrating control points such as temperature sensors. When possible, to reduce project costs, the facility staff should complete the calibration work under the direction of the commissioning provider. If data loggers are used, facility staff can usually assist in the installation and removal of the loggers. The trend-logging plan may be carried out

by the facility staff, but assistance may be required from the controls vendor, particularly in developing, formatting, and downloading computer files for analysis by the commissioning provider. Results from monitoring, via trend logs or data loggers, are provided in annotated graphical or columnar format for reporting purposes.

The commissioning provider usually directs the functional tests. Facility staff, a control vendor, or other appropriate parties assist with the hands-on operation of the equipment being tested. The commissioning provider documents manual testing and observed results on the test plan forms. The forms also describe the piece of equipment or the system and the detailed test procedures.

After diagnostic monitoring and testing are completed, the findings are analyzed and checked against the site-assessment information. Any resulting changes, additional deficiencies, or potential improvements are summarized on the Master List.

5. Selecting the most cost-effective opportunities for implementation

The commissioning provider generally completes an analysis of the opportunities and makes recommendations for implementation based on which improvements are most cost-effective.

Once the site assessment and diagnostic testing are complete and the Master List is filled out, owners decide which items on the list provide the most benefit and effectively meet the project objectives. For some projects, managers may want to implement the entire Master List but may need to prioritize the improvements according to cost-effectiveness. For example, in some buildings it may be more cost-effective to implement plant-related control strategies before performing more labor-intensive fixes such as fine-tuning air-side economizing. To help with this decision-making process, the commissioning provider generally completes an analysis of the opportunities and makes recommendations for implementation based on which improvements are most cost-effective. It is not unusual to expect a simple payback of 18 months or less for improvements that produce energy savings. The savings generated from these improvements can sometimes pay for other improvements that have less quantifiable benefits.

Many retrocommissioning improvements are straightforward, and there is confidence in their benefits. In such cases, the building management and staff may not need any savings verification to justify implementation. Other improvements—such as those related to comfort, IAQ, and equipment malfunction—may not have easily quantifiable savings benefits, but facility staff often want to implement them because they simply want the building to “work right.” The building management and staff always make the final decision on which deficiencies and improvements to address first. For additional discussion on verification issues, see “Developing and communicating the objectives” in the first section of this chapter.

Investigation phase deliverables

The site assessment may be one of the primary products, if not the only primary product, coming out of the project. Some projects require only completion of the investigation phase, making the assessment and the Master List the primary deliverables. The assessment generally includes gathering information on the condition of equipment, including equipment nameplate information as well as the operating strategies. In many cases it is not necessary to require the entire assessment as a deliverable. For example, if the building does not have an adequate current list of equipment with nameplate information, the maintenance or equipment condition part of the assessment becomes the main deliverable. Or, if the building lacks written control strategies, the operating part of the assessment is valuable for developing this missing information in-house. However, if the assessment findings are the most important product, then the Master List alone adequately fulfills this requirement and the site assessment may be dropped from the deliverable list.

Deliverables that may be expected as part of the investigation phase are

- short-term diagnostic monitoring and functional test plans,
- the Master List of deficiencies and potential improvements,
- completed site-assessment forms (optional),
- completed functional tests, and
- a list of selected improvements for immediate implementation, including costs and ROIs.

Implementation Phase

During the investigation phase, several of the simple, obvious, and less expensive repairs and improvements are usually completed. During the implementation phase, the more complicated and expensive ones are completed. This section discusses implementing improvements and verifying the results, along with some important issues to consider during these activities.

1. Implementing improvements

A primary goal for most retrocommissioning projects is actually to implement the major cost-effective improvements so that results can be realized. Although the investigation phase provides important information and products, unless improvements are actually put in place, the retrocommissioning process remains incomplete. Depending on their availability and expertise, in-house O&M staff may implement the

improvements. However, in some cases the implementation may require outside help. For example, hiring a controls contractor may be necessary if in-house staff lacks the expertise, access, or time required to make control strategy changes at the program level.

Retaining the commissioning provider through the implementation phase, whether the implementation work is done in-house or outsourced, is worth considering. Because the commissioning provider has an intimate knowledge of the building systems and needed improvements, having the commissioning provider supervise the implementation phase may ultimately save time and reduce costs. Also, it is often necessary (and highly recommended) that some functional retesting be performed after implementation. Retesting is discussed in more detail below. Through the retesting process, the commissioning provider ensures that the improvements are working as expected and that they positively affect other systems and equipment as well as the building occupants. It is not unusual for the retesting to uncover related or hidden problems that could lead to more improvements.

2. Retesting and remonitoring

Once an improvement or “fix” is completed, retesting to confirm that the affected equipment is operating properly can be done with EMCS trending, manual testing, or data-logging. In some cases, it may be necessary to use a combination of these methods. For example, retesting might involve manual tests of the function of repaired items such as damper motors or valves to verify that they stroke properly, followed by EMCS trending or data-logging to determine that they are modulating to maintain the desired setpoint at the appropriate times.

It is often desirable and enlightening to reinstall several if not all of the data loggers (or reinitiate the original EMCS trends) and remonitor operations to obtain several days of post-implementation data. The data are then compared to the original data (pre-implementation data) in order to confirm that the improvements are integrated and have the desired overall positive effect for the building. This technique can also be used to benchmark the final performance of the improvements. This benchmarking information can then be used to establish criteria or parameters for tracking whether or not the improvements are performing properly throughout the life of the equipment or systems. (See also the discussion of the project hand-off phase below.)

Retesting and remonitoring may reveal the need for further improvements. Often, addressing one deficiency uncovers other opportunities for more savings or improved comfort. At this point it is also important to use any of the applicable post-test and monitoring data to check and adjust the original energy savings estimates to make them as accurate as possible.

Implementation phase deliverables

The following deliverables may be expected as part of the implementation phase

- completed repairs and improvements (these can be noted on Master List);
- final estimated energy savings calculations for energy saving improvements.

Project Hand-Off Phase

Although project handoff is the final phase, it is not the end of the owner's or building staff's effort to maintain the investment in retrocommissioning. The products and recommendations from this phase of the project should be integrated into the building's O&M and energy management program so that the estimated return on the retrocommissioning investment can be realized. The three steps in the project hand-off phase are discussed below.

1. Completing the final report

The commissioning provider prepares a comprehensive final report that includes several of the required deliverables for the project. A typical final report contains the following:

- executive summary;
- analysis of major findings and results;
- building and systems descriptions;
- scope of the commissioning project;
- Master List of improvements, including training needs and maintenance recommendations;
- detailed description of improvements that were implemented, with cost and savings information;
- list of recommended capital improvements for further investigation (discussed below);
- original and corrected commissioning plan;
- EMCS trending plan and logger diagnostic, monitoring plan and results;
- all completed functional tests and results.

During the normal course of projects, the commissioning provider may be required to review current equipment and system efficiencies, operating strategies, and conditions not only for O&M improvements but also for possible energy-efficient capital improvements. Although retrocommissioning does not involve implementing expensive energy-efficiency measures, it is often the first step toward obtaining these improvements. Therefore, the commissioning provider should provide a list of recommended improvements as part of the project handoff. The list need not be limited to energy-saving or cost-saving capital improvements. Regarding the energy savings measures, however, the list recommends areas for *further investigation* and should not require extensive supporting energy calculations or building models. If and when the opportunity for further improvements arises or the facility budget permits such improvements, the list can be used as a starting point for a comprehensive energy study. The list should go beyond the generic to include realistic and customized recommendations based on the facility. It should reference equipment names, room numbers, areas of the building, and so on. Figure 4 is an example of recommended capital improvements taken from an actual project.

- Energy-efficient lighting retrofit (all interior lighting including exit lighting)
- Addition of lighting sweep control for interior lights not in 24-hour-use areas
- Addition of occupancy sensors for lighting in offices, restrooms, conference rooms, storerooms building-wide
- Addition of photo cells on exterior lights on south side of the building
- Daylighting controls for corridors and lobbies with extensive windows
- Variable frequency drives on primary air handlers #1 and #2
- CO_2-based ventilation control for conference room 2000

Fig. 4. Example of a list of recommended capital improvements.

2. Maintaining the investment benefits

Developing a recommissioning schedule and procedures, instituting methods for tracking results, and training staff are key elements in retaining the cost savings and other benefits gained from retrocommissioning throughout the lives of the building equipment and systems.

Recommissioning procedures and schedule

In this guide, recommissioning has been defined as “a *periodic event* that *reapplies* the original commissioning tests in order to keep the building operating according to design or current operating needs.” Owner commitment to performing regular recommissioning increases the chances that the improved equipment and systems will continue to perform according to their original intent. In order to ensure

continuing performance and energy cost savings, a recommissioning schedule should be incorporated into the overall O&M plan for the facility. The commissioning provider may be required to develop the schedule as one of the project deliverables.

Depending on the types of the improvements and how often the building changes, recommissioning schedules can vary considerably. If building use remains stable and tenants rarely if ever request major changes (such as moving or constructing walls or installing additional ductwork), then recommissioning may be scheduled less frequently than for a building where changes occur often or are significant. Also, the frequency of recommissioning activities may be different for different areas of the building. Equipment that serves an area with constant tenant requests for operating schedule changes or construction, etc., will need recommissioning more often than equipment that serves more stable areas. In some cases, it may be convenient and appropriate to incorporate recommissioning activities into the regular annual or semiannual preventive maintenance requirements. This approach may be particularly important for major plant equipment. Any one of or a combination of the following parties may perform recommissioning:

- trained in-house O&M staff,
- trained outside O&M service contractors, and/or
- commissioning provider.

Tracking results

Continuing to evaluate the results of the retrocommissioning project over time will help owners and managers understand when it may be important to reevaluate the improvements to make sure they are still functioning properly. It may be appropriate and cost-effective to continue using some of the M&V methods discussed in the Planning Phase section. For example, simply continuing to log the frequency of comfort complaints can often indicate whether problems have arisen with the implemented improvements. Tracking energy bills and the energy use index for each retrocommissioned building and comparing energy use indexes among similar buildings are other inexpensive ways to check for possible problems. (Owners should be aware, however, that these are not always accurate tracking methods because of the effects that weather, occupancy, and building use changes have on energy use. These effects can sometimes either mask problems or suggest problems when none actually exist.)

As long as regular calibration checks are performed on strategic sensors, staff can use the EMCS to track whether or not improved control strategies and sequences of operation are still performing as expected. Trends may be either permanently or periodically set up to gather data that can be compared against benchmark criteria or parameters. When the trended data moves outside those parameters, a problem may exist. The benchmarking parameters can be generated during the post-implementation monitoring or EMCS trend logging, as discussed in the Implementation Phase section. The commissioning provider may be the best person to set up methods for tracking the performance of improved systems.

3. Project closeout meeting

Once the commissioning provider has submitted the final report for review by the owner and the owner's staff, it may be appropriate to hold a project closeout meeting with the retrocommissioning team. Such a meeting is valuable for discussing what worked and what didn't, and for identifying the lessons learned during the project. It also provides an important opportunity to recognize individual successes, celebrate the overall success of the project, and discuss next steps. Next steps may include developing an organization-wide plan for retrocommissioning all of the organization's buildings. Next steps may also include selecting an approach for deciding which capital improvements to install.

The final report, including the test and diagnostic procedures used during the retrocommissioning effort, should be delivered to the owner and the person or persons responsible for the recommissioning. Reapplying these procedures during recommissioning greatly reduces the cost of the recommissioning effort.

Acceptance of the final report by the owner or owner's representative concludes the hand-off phase of the project.

Hand-off phase deliverables

Typical deliverables for the hand-off phase are

- the final report,
- recommended capital improvements for future investigation,
- revised or upgraded building documentation (if required as part of the project), and
- the recommissioning plan or schedule and methods for tracking improvements. **O**

8 Organization-Wide Planning

For owners and managers of multiple buildings, there may be benefit in retrocommissioning several buildings simultaneously rather than one at a time. Because of the learning curve involved with implementing anything new, however, it may be wise to start with one or two buildings to ensure that the process, the team, and the method of selecting a commissioning provider are working as expected. Much can be learned from doing just a single project. The knowledge gained from this experience can feed into organization-wide guidelines that incorporate commissioning and retrocommissioning into the organization's energy management program.

For organizations that do not have a formal energy management program, retrocommissioning can be a first step in developing one. Some building owners use commissioning and retrocommissioning as a foundation and catalyst to ensure that all of their buildings' systems perform optimally. They consider this fundamental to the success of their organization's overall energy management program. Developing or fine-tuning the energy management program, including the incorporation of commissioning and retrocommissioning guidelines, can be an additional task for the commissioning provider. **O**

9 Conclusion

Although this guide focuses on the retrocommissioning process and its advantages, all three types of commissioning—retrocommissioning, commissioning, and recommissioning—play an equally important role in ensuring that buildings perform efficiently and provide comfortable, safe, and productive work environments for owners and occupants. For new construction and retrofit projects, commissioning should be incorporated early, during design, and last throughout the length of the project. For buildings that were never commissioned, the retrocommissioning process can yield a wealth of cost-saving opportunities while enhancing a building's environment. Finally, once a building is commissioned or retrocommissioned, incorporating recommissioning into the organization's O&M program (by periodically reapplying the original diagnostic testing and checklist procedures) helps ensure that cost savings and other benefits gained from the original process persist over time. **O**

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