Guideline to the Commissioning Process for Existing Buildings, or "Retro-Commissioning"

The New York State Energy Research and

Development Authority

(NYSERDA)

Developed By

Portland Energy Conservation, Inc. (PECI)

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TABLE OF CONTENTS

LIST OF ACRONYMS 1

GLOSSARY 2

FOREWORD 4

ABOUT NYSERDA 5

THE BASICS OF COMMISSIONING AND RETRO-COMMISSIONING 5

COMMISSIONING PROGRAMS AND ACTIVITIES AT NYSERDA 7

INTRODUCTION 12
- I. PURPOSE 12
- II. DEFINITION 12
- III. OBJECTIVES 13
- IV. COSTS AND BENEFITS 13

THE RETRO-COMMISSIONING PROCESS 14
- I. PLANNING… 16
- II. INVESTIGATION 23
- III. IMPLEMENTATION 27
- IV. HAND-OFF 28

PARTICIPANTS AND RESPONSIBILITIES 30
- I. OWNER OR OWNER'S REPRESENTATIVE 30
- II. BUILDING OPERATOR/O&M STAFF 31
- III. RETRO-COMMISSIONING SERVICE PROVIDER 31
- IV. CONTRACTOR OR MANUFACTURER REPRESENTATIVES 32
- V. DESIGN PROFESSIONALS 32
- VI. TESTING SPECIALISTS 33

CONCLUSION 33

APPENDIX A: STRATEGIES FOR REDUCING RETRO-COMMISSIONING COSTS 34

APPENDIX B: RETRO-COMMISSIONING FIRM EXPERIENCE 37

APPENDIX C: REQUEST FOR PROPOSAL CHECKLIST FOR RETRO-COMMISSIONING SERVICES 39

APPENDIX D: LIST OF POSSIBLE DELIVERABLES FOR A RETRO-COMMISSIONING PROJECT 40

APPENDIX E: BUILDING INFORMATION SUMMARY 41

APPENDIX F: SAMPLE ASSESSMENT FORMS: 44

APPENDIX G: SAMPLE MASTER LIST AND FINDINGS SUMMARY 49

APPENDIX H: SAMPLE DIAGNOSTIC MONITORING AND TRENDING PLANS 57

APPENDIX I: SAMPLE FUNCTIONAL PERFORMANCE TESTS 65
APPENDIX J: COMMISSIONING RESOURCES 78

List of Acronyms

BCA	Building Commissioning Association
Cx	Commissioning
DEC	Department of Environmental Conservation
EMCS	Energy Management Control System
ESPC	Energy Savings Performance Contract
EUI	Energy Use Index
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
LEED™	Leadership in Energy and Environmental Design
NYSERDA	New York State Energy Research and Development Authority
NYGBTC	New York Green Building Tax Credit
O&M	Operation and Maintenance
RCx	Retro-commissioning
RFP	Request for Proposals
RFQ	Request for Qualifications
SBC	System Benefits Charge
TAB	Testing Adjusting and Balancing
USGBC	United States Green Building Council

Glossary

Commissioning

The process of ensuring that systems on new construction projects are designed, installed, functionally tested, and capable of being operated and maintained according to the original design intent and the owner's operational needs.

Diagnostic Monitoring and Test Plan

A plan developed by the retro-commissioning provider to direct the energy management control system trend logging, stand-alone portable datalogging, and manual functional performance testing.

Energy Use Index (EUI)

An index usually expressed in BTUs/Square Foot. EUI is used to compare energy consumption relative to similar building types or to track consumption from year to year in the same building.

Functional Performance Tests

Tests used to diagnose and document equipment system performance issues.

Master List of Findings

A summary list generated during the investigation process outlining each retrocommissioning finding, including "field fixes" made during the course of the investigation. The master list typically contains the following categories of information-finding: identifying number, type of equipment, finding description, recommended improvement, and estimated energy savings.

Retro-commissioning

A systematic investigation process to optimize an existing building's performance. Typical tasks are identifying and implementing relatively low-cost operational and maintenance improvements.

Retro-commissioning Plan

A document developed by the commissioning provider for use by the entire project team. The document provides a brief description of the building and its systems, and an outline of the project's goals. It also briefly describes the scope of each retro-commissioning task, project team member's roles and responsibilities, and appropriate contact information for each team member.

Retro-commissioning Service Provider

A building systems expert who leads the retro-commissioning process, this person can also be called a commissioning provider (CP). This person develops a building specific retro-commissioning plan, coordinates all of the team members tasks, develops a diagnostic monitoring and test plan, conducts or oversees the monitoring and functional testing of the building systems, and develops a master list of findings and an interim report with energy saving estimates. After the owner has selected the findings they wish to implement, the retro-commissioning provider provides selected oversight of the implementation process, retests systems to verify performance, recalculates energy savings from the implementation process, and produces a final report.

Retro-commissioning Team

The individuals that implement a retro-commissioning process. At a minimum, the team will consist of the building owner or their designated representative, building operator, and retro-commissioning service provider. Teams may also include service contractors, equipment manufacturers, design professionals, and testing specialists.

Scoping Study

A low-investment investigation to determining whether retro-commissioning is appropriate for a particular facility. The scoping study helps plan, scope, and budget a full retro-commissioning study. A scoping study helps an owner who is considering retro-commissioning feel confident that the building is likely to have good low-cost, energy-saving opportunities prior to investing in a full retro-commissioning effort. Most scoping studies are accomplished in a short time frame (one to three days) and usually consist of a utility bill analysis and a building “walk-through”.

Foreword

New Yorker's are fortunate that our energy supplies are secure and readily available. Yet as we plan for investment in the State's future, we must consider how to make New York more efficient and environmentally sound, while meeting our future growth needs and improving our economy.

The concept of balancing economic growth with environmental needs has become commonly known as sustainable development. While there is ongoing discussion about what this term encompasses, a major issue concerning future growth will always include how buildings are built and how they use energy. Buildings are the largest energy-using sector in New York State. In 2001, buildings accounted for 50% of the State's total energy consumption. Making buildings more efficient is an important step towards sustainable growth in New York State.

Commissioning and *retro-commissioning* buildings are key processes to help New York accomplish our goal of sustainable growth. *Commissioning* is a process that starts at the beginning of the design stage to verify that the building design will meet all of the building's occupants' needs, and culminates in the inspecting, testing, balancing and verifying that new building systems are operating properly and efficiently. *Retro-commissioning* is a similar process to optimize equipment operation and performance in existing buildings.

Commissioning and *retro-commissioning* help buildings: use energy more efficiently, become less expensive to maintain and operate, and offer occupants greater comfort. Commissioning and retro-commissioning not only reduces the energy consumption and operating costs in buildings, but also increases the resale value of buildings, improves the productivity of its occupants, and can increase the net operating income realized by building owners who rent out space in their buildings. In addition, returns for retro-commissioning services typically pay for themselves in energy savings in two years or less.

Understanding how we use energy in our buildings and how it affects our economy is an important first step towards ensuring our future growth and protecting our environment. Equally important is implementing energy policies and management practices that maintain the balance between a strong economy and a healthy environment.

Commissioning and *retro-commissioning* are two practices that can help ensure our economic growth and help protect our environment and our health. We are pleased to provide this ***Guideline to the Commissioning Process for Existing Buildings*** to further the use of the commissioning process in New York State. In so doing, we are investing in an economic and environmentally sound future for New York State.

Peter R. Smith, Acting President

New York State Energy Research and Development Authority

About NYSERDA

The New York State Energy Research and Development Authority (NYSERDA) is a public-benefit corporation created in 1975 by the New York State Legislature. Since its creation, the role of NYSERDA has constantly adapted and expanded to meet the changing needs of the State. NYSERDA founded itself on bringing innovation and technology to influence energy related decisions that bring about positive economic and environmental benefits. NYSERDA derives its funding from several sources including: the System Benefits Charge, State appropriations, Federal grants, and corporate funding. NYSERDA actively participates in a variety of energy, economic, and environmental topics across New York State, including: renewable energy development, energy efficiency, the development of new processes and materials, combined heat and power/distributed generation, peak-load reduction, energy planning, community development and investment, and environmental monitoring.

NYSERDA assists thousands of businesses and hundreds of thousands of residents each year through its programs. NYSERDA's efforts have helped existing business and industries, as well as attracting new business to the State, develop and implement energy use practices that make them more efficient, and help them expand and maintain their competitive edge in the market. NYSERDA has also played a critical role in lowering energy bills, reducing power plant emissions, and reducing the peak demand on the State's electric grid.

As part of NYSERDA's research and development activities, some 400 innovative projects have helped the State's businesses and municipalities with their energy and environmental problems. Since 1990, NYSERDA has successfully helped develop and bring into use more than 125 innovative, energy-efficient, and environmentally beneficial products, processes, and services.

Commissioning and *retro-commissioning* are two processes NYSERDA supports in its effort to produce a permanent improvement in the construction and on-going operation and management of buildings in New York State. NYSERDA has supported several hundred projects that have included components of commissioning or retrocommissioning since 1996. In addition, NYSERDA's research and development efforts have supported the development and deployment of several commissioning technologies. Commissioning has recently been cited by the American Council for an Energy Efficient Economy as having the second most effective cost/benefit ratio for investing in buildings' energy efficiency in the nation. NYSERDA offers several programs that are designed to encourage and help standardize the commissioning process into the construction, renovation, and building management processes in New York.

The Basics of Commissioning and Retro-commissioning

As a concept, commissioning and retro-commissioning have been in the building marketplace for many years. However, only in the past several years has *commissioning* and *retro-commissioning* become commonly discussed as potential management practices. Many attribute the recent rise in use of commissioning and retro-commissioning to the increased market acceptance of green building practices and the high rate that buildings fail to meet their design intent or the requirements of the building's occupants.

Construction and building management include the integration of many specialized trades that often perform their work independent of each other. Effective communication and issue resolution is vital to building and managing an efficient and lower maintenance building.

Without verification of system interaction and performance, it is unlikely that building owners or occupants will have a building that meets their needs or expectations. The common result from many construction projects that do not include commissioning is a building that has unexpectedly high operations and maintenance costs, does not provide the required comfort for its occupants, is not fully operational, is over budget, or runs beyond its construction schedule.

Commissioning is a systematic process that addresses all of these issues and has been used successfully. Projects like the renovations at the Pentagon used commissioning to keep it on schedule and budget. Effective commissioning is an intentional, visible, cooperative, and proactive management process. Best practice commissioning includes: a formal design intent, design review, installation verification, proper system start-ups, functional-performance tests, operations and maintenance training, confirmation of completeness of all equipment operation manuals, and complete documentation of the final installation configurations. Commissioning helps coordinate the construction schedule and verifies systems perform as designed under all operating conditions. The proper operations and maintenance training of a facility's staff help to ensure that the equipment in the building will perform as designed throughout the equipment's life. The earlier in a construction process commissioning occurs, the larger the benefits that will result. In many cases, however, commissioning is not integrated into the construction process until well after the design phase of the project. Despite a late introduction into the project, it is never too late to commission a construction project. In short, commissioning benefits include:

- Reduced number of change orders and additional claims;
- Fewer project delays;
- Compliance with all start-up requirements;
- Shorter building turn-over and transition period;
- Less post-occupancy corrective work and disruptions;
- Minimization of cost and schedule effects from design changes;
- Improved indoor environmental quality, occupant productivity and comfort;
- Lower energy and operation costs; and
- Value-added quality construction.

Retro-commissioning involves a similar process of verifying that installed equipment is operating efficiently and is capable of providing the services necessary to meet the building's occupants' needs. Retro-commissioning can solve issues of high energy and maintenance costs, occupant complaints, indoor environmental quality, and shorter than expected equipment lives.

COMMISSIONING PROGRAMS AND ACTIVITIES AT NYSERDA

NYSERDA administers a number of programs and initiatives that support commissioning and retrocommissioning in many ways. As you read through these Guidelines, keep in mind the list below of the most commonly used programs and how NYSERDA may be able to assist you in your project. Interested customers should contact NYSERDA to discuss their project to verify that they are interested in the most appropriate program and that they meet program eligibility requirements. Other organizations, such as the Dormitory Authority of the State of New York (DASNY), the Long Island Power Authority (LIPA), the New York Power Authority (NYPA), and the Office of General Services (OGS) may also provide assistance to support customers' commissioning and retro-commissioning efforts. Interested customers should contact these organizations for more information.

New York Energy $mart[SM] New Construction Program and Green Building Program Financial Incentives

NYSERDA's New Construction Program and Green Building Program provides financial incentives to improve the energy efficiency of new and significantly renovated buildings. This program provides cost-shared technical assistance to evaluate electric energy-efficiency improvements during the design process. In addition to this design assistance, incentives are also available to offset a portion of the incremental cost of installing electric energy-efficiency measures that exceed standard design practice. This program has a capital cost incentive cap of $400,000 per building, and provides additional cost-sharing for technical assistance, *commissioning services*, and evaluating green building opportunities in qualified building projects. Additional funding is available for building integrated photovoltaics and advanced day-lighting technologies. All projects receiving over $100,000 in New Construction Program capital incentives are required to implement at the minimum a post-construction commissioning plan. The Green Building Program portion of this offering is being successfully used by many projects to assist building owners comply with the requirements of the U.S. Green Building Council's LEED[TM] rating system and the New York State Green Building Tax Credit.

NYSERDA's Green Buildings Program has also supplied technical and financial assistance in the development of the New York City Department of Design and Construction's High Performance Building Guidelines.

Project website: **http://www.nyserda.org/815pon.html**

http://www.nyserda.org/green.html

Program contact: NYSERDA

Toll free at 1 (866) NYSERDA

Info@nyserda.org

Technical Assistance Program

This program assists businesses, institutions, local governments, and other building owners with detailed on-site engineering studies. These can include, but are not limited to: technical and cost-benefit analyses; assessments of industrial process improvements; design and planning assistance; and *commissioning of equipment, systems, and buildings*. These services are provided on a cost-shared basis. Each project is specifically tailored to meet the customer's energy-related needs.

According to a survey of NYSERDA's clients, two-thirds of all projects implement recommendations made by Technical Assistance contractors. Each dollar spent on engineering services has resulted in $14 in capital improvements and $4 per year in energy savings. Due to the funding source for this program, eligible commissioning projects must have a primary focus of improving energy efficiency. The final reports for these projects must include a detailed list of all deficiencies identified and corrected as part of the commissioning evaluation, with associated energy savings calculations. These reports must identify the assumptions that the energy savings are based upon.

Program website: **http://www.nyserda.org/techasst.html**

Project contact: NYSERDA

Toll free at 1 (866) NYSERDA

Info@nyserda.org

FlexTech

The FlexTech program primarily focuses on increasing productivity and economic competitiveness by identifying and encouraging the implementation of cost-effective energy-efficiency measures. NYSERDA has contracted with 36 highly qualified firms that were competitively selected through an RFP process. These firms provide a variety of technical assistance services to eligible customers. Each project is custom-tailored to fit the customer's energy-related needs. Due to the funding source for this program, eligible commissioning projects must have a primary focus of improving energy efficiency. The final reports for these projects must include a detailed list of all deficiencies identified and corrected as part of the commissioning evaluation, with associated energy savings calculations. The assumptions the energy savings are based upon must also be identified in the report.

These services are provided on a case-by-case, cost-shared basis, and include:

- Engineering feasibility and technical assistance studies;
- Detailed analyses of specific energy-efficiency projects;
- Process improvements;
- Technical training and seminars on energy-efficiency topics and technologies;
- Engineering in support of project-financing proposals;

- Commissioning of energy-efficiency measures from pre-design through post-installation;
- Sustainable development and green building assistance.

Program website: **http://www.nyserda.org/flextech.html**

Project contact: NYSERDA
Toll free at 1 (866) NYSERDA
info@nyserda.org

New York State Green Building Tax Credit

Through its FlexTech and New Construction Program, NYSERDA has provided computer modeling and materials' analysis to building design teams to help make new and rehabilitated commercial, industrial, and institutional buildings environmentally responsible, economically viable, and healthier places in which to work. Projects applying to the New York State Green Building Tax Credit are required to be commissioned.

NYSERDA, along with its consultant Steven Winter Associates, provided technical assistance to the New York State Department of Environmental Conservation (DEC) in developing the technical components of proposed draft regulations for New York State's Green Building Tax Credit. For more information on the tax credit, please see:

Program website: **http://www.nyserda.org/green.html**
http://www.dec.state.ny.us/website/ppu/grnbldg/index.html

Program contact: Craig Kneeland
(518) 862-1090 Ext. 3311 or toll free at 1 (866) NYSERDA Ext. 3311
cek@nyserda.org

Executive Order No. 111, *"Green and Clean" State Buildings and Vehicles*

On June 10, 2001, Governor Pataki issued Executive Order No. 111, *"Green and Clean" State Buildings and Vehicles*. This is one of the most aggressive directives ever issued to address energy use and environmental issues through procurement standards and design practices. As a fundamental component to the Governor's Order, State agencies, department, authorities and other organizations where the Governor has executive authority are directed to begin incorporating *commissioning* and *retro-commissioning* into their construction and building management plans. Affected Stated entities are directed to seek out funding sources and assistance, similar to the previously mentioned programs, to assist them in complying with this directive. Other facilitating agencies, such as the Dormitory Authority of the State of New York, the Long Island Power Authority, the New York Power Authority, and the Office of General

Services also offer assistance to help affected state entities to comply with the *commissioning* and other requirements of Governor Pataki's Order.

Executive Order No. 111 Website:	www.nyserda.org/exorder111.html
Executive Order No. 111 Contact:	Matt Brown
	(518) 862-1090 Ext. 3336 or toll free at 1 (866) NYSERDA Ext. 3336
	mcb@nyserda.org

Future Goals of Energy Efficiency and Commissioning in New York State

As NYSERDA continues to administer the **New York Energy $mart**[SM] Program through 2006, energy efficiency, peak-load reduction, and electric grid reliability will continue to be key areas of responsibility. In order to achieve these goals, NYSERDA will also continue to help foster and shape the green building market in New York State and keep stressing economic growth and environmental protection to foster sustainable energy decisions.

The operational efficiency of buildings, as the single largest consumer of energy in New York State, will continue to be a major focus of NYSERDA's activities. Studies indicate a building's efficiency can be dramatically increased with minor financial investments and disruption to the operations of a building. NYSERDA completed a study of buildings commissioned as part of its initial assessment of commissioning in 1996. This study showed that the energy efficiency of buildings were able to exceed the requirements of the New York State Energy Conservation and Construction Code of the time by an average of 32%, which reduced annual carbon dioxide emissions by more than 22,000 tons. In addition, the peak-electric demand can be reduced in buildings studied by an average of 40%.

Commissioning and *retro-commissioning* can significantly reduce a building's energy use and operating costs. On average, a sample of commissioning projects that have participated in NYSERDA's New Construction Program that have been commissioned for green building purposes, have been completed for less than 1% in construction cost, with a simple payback of 4.5 years. Retrocommissioning has also proven to be cost-effective. A study of 44 retrocommissioning projects found energy savings of 5 to 15%, resulting in simple paybacks, based on energy savings alone that rarely exceeded two years.[1] Through its **New York Energy $mart**[SM] Program, NYSERDA is committed to supporting commissioning and retro-commissioning projects to help New Yorkers realize the energy savings that can result from this practice.

As part of its overall market support, NYSERDA is a member of the Building Commissioning Association and the U.S. Green Buildings Council. NYSERDA will continue to play a role in these organizations and support commissioning as appropriate based upon our mission. The President of NYSERDA is also a key member of the Governor's advisory network in its role as coordinator of New York State's Energy Plan, Chair of the Advisory Council on State Energy

[1] J. Gregerson, "Cost Effectiveness of Commissioning 44 Existing Buildings," in *Proceedings of the National Conference on Building Commissioning* (Huntington Beach, Calif., April 28-30, 1997)

Efficiency for Executive Order No. 111 and Chair of the Green House Gas Task Force. The President of NYSERDA is also the Chair of the Governor's Energy Planning Council. To help meet all of its responsibilities to the State, NYSERDA's Energy Analysis Program provides data and analysis to keep the public and government decision makers informed of trends in all segments of the energy market.

Introduction

I. Purpose

This guideline provides readers with basic information about applying the commissioning process to existing buildings, or "retro-commissioning." *Retro-commissioning* (RCx) is a process of verifying that installed equipment is operating efficiently and is capable of providing the services necessary to meet the building occupants' needs. The RCx process addresses problems that lead to high energy and maintenance costs, occupant complaints, poor indoor environmental quality, and premature equipment failure.

It is estimated that New York State has more than one hundred thousand existing public and private buildings that could benefit from the RCx process. Governor George E. Pataki's Executive Order No. 111, *"Green and Clean" State Buildings and Vehicles*, officially recognizes RCx as a key strategy in complying with the goal of reducing energy use in State facilities by 35% from 1990 levels by 2010. In order to promote RCx and its benefits, the New York State Energy Research and Development Authority (NYSERDA) offers financial assistance for both public and private RCx projects through its Flex Tech and Technical Assistance programs. Note: Due to the funding sources for these programs, the primary goal of RCx projects must be to improve energy efficiency. To receive these incentives from NYSERDA, formal energy-saving calculations are required for each deficiency that is identified.

This guideline explains RCx terminology, its phases and procedures, the roles and responsibilities of the team members, costs, benefits, how to get started and how to increase a project's cost effectiveness. The guideline is written specifically for those interested in obtaining cost-effective operation and maintenance (O&M) improvements that do not entail a large capital investment. Although this is not a detailed "how-to" manual for commissioning service providers, it offers valuable information on the RCx process and the roles and responsibilities of the building owner, building staff, and RCx service providers.

II. Definition

Retro-commissioning is a systematic investigation process for optimizing building performance by identifying and implementing relatively low-cost operational and maintenance improvements. RCx is not a substitute for major repair work. Known problems should be repaired before RCx begins.

The RCx process not only optimizes how equipment and systems operate, but how the systems *function together*. When carried out in a methodical way, RCx can sometimes preclude the need for expensive capital improvements. Often, RCx is cost-effective enough to be funded entirely by the building's operating budget.

RCx may or may not emphasize bringing the building back to its original design. When the original design documentation no longer exists or the occupant's needs have changed, the RCx service provider may assist the building staff in creating new building documentation based on the current operational needs of the occupants.

Although in some cases the RCx process is sufficient for meeting project goals, in others it is only the first step in improving the facility's performance. RCx is in some cases followed by a more thorough energy study of potential capital improvements recommended during the RCx process.

III. Objectives

The RCx process is a project-specific effort. Each project's focus and goals, as well as the level of rigor, depend on the needs of the owner and occupants, the budget, and the condition of the facility and equipment. RCx most often focuses on dynamic energy-using systems with the goal of reducing energy waste, obtaining energy cost savings, and identifying and fixing existing problems. Many owners use retrocommissioning to:

- Reduce energy and demand costs;
- Bring equipment to its proper operational state;
- Reduce occupant complaints;
- Improve indoor environmental quality;
- Reduce premature equipment failures;
- Improve facility operation and maintenance procedures; and
- Reduce staff time spent on emergency or complaint calls.

In some cases RCx may be undertaken at the same time as other complementary processes or projects such as major equipment replacements or major retrofits (upgrades).

IV. Costs and Benefits

RCx project costs typically range from $0.10 to $0.50 per square foot. However, depending on the complexity of the systems and project goals, costs can vary. Many RCx projects identify energy-saving findings that, when repaired, can yield simple paybacks ranging from two months to two years. It is important to bear in mind that cost and payback time, like the process itself, are unique to each project. Variables affecting both include:

- Scope of the project;
- Number and complexity of systems;
- Size of the facility;
- Equipment condition;
- Commissioning service provider rates; and
- Level of on-site staff interfacing with the project.

Quantifying the benefits of the RCx process can be difficult. Benefits such as energy savings can be derived relatively easily by calculation or monitoring systems. Other benefits of the process including: extended equipment life, improved worker productivity, and reduced operation and maintenance (O&M) costs, though less easily quantified, should not be overlooked. For owners concerned about indoor environmental quality (IEQ) litigation and improving the building's asset value, documenting the RCx process may be a primary goal of the project and may help lower insurance risks and improve worker productivity.

These benefits are of value not only to owners who occupy the facility, but to owners who rent building space as well. Although little research to date documents the link between building comfort and worker productivity, common sense tells us that comfortable employees are more productive. How long will tenants who are experiencing comfort-related productivity problems remain tenants? This issue is of critical importance for landlords as tenant turnover can be costly. Table 1 shows an example of the estimated cost of losing a tenant in Class A office space.

Table 1. Cost of Losing a Tenant[2]

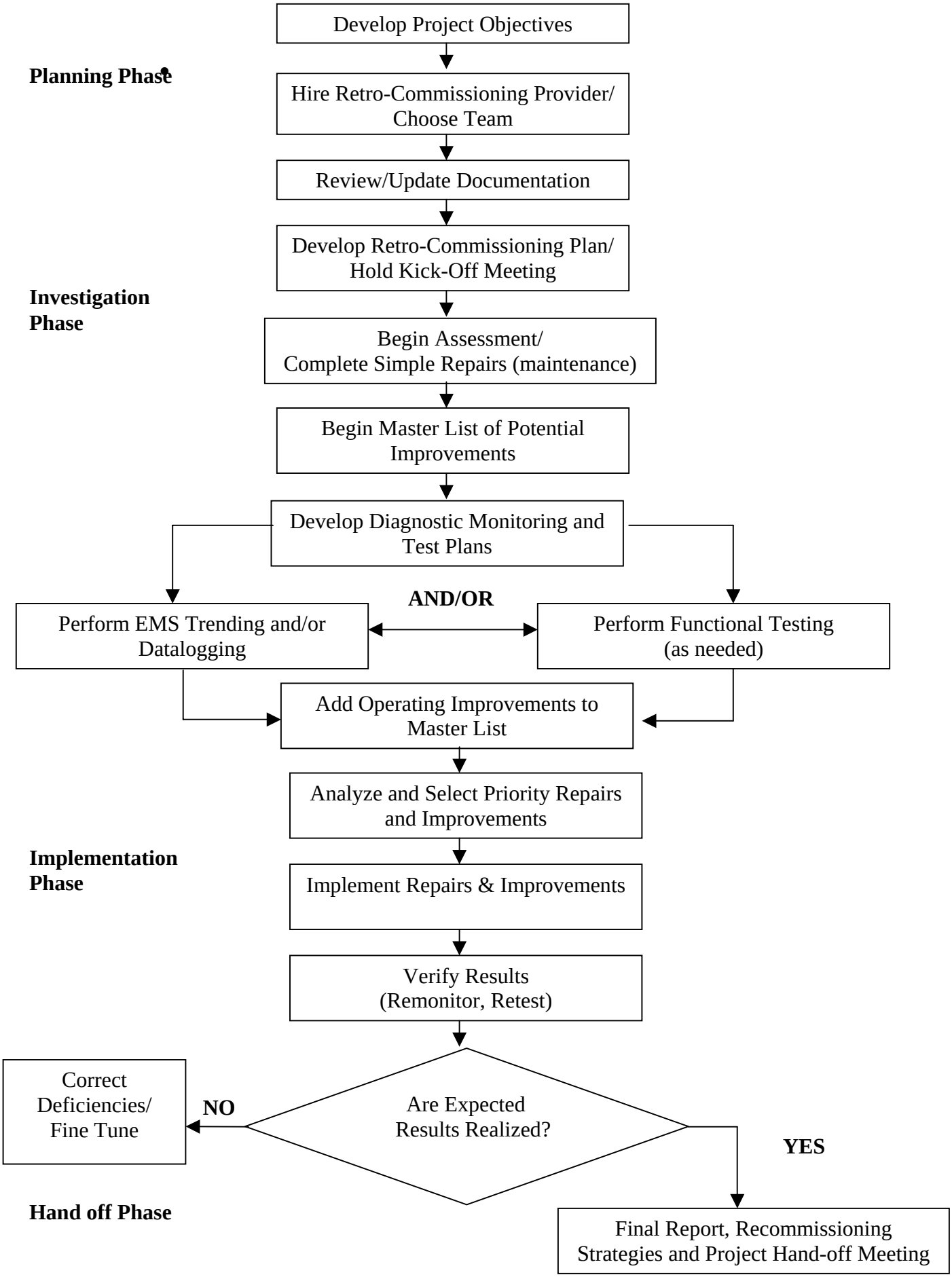
Five-year lease value	$612,500
Rent loss due to vacancy	$30,625
Improvements for new tenant	$35,000
Leasing commission	$30,625
Total cost of losing tenant	**$96,250**

Assuming a 3,500 square foot Class A office space rented at $35/square foot a year, a typical five-year lease has a value of $612,500. If a tenant leaves, this space will remain vacant an average of three months, for a total rent loss of $30,625. Improvements and build-outs to satisfy a new tenant could cost $10/square foot, or $35,000. In addition, the building owner often pays a leasing commission of 5% of the five-year lease value, or $30,625. Thus, the total cost of losing one tenant could run $96,250 or 15.7% of the five-year lease value. If a building develops a reputation for being uncomfortable and unproductive, the vacancy period could last longer. Market research shows that dissatisfied customers, in this case tenants, are likely to complain to seven to 10 of their peers.

The Retro-commissioning Process

A well-planned and executed RCx project typically occurs in four distinct phases: Planning, Investigation, Implementation, and Handoff. The following flow chart outlines each phase and the specific tasks it includes. In some cases the tasks may overlap, occur simultaneously, or be eliminated entirely. Variables that affect the RCx process include the condition of the facility, scope of the project, budget, and availability of in-house expertise. Sometimes the Planning phase is completed partially or fully by the owner or building staff before the RCx service provider is brought on board.

[2]Data revised by PECI based on format developed by David Zier of Melvin Mark Company, 2000.


Planning Phase
Develop Project Objectives
Hire Retro-Commissioning Provider/ Choose Team
Review/Update Documentation
Develop Retro-Commissioning Plan/ Hold Kick-Off Meeting
Investigation Phase
Begin Assessment/ Complete Simple Repairs (maintenance)
Begin Master List of Potential Improvements
Develop Diagnostic Monitoring and Test Plans
AND/OR
Perform EMS Trending and/or Datalogging
Perform Functional Testing (as needed)
Add Operating Improvements to Master List
Analyze and Select Priority Repairs and Improvements
Implementation Phase
Implement Repairs & Improvements
Verify Results (Remonitor, Retest)
Are Expected Results Realized?
NO
Correct Deficiencies/ Fine Tune
YES
Hand off Phase
Final Report, Recommissioning Strategies and Project Hand-off Meeting

I. Planning

The primary tasks for the Planning phase are developing internal goals and support for the project, selecting and hiring a RCx service provider, and assembling the team that will see the project through to completion. All of these initial steps are critical to ensuring a successful RCx project. The following discusses the major planning phase activities.

Develop Project Objectives

The RCx process begins by defining project goals in writing and clearly communicating the goals to the project team. Often the primary goal is to obtain cost savings from improving the operation of the building's energy-using equipment, given the current operating requirements. Identifying and eliminating potential indoor environmental quality and occupant complaints are often high on the list of RCx objectives. The goals and scope may need to be coordinated with requirements established by outside funding sources. The following examples list objectives from an actual RCx project:

- Obtain and verify cost-effective energy savings. Verification will require limited performance monitoring of selected building systems.
- Identify and recommend improvements to operational strategies and maintenance procedures, focusing on those measures that sustain optimal energy performance and reduce operating costs.
- Identify HVAC-related health and safety issues as they present themselves during the normal course of the RCx work.

RCx is often conducted in association with a major retrofit project implemented as part of an Energy Savings Performance Contract (ESPC). In these cases, it is important to consider whether RCx should be conducted *before*, or as *part of*, the agreement. There are two primary reasons for performing RCx *before* obtaining an energy-savings agreement. The low-cost/no-cost energy savings gained from RCx remains with the building (the owner gets all of the savings) and does not become part of the financial agreement. And by optimizing the existing equipment, only the most appropriate capital measures are selected and financed through the agreement.

When RCx is performed *before* the energy savings agreement is finalized, it is important to inform the contractor about the RCx activities and provide a copy of the Final Report. Because RCx often lowers energy bills, an uninformed contractor may use energy bills from prior years to determine the energy baseline. The result could be an inaccurate baseline, resulting in lower cost savings than expected and less project cash flow than planned, potentially leading to a disagreement between the owner and the energy savings contractor.

RCx performed up-front to capture low-cost savings may not be a wise choice if the savings from the retro-commissioning does not remain with the building's operation and maintenance budget, but instead goes into a "general fund." In this case, it may be more advantageous for the facility if the low-cost/no-cost improvements were part of the performance contract. This way, a portion of the savings stays with the building as part of the financial arrangement. Integrating the RCx measures into the energy-savings agreement is a way to capture the savings as part of the investment repayment. The amount invested can be increased when the savings estimates are higher. Also, the savings gained from bundling these measures with the capital upgrades,

especially if some of the upgrades are marginally cost-effective (good value but long paybacks), helps to increase the overall viability and attractiveness of the ESPC funding.

RCx conducted as *part of* an energy-savings agreement will also ensure that new equipment performance is not hindered because it interfaces with older equipment, components, or systems that are malfunctioning. When commissioning is specified solely for new equipment, it often stops short of the holistic perspective of the whole-building RCx process, which evaluates how new equipment interfaces with existing systems and their performance. This is especially true for energy management control systems. Controls are an area where difficulties and misunderstandings often occur between building owners and performance contractors. For this reason, it is a good idea to specify commissioning for both the new and existing equipment. Note: NYSERDA's Commercial Industrial Performance Program (this is an ESPC program) does not fund RCx services but will fund electrical energy-saving capital equipment upgrades identified by a RCx project for eligible projects. Building owners interested in commissioning performance-based projects may be eligible for co-funding the commissioning portion of the project through one of NYSERDA's Technical Assistance programs.

Select the Building

Some buildings or groups of buildings make better candidates for RCx than others. Although owners often want to RCx their worst performing buildings, these facilities should not necessarily be given priority to be retro-commissioned as the worst performing buildings are not necessarily cost-effective candidates (these buildings should receive priority for a comprehensive energy-feasibility study). Newer buildings, on the other hand, often provide the most energy savings and non-energy benefits for the least cost.

When is RCx appropriate? Indications that a building may be a candidate for RCx include:

- An unjustified, high energy-use index (Btus/square foot);
- Persistent failure of building equipment, control system or both; or
- Excessive occupant complaints about comfort.

To some extent, it is easier to answer this question by describing when RCx is not appropriate. This includes cases where:

- Most of the equipment and systems are either outdated or at the end of their life;
- Major system design problems exist; or
- Major equipment malfunctions exist such that the best remedy is an equipment replacement.

Many buildings in New York are owned or managed by government agencies, investment trusts, or property management firms, all of which have diverse building portfolios. These organizations are prime candidates to undertake RCx because their broad holdings allow them to select the buildings with the most potential for success in the RCx process. Owners of multiple buildings may want to develop a spreadsheet to better understand, compare, and prioritize their building stock to determine which sites present the most opportunity for RCx. When evaluating a candidate for RCx, it is helpful to consider the following information:

General Information

- Building type
- Number of occupants

- Size (gross square feet)
- Year of construction
- Year of last renovation

Building Equipment

- Central heating/cooling plant
- Packaged units
- District heating
- District cooling
- Computer energy management system
- Age of primary heating/cooling equipment

Energy Data (Ideally, three years worth)

- Annual hours of operation
- Annual energy use (kWh/year)
- Annual electric use per square foot (kWh/square foot)
- Peak demand for last 12 months
- Natural gas use (ccf/year)
- Annual gas use (Btus/square foot)
- Annual district heating (lbs of steam/year)
- Annual district cooling (Ton hours/year)
- Average annual energy use index (EUI) for region/city for similar type building. EUI's are typically measured in (Btus/square foot)

It may be necessary to conduct a preliminary "walk through evaluation" or scoping study of the building candidates in order to make the final decision on which building(s) to RCx. A scoping study often reveals problems and opportunities that database analysis and phone conversations with building staff cannot. The scoping study offers a low-investment opportunity to determining whether RCx is appropriate for a particular facility. Highly qualified building operational staff may be qualified to do this type of study. It also provides the owner and provider with a planning mechanism that helps define the objectives, scope, and budget for the larger RCx effort. A scoping study is accomplished in a short time frame (one to three days) and consists of a utility bill analysis and a building "walk-through". These two activities result in a brief report that describes the possible energy-saving opportunities and recommends an approach to capturing the savings. A scoping study helps an owner who is considering RCx feel confident that the building is likely to have good low-cost, energy-saving opportunities prior to investing in a full retro-commissioning effort. Some organizations use the scoping study to justify and get buy-in from upper management or outside funding sources for the need for RCx. A scoping study and preliminary report may be required by organizations that offer incentives for RCx activities that provide energy savings.

Obtain Support and Buy-in from Building Management and Occupants

In order to complete a successful RCx project, the building owner must secure management commitment and the support of building staff. No less important is acquiring occupant cooperation and support, and allocating adequate time and funds. Before beginning a RCx project, it is important to understand the resources available for accomplishing the work. Most

successful RCx projects have an internal "champion" to help push the project and convince others of the value of this process. Analyzing your organization's way of allocating funds for maintenance expenditures and capital improvements may reveal sources of funding for RCx that would have gone unused or been spent on other projects. The fact that RCx projects typically have quick paybacks and immediately address building problems, may help convince decision makers to allocate funding. Using outside resources to pay for some or all of the RCx costs should also be investigated. For example, NYSERDA has funding available for RCx projects through its Technical Assistance and Flex Tech programs. The primary goal of projects that apply for NYSERDA funding must be to improve energy efficiency and must include calculations quantifying energy savings as part of the RCx process.

Select and Hire a Retro-commissioning Provider

The network of qualified RCx service providers in New York is growing. NYSERDA is supporting the growth of the State's RCx infrastructure by funding RCx projects through its Flex Tech and Technical Assistance Programs, and engaging in marketing and outreach efforts. The Flex Tech program includes a number of professional engineering firms capable of providing RCx services on its pre-approved list. The list of these consultants can be obtained on-line at: www.nyserda.org/flextechconsultants.html The Building Commissioning Association (BCA) is another resource to find RCx service providers. The BCA is a professional organization with the goal of "achieving high professional standards, while allowing for the diverse and creative approaches to building commissioning that benefit our profession and its clients." A list of BCA members can be found on-line at www.bcxa.org. Utilities, professional associations, and other government agencies may also have lists of commissioning service providers that can be used as a starting point for choosing a commissioning service provider.

At the time this Guideline was written, there is no certification process for commissioning service providers enacted, however, the Building Commissioning Association is in the process of developing one. In the absence of certification, it is necessary to determine if a potential commissioning service provider has the necessary experience to provide services for your project. Appendix B contains two forms to help define the required experience of a retro-commissioning service provider. These sample forms should be customized to reflect the needs and priorities of each specific project.

The typical approach for seeking RCx services includes:

- Evaluating the commissioning service provider's experience with similar building systems and problems
- Requesting and contacting references
- Evaluating ancillary skills such as diplomacy, negotiation, communications, meeting facilitation, listening, investigation, and reporting abilities

Considering the following factors:

- Is retro-commissioning a core business or a primary business component of the firm?
- Are any work samples, such as final retro-commissioning reports, available for review?

- Are there any lists of retro-commissioning service providers available from local utilities or state and local government organizations?
- Is the firm a full member of the Building Commissioning Association (BCA)?

It is important that the skills of the RCx service provider match the goals and scope of the project. For example, if improving indoor environmental quality (IEQ) is the primary objective for RCx, then the individual or firm hired for the job must be skilled at investigating and solving IEQ problems. If the primary goal for the RCx project is to improve energy efficiency, then the individual or firm hired for the job must be skilled at investigating and documenting energy-efficiency improvements.

Typically, qualified RCx service providers are identified and selected through either an existing relationship with the owner, a Request for Qualifications (RFQ), or a Request for Proposals (RFP) process. A RFQ allows an owner to select a provider by evaluating their qualifications without first developing a detailed scope of the work. In this way, the desired scope of work can be developed while a group of qualified firms and their references are being established and contracted.

Alternatively, a Request for Proposals (RFP) may be issued. Most government entities and many corporate owners may be required by their financial restrictions to use an RFQ/RFP process. A sample RFQ/RFP template document is available for download from NYSERDA's website at: http://www.nyserda.org/commissioning.html Appendix C contains a checklist of factors to consider when putting together a RFQ or RFP.

As part of an RFQ/RFP, the owner or manager should provide a list of expected products or deliverables resulting from the RCx process. Some possible deliverables could include:

- Retro-commissioning Plan;
- Master List of Findings and Improvements;
- Progress Reports and Meeting Minutes;
- List of Recommended Capital Improvements for Further Investigation;
- Final Report; and
- Recommissioning Manual.

The number and type of deliverables will depend on the scope of the project. Appendix D contains a list of suggested deliverables that may be required for each phase of the project.

Additionally, you may want to see an example of the service provider's work, such as a Final Report, testing and monitoring protocols, or a list of recommendations with savings estimates from a recent project. If the project is large or complicated a pre-proposal meeting, including a site visit to the buildings that are included in the project, may be necessary. This approach helps level the playing field so that each party has the same information when developing their bids and helps the service providers more accurately bid on the project.

Some projects may require two phases of bidding. On complex projects or neglected buildings, without first completing the planning and investigation phases (discussed later in the document), some service providers have a difficult time in accurately accessing how much time will be required to complete the RCx implementation and hand-off phase tasks. The bidding service provider(s) may request to initially bid only on the planning and investigation phases of the project and negotiate or bid again for the implementation and hand-off phases later. This approach helps them in providing a more comprehensive and accurate cost estimate and realistic scope of work.

Build the In-house Team

RCx projects typically require building managers, facilities personnel, and retro-commissioning service providers to work together as a unified team. It is important that the necessary skills and authority are represented in each group. Ultimately, the project team should consist of only those people most critical to accomplishing the work. It is the owner's responsibility to bring the overall team together. Most organizations hire a RCx service provider to guide the project. However, the most cost-effective and beneficial projects also involve at least one in-house staff person with expertise in the building's control system, HVAC equipment, and lighting systems. The ideal in-house team member will be familiar with the building history and understand why and how the systems are operated. In addition to the information they provide, the staff person benefits from participating in the RCx process in the training and knowledge they acquire. In-house O&M staff can be expected to learn about the equipment and its operation, as well as troubleshooting and testing methods that can later be applied to the facility's daily O&M program. Appendix A provides tips on how in-house staff participation prior to and throughout a RCx project can reduce overall RCx costs and increase the benefits of the process.

For buildings with in-house staff, the building operator is one of the most important team members. Ideally, the operator will have in-depth knowledge of the building control systems, understand how and why equipment and systems are currently operated and maintained, and have access to historical data. Buildings with maintenance service providers or existing relationships with controls contractors, should also include these groups in the RCx process.

The RCx service provider may have varying levels of involvement in the process, depending on the level of trust and confidence established. The RCx service provider must have experience in troubleshooting, problem solving, diagnostic monitoring, testing, and analysis in order to identify problems with building systems that must be solved. The RCx service provider must also be provided the authority to question any current uses of equipment, practices, or methods that may be causing problems and identify useful and cost-effective solutions for the problems.

Develop the Retro-commissioning Plan and Hold a Kickoff Meeting

After gaining a clear understanding of the project goals, the RCx service provider has the primary responsibility for developing the final RCx work plan and seeking input and review from the owner and owner's staff. Including the building operating staff during the final retro-commissioning work plan's development facilitates the building operating staff's desire to see the process succeed.

The final work plan usually includes the following:

- General building information and contact (name, address, telephone numbers, etc.);
- Project goals;
- Building and systems description (brief);
- Project scope;
- Roles and responsibilities;
- Schedule (for primary tasks);
- Documentation request;
- Investigation scope and methods;
- Implementation phase requirements; and
- Project hand off.

The scheduling of project work should coincide with the project goals. For example, if there are increased complaints regarding cooling, 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 changes during the course of the project.

Generally, the RCx service provider facilitates a kick-off meeting with the development of the final work plan as the primary focus. The kick-off meeting brings all of the team members together to review, discuss, and agree to the final RCx work plan. The primary role of the owner or manager is to reiterate the objectives for the project and show support. Each team member's responsibilities are discussed and the schedule is agreed to. The kick-off meeting sometimes includes people who have a vested interest in the project but are not directly responsible for performing work, for example a representative of the local utility.

II. Investigation

The primary goals of the investigation phase are understanding how and why building systems are currently operated and maintained, identifying issues and potential improvements, and selecting the most cost-effective "fixes" for implementation. Depending on the scope of the project, this phase may look at all aspects of the current O&M program as well as the management structure, policies and user requirements that influence them. Tasks during investigation may include interviewing management and building personnel, reviewing current O&M practices and service contracts, spot testing equipment and controls and trending or electronic data logging of pressures, temperatures, power, air and water flows, and lighting levels and use.

The investigation phase is generally the most time consuming and expensive part of the retro-commissioning process. The following discusses the major investigation phase activities.

Gather and Review Facility Documentation

The RCx service provider uses building documentation to develop the site assessment forms and the diagnostic and functional test plans that will be required to verify equipment performance. The collection of building documentation begins immediately after the project has been approved for go-ahead. Important documentation categories include the Energy Management Control System (EMCS), operation and maintenance manuals, original design intent documents, equipment lists, and test, adjust and balance (TAB) reports. Appendix E provides more detail about what kinds of information that should be collected.

Begin Assessment and Complete Simple Repairs, Begin Master List of Potential Improvements

The goal of the site assessment is to learn how and why building systems and equipment are currently operated and maintained, and to discuss with building staff and occupants what they consider to be the most significant problems. The site assessment usually includes interviewing building staff and users. After the site assessment the RCx service provider begins to develop a list of cost-effective strategies and recommended improvements for optimizing building performance.

Some projects may require the RCx service provider to develop a formal site-assessment document that includes a detailed building staff interview regarding operating strategies and an in-depth site survey of equipment condition. Assessment forms help guide the interview process with building staff. Site assessment forms are also developed for each piece of equipment and system that is selected for RCx. Assessment forms may address either operation or maintenance issues or both depending on the scope of the project. Appendix F contains sample assessment forms for a hydronic pumping system and a sample of an operation and maintenance interview questionnaire.

The site-assessment is an *information-gathering exercise*. Interviewing building operators who possess an historical knowledge of the building and experience working with its control systems expedites this task. Due to their familiarity with the building and its systems, O&M staff may already have most of this information on hand. Filling out the assessment forms helps them organize the information and better target the RCx activities. Minor repairs and simple improvements may be implemented during the assessment, however, the major problem-solving and improvement recommendations generally occur at the end of the investigation phase, after all the information is analyzed.

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 maintenance 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; and
- Current O&M practices.

Depending on the scope of the project, the site assessment can take anywhere from one to several days to complete. It is common for many problems and obvious corrections to reveal themselves during this phase. 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 Findings (discussed later) and documented on the applicable site assessment form. Engineering calculations can often be applied later to determine the value of these adjustments and repairs. Appendix G contains a sample of a Master List of Findings.

The site assessment should uncover the best opportunities for optimizing energy-using systems and improving O&M practices. It provides the starting point for evaluating the effectiveness of improvements and O&M activities. It also provides a basis for recommending where diagnostics and testing may be appropriate. Diagnostic testing helps to better pinpoint problem causes and verify that a problem does in fact exist.

In some cases, it may be necessary to require the entire site 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. Alternatively, if the building lacks written control strategies, the operating part of the assessment is valuable for developing this missing information in-house.

Develop Diagnostic Monitoring and Test Plans

The results of the site assessment should indicate areas where future investigation is needed. In these cases, the RCx service provider should develop the appropriate diagnostic monitoring and test plans.

Diagnostic monitoring and testing allows the RCx service provider to observe temperatures along with critical flows, pressures, speeds, and electrical currents of the system components under typical operating conditions. By analyzing this information, the RCx service provider determines whether the systems are operating correctly and in the most efficient manner. Three typical diagnostic methods are: energy management control system trend logging, stand-alone portable datalogging, and manual functional testing. Often a combination of these methods is used. Appendix H contains examples of sample diagnostic datalogging and trend logging plans.

The RCx service provider and the owner schedule the implementation of the diagnostic monitoring, testing, and the associated preparatory work. Preparing for monitoring and testing may include checking and calibrating control points such as temperature sensors. In order to reduce project costs, the facility staff should complete the calibration work under the direction of

the RCx service provider. If data loggers are used, facility staff should assist in the installation and removal of the loggers, when possible. The trend logging plan may be carried out by the facility staff, but may require assistance from the controls vendor, particularly on developing, formatting and downloading computer files for analysis by the RCx service provider. Results from monitoring, via trend logs or data loggers, are provided in annotated graphical or columnar format for reporting purposes.

The retro-commissioning service provider usually directs the functional performance tests. Facility staff, a control vendor, or other appropriate parties assist with the hands-on operation of the equipment being tested. The RCx service provider documents manual testing and observed results on the test plan forms. The forms also describe the piece of equipment or system and the detailed test procedures. In some cases these forms are adapted from new construction commissioning functional performance tests. Appendix I contains an example of a functional performance test form.

After diagnostic monitoring and testing are completed, the findings are analyzed and checked against the site-assessment information. Any resulting changes, additional findings, or potential improvements are summarized on the Master List. At this point the RCx service provider will estimate the savings associated with the findings. These estimates will help the owner to prioritize which findings they wish to implement later in this process.

Develop an Initial List of Findings

Concurrent with the site assessment, the RCx service provider will begin to develop a Master List of Findings. The Master List is one of the most significant deliverables from the RCx process and ultimately becomes an important decision-making tool for the facility manager and building staff. Every finding from the investigation phase is summarized on the Master List, including those "field fixes" made during the course of the investigation. The master list should contain the following categories of information-finding: identifying number, type of equipment, finding description, recommended improvement, estimated energy savings, etc. Appendix G contains samples of different Master List findings formats.

To better understand the findings, the owner or manager may require the RCx service provider to categorize them according to type or source. For example, findings may fall into four primary categories: maintenance, operation, design, or installation. Understanding where the more costly findings fall helps management understand where organizational improvements may be needed. For example, several findings falling under the "installation" category may indicate a need for the owner to require commissioning for future new construction or new equipment installations. Such findings may also suggest taking a hard look at who is providing the installation service. If the majority of problems are maintenance related, it may indicate a need for additional staff, more training, or a better-managed service contract.

After the Master List of Findings is complete the RCx service provider assembles an interim report highlighting the process and findings. The interim report is a primary decision-making tool for the owner and typically contains a Master List of the RCx findings and recommended solutions, and a cost benefit analysis. An implementation plan may also be included depending on the RCx scope of work's requirements. See Appendix G to see a sample of how a finding may be detailed to include an implementation plan. The methodology for arriving at the costs and benefits or energy cost savings is also included along with any engineering calculations. For projects receiving outside funding, like NYSERDA funds, the project team should clarify before

the project begins any specific documentation or application processes that are required for payment of incentives.

The following are typical deliverables for the investigative phase:

- Short-term diagnostic monitoring and functional test plans;
- The Master List of Findings and recommendations;
- Completed test and monitoring plans;
- List of repairs, adjustments, and other improvements made during investigation; and
- List of selected improvements for immediate implementation including costs and ROIs (estimates of return on investment).

Many building owners use maintenance service contracts to augment their O&M program. Where this is the case, a service contract review may be a required deliverable for the RCx process. This can be particularly important if the timing of the retro-commissioning project coincides with the service contract renewal. The RCx service provider may find ways to increase the value of the service contract by adding critical operational checks to the traditional maintenance check out procedures.

Analyze, Prioritize, and Select Repairs and Improvements

Once the site assessment and diagnostic testing are complete and the Master List is finished, the owner decides which items provide the most benefit and effectively meet the project objectives. If the project is receiving outside funds the implementation requirements of this funding source must also be considered.

On most projects, managers and building owners need to prioritize 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 the fine-tuning of an air-side economizer. The RCx service provider can assist with this decision-making process by analyzing the opportunities and making recommendations for implementation based on the cost-effectiveness of various improvements. Many building owners expect a simple payback of two years or less for improvements that produce energy savings. Many typical findings that result from RCx projects can provide much faster paybacks if some of the work can be accomplished by in-house staff. The savings generated from these improvements can sometimes pay for other improvements that are more capital intensive or have less quantifiable benefits, such as those related to comfort, IEQ, and equipment malfunction.

III. Implementation

During the implementation phase, the more complicated and expensive findings that were not rectified during the investigation phase are completed. This section discusses implementing recommendations from the interim reports and verifying the results, along with some important issues to consider during these activities. The following are Implementation phase activities.

Implement Repairs and Improvements

A primary goal for most retro-commissioning projects is to actually implement the major cost-effective improvements so that results can be realized. Although the investigation phase provides important information, unless improvements are actually put in place, the RCx process remains incomplete. The implementation process may be carried out in-house depending on the ability and expertise of O&M staff. In some cases, implementation will require outside contractors. 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 RCx service provider through the implementation phase, whether the implementation work is done in-house or outsourced, is worth considering. Because the RCx service provider has an intimate knowledge of the building systems and needed improvements, having him or her develop an implementation plan and supervise the implementation may ultimately save time and reduce costs. In addition, it is highly recommended that some functional retesting be performed after implementation. Retesting is discussed in detail below. Through the retesting process, the RCx service provider ensures that improvements are working as expected and that they positively affect other systems, equipment and building occupants. It is not unusual for the retesting to uncover related or hidden problems that could lead to more benefits.

Verify Results (Remonitor and Retest)

Once an improvement or “fix” is completed, retesting to confirm that the effected equipment is operating properly can be done with EMCS trending, manual testing, or datalogging. In some cases, it may be necessary to use a combination of these methods. For example, retesting might involve manually testing the repaired items such as damper motors or valves to verify that they stroke properly, followed by EMCS trending or datalogging 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, the data loggers (or re-initiate the original EMCS trends) and remonitor operations to obtain several days of post-implementation data. The data is then compared to the original data (pre-implementation data) in order to confirm that the combination of improvements are integrated and have the desired 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.

Retesting and remonitoring may also reveal the need for further improvements. Often fixing one problem reveals other opportunities, leading to more savings or improved comfort. At this point it is also important to use applicable port-test and monitoring data to check and adjust the original energy savings estimates to increase their accuracy.

IV. Hand-off

At this point the RCx process is almost complete. The RCx service provider produces a Final Report documenting the process and its findings, and holds a project close-out meeting. Any additional tasks requested by the owner are also completed at this time.

Final Report

The RCx service provider prepares a Final Report. The owner may specify what information is included. Ideally, the Final Report contains:

- Executive summary;
- Project background;
- The RCx plan;
- The Master List of Findings with a description of the improvements implemented;
- A cost/benefits analysis for the estimates of savings and the actual improvement costs for each improvement implemented;
- A list of capital improvements recommended for further investigation;
- The EMCS trending plan and logger diagnostic / monitoring plan and annotated results;
- All completed functional tests and results;
- Recommended frequency for RCx by equipment type with reference to tests conducted during initial RCx; and
- Complete documentation of revised or new strategies adopted to optimize systems operation along with the rationale that lead to selection of these strategies.

If the owner intends to recommission the facility in the future, it is recommended that the RCx service provider develop a recommissioning plan and schedule. A building owner's commitment to performing regular recommissioning increases the chances that the O&M improvements will return benefits as originally intended. In order to ensure persistence of performance and energy cost savings, a recommissioning plan should be incorporated into the overall O&M plan for the facility. At minimum, the RCx service provider should be required to recommend a recommissioning schedule as a part of the project deliverables. Depending on the type of improvements and how often the building changes, recommissioning schedules can vary considerably. 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 will need recommissioning more often than equipment that serves more static areas.

Closeout Meeting

After the RCx service provider has submitted the Final Report for review by the owner and owner's staff, it is recommended that a project close-out meeting be held with the RCx team. This meeting is valuable for discussing 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 both new building and existing building commissioning, investigating and installing capital intensive measures and selecting a method for tracking the buildings energy use over time.

Other Tasks

Owners may wish to have enhanced tasks added to the RCx service providers scope of work.

Update or Create Building Documentation

Depending on their contract, the RCx service provider can leave the building's O&M staff with a complete package of building documentation in order to improve the persistence of RCx's benefits. The following tasks can be completed by RCx service providers, as appropriate to the project:

- One-line drawing schematics of each system investigated;
- Finalize the O&M plan outline, including the examination of and enhancement of current maintenance or service contract procedures;
- Develop a list of required O&M documentation and a systems operations manual, including full-written sequences of operation for equipment that still may be missing documentation of its sequences;
- Develop an energy-efficiency plan;
- Develop guidelines for implementing a preventative maintenance plan;
- Develop a comprehensive training plan or recommendations for appropriate building staff to attend training in general O&M concepts and for specific equipment and systems. This will include both building operators and facility managers or owners.;
- Develop guidelines and recommendations for incorporating an energy accounting and tracking system. Include benchmarks for whole building energy use and primary plant equipment efficiency tracking.;
- Develop a list of operational strategies for the owner to incorporate in the future; and
- Develop a recommissioning schedule and plan.

Some owners may also wish to include the development of new manuals as part of the RCx process. This manual provides the building operators with a more detailed overview of their equipment and strategies to help them in operating their equipment as efficiently as possible. The development of this manual may assist building owners to comply with high performance/sustainable building certifications like the U.S. Department of Energy's ENERGY STAR® Building Label, or the U.S. Green Buildings Council (USGBC) Leadership in Energy and Environmental Design™ (LEED) Existing Buildings program. A recommissioning systems manual typically includes:

- A brief design narrative of all systems investigated (brief description of the system, it purpose and general operation), with corrected and created sequences of operation;
- A description of and rationale for all energy-saving features and strategies with operating instructions and caveats about their function and maintenance relative to energy use;
- Recommendations for recalibration frequency of sensors and actuators by type and use;
- Specific recommendations regarding seasonal operational issues that affect energy use;

- A list of all user adjustable setpoints and reset schedules with a discussion of the purpose of each and the range of reasonable adjustments with energy implications. Include a schedule frequency to review the various setpoints and reset schedules to ensure they are at current relevant and efficient values.; and
- A list of time of day schedules and a schedule frequency to review them for relevance and efficiency.

Train Operators

The RCx service provider either provides the training or ensures that the contractor/manufacturer provides adequate training for operating staff. Training may also address other areas of building operation that are of particular concern to the owner. If necessary, the RCx service provider schedules and performs deferred testing (seasonal testing).

Participants and Responsibilities

RCx is a team effort. Depending on the project scope the RCx team may simply consist of the RCx service provider and a designated member of the operating staff. Budget considerations and the characteristics of the project usually dictate the number of team members and their responsibilities. For cost-effectiveness, the RCx team should be streamlined to fit the complexity of the project. The owner should consult with the RCx service provider about the makeup of the team. The RCx service provider can review the scope of work and advise the owner on how to consolidate roles and tasks to best meet the needs of the project. A RCx team will include some or all of the following people:

- Owner or owner's representative;
- Building operator/O&M staff;
- RCx provider;
- Equipment contractor or manufacturer's representative;
- Design professionals; and
- Testing specialists.

I. Owner or Owner's Representative

The owner's most significant responsibility is to support the RCx service provider's efforts. Other responsibilities include:

- Determining the project's budget, schedule, and operating requirements;
- Determining the objectives of the project and communicating them to the team members;
- Hiring the RCx service provider and other members of the project team;
- Assigning appropriate in-house staff to the project;
- Defining the building protocols (see Planning phase above);
- Defining the lines of communication between the team members;
- Working with the RCx service provider to establish the final RCx work plan and how to best leverage existing resources to streamline the project and reduce costs;

- Supporting the RCx service provider by facilitating communication between other project team members as needed;
- Informing the building occupants of the intended RCx work as needed;
- Requiring and reviewing progress reports and meeting notes; and
- Attending training sessions and meetings when appropriate.

II. Building Operator/O&M Staff

Building operators should assist with, or at least observe, as much of the RCx process as possible in order to improve their understanding of the equipment and control strategies. This knowledge will enable them to retest or recommission systems periodically as part of their ongoing O&M program. The following list includes tasks that building operators are typically responsible for, depending on their skill level:

- Gathering building documentation;
- Providing detailed input into the initial assessment and investigation process;
- Performing appropriate preventive maintenance prior to any diagnostic or functional testing;
- Installing and removing short-term diagnostic monitoring equipment;
- Gathering trending information from the EMCS as required;
- Assisting with the performance of manual functional testing as needed; and
- Attending project meetings and training as required.

III. Retro-commissioning Service Provider

The RCx service provider's tasks and responsibilities depend on the scope of the project, its budget and the skill of the building O&M staff. Typical RCx responsibilities include:

- Identifying what documentation, drawings, data, and other information will be required;
- Developing a building-specific final retro-commissioning work plan;
- Developing agendas and facilitating all meetings;
- Submitting progress reports and meeting notes to the project and facility manager as determined by the owner;
- Performing detailed on-site assessment of the present maintenance practices and operating strategies, noting all possible findings and improvements;
- Understanding the warranties and service contracts that are in place and how they can be leveraged on the project;
- Developing monitoring and testing plans;
- Performing short-term diagnostic monitoring, using EMCS trend logging where appropriate;
- Developing, performing or overseeing, and documentation of functional test procedures as needed;
- Developing a Master List of Findings;
- Recommending system or energy-efficient capital improvements for further investigation;

- Prioritizing the most cost-effective improvements for implementation for existing systems;
- Supervising implementation of the selected improvements;
- Performing post-installation monitoring and testing activities as needed;
- Calculating the estimated energy savings based on the before-and-after short-term energy measurements;
- Assisting in operators training, as needed; and
- Submitting a final report and all specified deliverables.

IV. Contractor or Manufacturer Representatives

Installing contractors, maintenance service contractors, controls contractors and manufacturer representatives can be important contributors to the RCx of existing equipment. If equipment is still under warranty or covered by a service contract, it is important that the responsible company or individual be brought in early in the process, especially if a warranty will be void if someone else manipulates the equipment.

Contractor or manufacturer responsibilities consist mainly of performing the hands-on testing of the system they installed and/or service such as the chillers or boilers. Contractors may also be responsible for fixing any problems found during the RCx process. Compensation for these parties depends on the extent of the service contract or warranty coverage.

Some owners do not have full- or even part-time building operators or some may employ building operators with minimal skills or time. These owners often use service contracts to cover most of their HVAC, controls, and electrical systems. In these cases, the service contractor may take on RCx tasks that building operators would usually perform. The contractor may be requested to perform certain scheduled preventive maintenance tasks to coincide with the needs of the RCx project, as well as assist in performing the hands-on testing, diagnostics, and adjusting and calibrating of equipment. Controls contractors may contribute by assisting with trend logs and EMCS programming tasks.

The controls contractor will be an essential player on the RCx team when he or she is the person most familiar with the building's control sequences and programming. Control technician expertise can expedite the incorporation and testing of new or improved control strategies for the building. Although enlisting the time of a control technician may be expensive, limiting their assistance can reduce the overall cost-effectiveness of the project.

V. Design Professionals

The involvement of design professionals in the RCx process depends on the age of the equipment, the systems involved and whether there is a new installation occurring during the retro-commissioning process. When RCx involves a new installation, the designer of the equipment should be part of the team. Design professionals are otherwise not involved unless the RCx service provider needs additional expertise regarding design issues uncovered during investigation. In such cases, a design professional (ideally, the engineer who designed the original installation) may be brought on the team as a consultant to help resolve the issues.

VI. Testing Specialists

Testing specialists may also need to join the RCx team. Special equipment, such as variable-volume fume hoods, may require special testing expertise. Although the RCx service provider typically writes the test procedures, the actual testing may be completed by someone else who is an expert in the field. Testing, adjusting and balancing (TAB) professionals may be asked to verify water or air flows using special equipment if RCx identifies air or water balance problems. Some RCx service providers are also test engineers and thus fully-equipped to perform almost any test required. However, this is not always the case. Many RCx service providers are skilled at performing fundamental HVAC functional tests and calibration exercises, but rely on other professionals or test experts for more complicated testing.

Conclusion

For New York building owners, the RCx process can play an important role in ensuring that their facilities are energy-efficient, safe, productive and comfortable. As part of an overall asset management strategy, the benefits of a RCx project can improve a building's value and help reduce tenant turnover. For buildings that were not commissioned during construction, the RCx process is an excellent way to find new savings opportunities, identify and repair persistent building problems and improve a building's indoor environment. RCx benefits will persist when a facility's O&M program periodically reapplies the diagnostic tests and checklists developed during the RCx process. Appendix J provides a list of additional commissioning resources. NYSERDA's commissioning web page also contains information about commissioning in New York State: www.nyserda.org/commissioning.html

Appendix A: Strategies for Reducing Retro-commissioning Costs

Thorough preparation and participation by building staff prior to and throughout the project reduces overall costs. This section introduces strategies that in-house building staff can use for streamlining the project and increasing the effectiveness of the retro-commissioning service provider's time.

1. Gather building documentation
2. Perform appropriate preventive maintenance
3. Perform simple repairs and improvements as the project progresses
4. Perform diagnostic monitoring and functional tests
5. Implement selected improvements and repairs

These strategies should be planned as appropriate and introduced to the building staff before putting the retro-commissioning process into action. If the project, due to size or complexity, requires using a bid process for obtaining retro-commissioning services, the request for proposals should state which of the tasks discussed below are in-house building staff responsibilities. This helps the bidders understand what to expect from the owner's staff and develop their budgets accordingly.

Gather Building Documentation

Compile an *up-to-date* building documentation package prior to the retro-commissioning process. If this is not done ahead of time, the retro-commissioning service provider will need to gather this information. This packet should be available on-site and include as much information as possible including:

- Drawings relevant to the systems targeted for commissioning (preferably "As-Built" drawings if accurate);
- O&M manuals;
- Testing, adjusting and balancing (TAB) reports;
- Original design documentation;
- An equipment list with nameplate information, dates of installation, and submittals including pump curves and fan curves;
- List of outside service contractors regularly used;
- Copies of current service contracts;
- Control system documentation, such as sequences of operation, special control strategies, control diagrams, points list, control program or code, etc.;
- Energy-efficient operating strategies;
- Energy bill (electric, gas, steam, chilled water, etc.) or energy accounting information for at least the last 24 months along with a rate schedule, unit price, or supply contract information for each energy type; and
- Water and sewer usage and billings.

It is possible that some of the information will not be readily available, such as pump curves, fan curves, and written sequences of operation. However, the more documentation that in-house staff can update and compile, the less time the retro-commissioning service provider will spend

obtaining this information. Performance curves are generally available from the original installing contractor or the equipment manufacturer. Have the nameplate information, including the serial number and date of installation, available when contacting either of these parties. Appendix C contains a typical checklist of documentation required as part of retro-commissioning.

Perform Appropriate Preventive Maintenance

Special care should be taken to make sure that all in-house staff or an outside maintenance service contractor completes scheduled preventive maintenance (PM) work before retro-commissioning begins. For example, if retro-commissioning occurs during the cooling season, the annual PM tasks for the cooling plant and systems should be completed before commencing with the project. It is not cost-effective to hold up the retro-commissioning process because of dirty filters, loose belts, broken dampers, or loose electrical connections. These are typical preventive maintenance tasks that do not require a retro-commissioning service provider to find and recommend fixing. The retro-commissioning service provider's time is better used helping the building staff find and solve operating, design, and installation problems rather than equipment-care findings.

Perform Simple Repairs and Improvements as the Project Progresses

Depending on the skill level of the building staff, they can perform a number of improvements and repairs as the project progresses. Completing simple repairs and adjustments discovered during the early part of the investigation phase increases the effectiveness of the diagnostic monitoring and testing. For example, there is no sense in waiting to calibrate or relocate a sensor, or fix a binding damper only to have the diagnostic and testing phase of the project indicate, once again, that this is a problem. Also, finding an effective solution to a problem is often accomplished through a series of "fixes" occurring over the course of the project. Often what appears as a simple problem, once fixed, may allow the diagnostic testing to uncover a larger but more subtle problem, which can then be fixed. These "simple fixes," no matter how minor they appear, should be logged on the "Master List of Findings and Potential Improvements" (this list is discussed in more detail in the section titled "Investigation Phase").

Note that if energy and/or energy-related cost savings are retro-commissioning objectives, it may be important to ensure that energy and cost baselines are well established prior to performing any significant repairs or improvements.

Perform Diagnostic Monitoring and Functional Tests

It is often appropriate and cost-effective to have the most motivated and interested building staff assist with the short-term diagnostic monitoring, trend logging, and functional testing that occurs during the investigation phase of the project. This helps reduce project costs and provides the building staff with a learning experience that they can reapply later. If building staff are trained to initiate trend logs using the building's EMCS, a retro-commissioning service provider can reduce time spent on the task and the owner will not need to hire a controls contractor to do the trending. Building staff may also assist with the installation and removal of portable dataloggers used for short-term diagnostics and assist with carrying out functional test plans. This also reduces costs and gives the building staff exposure to different approaches to troubleshooting problems and investigating and verifying equipment performance.

Implementing Selected Improvements and Repairs

Depending on availability and expertise, O&M staff may be enlisted to implement the selected repairs and improvements. Using in-house staff to perform these tasks reduces costs. Hiring an

outside contractor to implement major repairs and improvements may cause the payback to increase to the point where the project is no longer cost-effective. The success of this cost-reducing strategy hinges on in-house staff training, knowledge, and willingness to carry out the work. Existing workloads of O&M staff should be analyzed to determine how schedules and workloads will be shifted to accommodate any additional work.

Appendix B: Retro-commissioning Firm Experience

Company Name	Contact Person	Title

Address	City	State/Prov	Zip/Postal Code

Telephone	Fax	E-Mail

Description of Business:

Activities

Percentage of overall business devoted to existing building services (Energy studies, diagnostics, repairs, retrofits, redesign) _____%

How long has the firm offered theses services _____Years

Average number of existing building projects performed each year: _____Projects

Systems or technologies for which firm has provided consulting/repair services (check all that apply)

- ❑ Pkg. or split HVAC
- ❑ Chiller system
- ❑ Boiler system
- ❑ Energy Mgmt. Sys.
- ❑ Variable Frequency Drives
- ❑ Lighting Controls
- ❑ Daylighting
- ❑ Electrical, general
- ❑ Electrical, emerg. power
- ❑ Envelope
- ❑ Fire/Life Safety
- ❑ Plumbing
- ❑ Commercial refrigeration
- ❑ Telecommunications
- ❑ Thermal Energy Storage
- ❑ Labs & Clean Rooms
- ❑ Security
- ❑ _____

Number of registered engineers on staff who have directed consulting/repair projects: _____

The firm has provided services in the following: (check all that apply)

Building Sector	**Energy Studies**	**Building Diagnostics**	**Existing Building Repairs/Tune-up**	**Equipment Retrofit Design**
• Office or retail	❑	❑	❑	❑
• Grocery	❑	❑	❑	❑
• Hospitals	❑	❑	❑	❑
• Laboratories	❑	❑	❑	❑
• Schools or universities	❑	❑	❑	❑
• Industrial / Manufacturing	❑	❑	❑	❑
• Special purpose–prisons, museums, libraries, etc.	❑	❑	❑	❑

Certifications, accreditations, and association memberships your firm's employees hold, and or training undertaken relevant to building retro-commissioning, diagnostics, repair, or retrofits

Appendix B: Retro-commissioning Task Experience On Projects

(Please fill in information for up to 8 projects your firm has done in the last 3 years-make additional copies of this page if required)

KEY:

Design Documents: Analyzed design documents and interpreted or recreated design intent

Diagnostics/Commissioning: Wrote a comprehensive diagnostics or retrocommissioning plan

Testing instruments: Used common HVAC and electrical testing instruments

FPT: Wrote functional performance test procedures

Datalogging: Set, retrieved, and interpreted data from stand alone datalogging devices

Testing: Performed functional tests (hands-on)

EMCS: Used building's EMCS system trend logging feature for diagnostics

Energy Saving Calcs: Developed energy savings calcs/estimates using spreadsheets, bin analysis or hand Calculations

Energy Modeling: Used energy modeling software to estimate savings

Technical Reports: Wrote technical reports for owner and NYSERDA-if applicable

Management: Managed multi-disciplinary project teams

Training: Developed or approved staff training

Review O&Ms: Reviewed completed O&M manuals or wrote a Systems Manual

Project Name, Date Bldg Size & Type	City & State Owner Contact Title and Phone	Name & Role of Persons(s) Assigned to Project by Firm	Systems your firm Consulted on/Repaired	(Enter "X" if your firm performed this task as part of this project)												
				Tasks Performed												
				Design Documents	Diangnostics/Cx Plan	Testing Instruments	FPT	Dataloggers	Testsing	EMCS	Energy Saving Calcs	Energy Modeling	Technical Reports	Management	Training	Review O&Ms

Appendix C: Request for Proposal (RFP) Checklist for Retro-commissioning Services

- ❑ Include clear objectives and assign priority to each (energy, comfort, building control, etc.)
- ❑ Provide information about the building. At minimum include:
  - A brief building description
  - Square footage
  - A general HVAC description (central plant as well as distribution systems for both heating and cooling); controls system description
  - A list of major equipment, including number and age of each type
  - A brief renovation, retrofit, and equipment replacement history
  - A building use description
- ❑ Provide as much information on the trending capabilities of the EMCS as possible. Ideally, a complete points list should be provided. This increases the bidders' ability to more accurately budget the data acquisition tasks. Also, state whether the system can be accessed remotely (by modem).
- ❑ Provide a list of available up-to-date building documentation.
- ❑ Include as complete a scope of work as possible. State the type of retro-commissioning expected (existing-building, new equipment, or combined new and existing systems). If it is unclear what the scope of work can realistically include, allow step one of the project to address developing a detailed scope of work. Or, hire an experienced retro-commissioning consultant to help develop the scope of work for inclusion in the RFP. The scope of work should include a list of equipment needing retro-commissioning. Also, clearly state for each phase of the project (planning, investigation, implementation, and integration) what the in-house building staff's and/or service contractor's responsibilities include and what the retro-commissioning provider responsibilities include. (For guidance, refer to Appendix I.)
- ❑ If the preferred data acquisition methods are known (datalogging, trending, functional testing) state them, otherwise specifically ask that the bidder detail their approach on these issues.
- ❑ Indicate what is expected for each of the retro-commissioning phases (planning, investigation, implementation, and hand-off). It is especially important for the bidders to know whether the contract proceeds through the implementation phase or ends with the investigation phase (detailed site assessment).
- ❑ Request the retro-commissioning service provider's general approach and a skeletal retro-commissioning plan for the project.
- ❑ List the specific support that the retro-commissioning service provider can expect from the facility staff and service contractors (particularly the controls vendor) and give the skill level of each of the facility staff. State how much testing and investigation can be done by facility staff.
- ❑ When requiring savings calculations/estimates, state the desired method for completing the work (qualitative ranking of measures for implementation using expert judgment, cost estimates and engineering calculations of savings, costs from actual bids and bin or computer simulations of savings).
- ❑ Any cost or energy savings calculations or estimates required of the retro-commissioning service provider prior to implementation and after post-verification should be clearly stated with the desired method.
- ❑ List the required retro-commissioning service provider's qualifications and qualifications for any subcontractors.
- ❑ Request work examples from previous projects (final report, Master List of Findings etc.)
- ❑ List the RFQ/RFP selection criteria.
- ❑ Give a cost range for the project.
- ❑ Provide a list of required deliverables (see section titled "Selecting a retro-commissioning service provider").
- ❑ Other RFQ/RFP checklist items: _____

Appendix D: List of Possible Deliverables for a Retro-commissioning Project

Phase	Activities	Primary products/deliverables[a]
Planning	1. Select project 2. Develop project goals and scope 3. Muster support 4. Develop team 5. Select and hire a retro-commissioning service provider 6. Develop the final retro-commissioning work plan and hold a kickoff meeting	• Final retro-commissioning work plan (including brief building and system description, project objectives, scope, list of team members, and schedule)
Investigation	1. Gather and review facility documentation 2. Perform a site assessment 3. Developing and implement the diagnostic monitoring and test plans 4. Select the most cost-effective opportunities for implementation	• Scoping meeting minutes, short-term diagnostic monitoring and functional test plans • Master List of Findings • Completed site assessment forms and functional test results • List of repairs, adjustments and other improvements made during investigation • List of selected improvements for immediate implementation
Implementation	1. Implementing recommendations 2. Retest and remonitor 3. Update building documentation 4. Train operators	Completed repairs and improvements (noted on revisions to Master List) • Revised or upgraded building documentation (if required as part of project • Final estimated cost and savings calculations for improvements • Training videos or text materials
Hand-off	1. Final Report 2. Other tasks	• Final report • Recommended capital improvements for future investigation • Recommissioning plan or schedule

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

Appendix E: Building Information Summary

Appendix E contains a list of typical building characteristics that can be placed in a spreadsheet or a database for comparing multiple buildings. This is useful for owners with multiple facilities who are interested in gaining a preliminary understanding of their building stock regarding retro-commissioning opportunities.

Building Identification

- ❑ Building Type (e.g., Office, Warehouse, Hospital)
- ❑ Number of Occupants
- ❑ Size (Gross Square Feet)
- ❑ Year of Construction
- ❑ Year of Last Renovation

Equipment

- ❑ Central Heating Plant (Boilers)
- ❑ Central Cooling Plant (Chillers)
- ❑ Packaged Units
- ❑ District Heating
- ❑ District Cooling
- ❑ Computer Energy Management System
- ❑ Age of Primary Heating Equipment
- ❑ Age of Primary Cooling Equipment

Energy Data

- ❑ Annual Hours of Operation
- ❑ kWh per year
- ❑ Annual Electric Use in kWh per Square Foot
- ❑ Peak Demand for Last 12 Months
- ❑ Natural Gas ccf per Year
- ❑ Annual Gas Use in BTU per Square Foot
- ❑ BTU per Square Foot per Year all Fuels
- ❑ District Heating (lbs. of Steam per Year)
- ❑ District Cooling (TN Hours per Year)
- ❑ Average annual BTU per Square Foot for region or city for similar type buildings

General Information

- ❑ Current set of all mechanical prints, electrical riser diagrams, and piping drawings (as-builts) including a roof or mechanical room layouts of HVAC equipment.
- ❑ Building equipment list (with nameplate information if available)
- ❑ Test and Balance Report for air and water (most recent and original if available).

- ❑ Recent energy audits (within the last five years)
- ❑ Names, addresses, and phone numbers of current service contractor
- ❑ Current energy accounting reports - previous 12 months.
- ❑ Copy of the utility bills (water, electric, gas, etc.) for the past two years

Energy Management Control System

- ❑ Name and address of installing contractor, distributor, manufacturer, and present service contractor (some of these may be the same).
- ❑ Manufacturer's literature (cut sheets)
- ❑ Control submittals (if still available)
- ❑ Operation and maintenance manuals
- ❑ User guide or manual
- ❑ Control drawings
- ❑ Written control strategies and sequences of operation
- ❑ Time of Day schedules by zone or tenant space
- ❑ Setpoint schedules by zone or tenant space for normal day, night setback (night low limit) and setup
- ❑ Points list
- ❑ Hard copy of the program
- ❑ Service contract
- ❑ Guarantee and warranties still in effect

Lighting

- ❑ Lighting control submittals (occupancy sensors, sweep controls, day-lighting controls etc.)
- ❑ Control drawings (or reflected ceiling plans showing location of lighting sensors or list of lighting sensor locations).
- ❑ Manufacturer's literature (cut sheets)
- ❑ Schedules
- ❑ Guarantees and warranties still in effect

Operation and Maintenance

- ❑ Preventive maintenance plan/schedules, logs or both (manual or computerized)
- ❑ Operation and maintenance manuals
- ❑ Invoices or O&M records for last three months of service
- ❑ Copy of any current service contracts (if applicable).
- ❑ List of recent repairs or rebuilds
- ❑ List of new equipment installations not on current List of Equipment

HVAC and Refrigeration Equipment

- ❑ Chillers
- ❑ Pumps Air Handlers
- ❑ Cooling Towers
- ❑ Packaged A/Cs
- ❑ Heat Pumps
- ❑ Terminal Boxes
- ❑ Heat Exchangers
- ❑ Thermostats
- ❑ Evaporative Coolers
- ❑ Refrigeration
- ❑ Compressors
- ❑ Condensers
- ❑ Air compressors
- ❑ Air Dryers
- ❑ VFDs

Appendix F: Sample Assessment Forms:

Pump Control Questions:

Circle or explain what function the pump(s) serves:

Condenser Water **Chilled Water Primary** **Chilled Water Secondary**

Heating Water Primary **Heating Water Secondary**

Other _____

Number of Pumps:_____ **Parallel** or **Series** (circle one)

Pump ID #(s):_____

Facility Name for Pumps:_____

- What causes the pump to initially start? _____
- What causes the pump to cycle?_____
- How is capacity controlled, VFD, etc?_____
  (If a VFD is used attach VFD Assessment Form to the appropriate Pump Form)
- If applicable, what is the differential pressure control point?_____
- If there is a lead/lag strategy, explain:_____
- If pumps are staged, explain: _____

Notes, Comments, and Observations:

Pump Nameplate Data:

Use N/A for not applicable and N/O for not obtainable or available.

Pump Function:→ (Heating water, condenser, etc)				
Pump ID or Number				
Pump Manufacturer				
Model Number				
Serial Number				
Age				
Impeller size				
Head pressure				
Suction Pressure				
Discharge Pressure				
GPM				
Motor Manufacturer				
Motor Model #				
Phase				
Volts phase to phase	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:
Volts phase to ground	Measured:	Measured:	Measured:	Measured:
Amps for each phase	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:	Nameplate: Measured:
KW	Measured:	Measured:	Measured:	Measured:
Power Factor	Measured:	Measured:	Measured:	Measured:
HP				
RPM				

Pump Condition Checklist:

Check if okay; enter comment number if deficient. Document comments by number in form provided below checklist. Use N/A for not applicable and N/O for not obtainable or available.

Pump ID:				
General condition good (clean and appear well maintained)				
No unusual noise or vibration				
No leaks				
Thermometers on supply and return				
Pressure gauges installed across pumps and functioning (if so, record pressures)	Suction: Discharge:	Suction: Discharge:	Suction: Discharge:	Suction: Discharge:
Pump rotation correct				
Properly balanced				
Strainers in place and clean? State when strainers were last cleaned				
Piping properly insulated				
Piping generally in good condition				
Valves in good condition - no leaks				
Water treatment in place and operating				

Use the back of this form or attach notes briefly describing the preventive maintenance program for the pumps.

Number	Comment

Summarize all findings and possible improvements on the Master List:

Sample Site-Assessment Form (Interview)

General O&M Questions

Has your heating system always met load? ☐ Yes ☐ No

Under what conditions has your heating system not met load?

What was the solution to this problem:

Has your cooling system always met load? ☐ Yes ☐ No

Under what conditions has your cooling system not met load?

What was the solution to this problem:

Do you feel you have any HVAC equipment that is undersized? ☐ Yes ☐ No

If yes, explain:

How do you compensate for the undersizing?

Do you feel you have any HVAC equipment that is oversized? ☐ Yes ☐ No

If yes, explain:

How do you compensate for the oversizing?

Is the building mechanical equipment (fans, pumps, etc.) scheduled to start-up simultaneously or is the start-up staged?

What HVAC adjustments do you make to unoccupied areas or spaces (turn-off HVAC, adjust thermostat to minimum heating and cooling, close-off diffuser, etc.)?

In your opinion, is the building HVAC system well balanced? ☐ Yes ☐ No

If no, explain:

Explain the method of humidification for the building:

Are there any problems with the humidification method (explain)? ☐ Yes ☐ No

Explain the method of dehumidification for the building:

Are there any problems with the dehumidification method (explain)? ☐ Yes ☐ No

From what areas in the building do you receive the most complaints (explain nature of complaints)?

What is your worst building problem and how do you deal with it?

Comments and Notes:

Appendix G: Sample Master List and Findings Summary

MASTER LIST - SAVINGS SUMMARY PROJECTION

EXISTING ENERGY USE

Building Area (Sq. Ft.)	Baseline Building	Existing Electric Energy (kWh/Yr)	Average Electric Demand (kW/Mo)	Existing Natural Gas (Therm Per Year)	Existing Annual Energy Cost	Existing EUI BTU/Sq.I per Year	Existing ECI ($/Sq.Ft. per Year)
385,599	FY 2001 Total Energy Use	16,925,248	2,758	468,437	$1,010,935	271.3	$2.62

Note: Energy Use Index (EUI) and Energy Cost Index (ECI) are based on gross building square footage

OPERATION AND MAINTENANCE / LOW COST MEASURES

Recommendation Selection Owner	PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Natural Gas Saved (Therm Per Year)	Annual Cost Savings	Implementation Cost	Simple Payback (Years)	%Total Cost Savings
	Yes	FTLB-01	Reduce Fan-coil Supply Fan Operating Hours	154,160	0	$5,122	$960	0.2	0.5%
	Yes	FTLB-02	Replace Exhaust Stream Filters	23,024	0	$787	$820	1.0	0.1%
	Yes	FTLB-03	Reset Condenser Water Temperature	48,769	0	$2,097	$80	0.0	0.2%
	Yes	FTLB-04	Reset Chilled Water Temperature	11,541	0	$496	$80	0.2	0.0%
	Yes	FTLB-05	Reduce Compressed Air System Pressure	8,309	0	$357	$20	0.1	0.0%
	Yes	FTLB-06	Lower Heating Water Temperature	4,540	939	$411	$80	0.2	0.0%
	Yes	FTLB-07	Heat Recovery Control Modifications	6,181	54,263	$19,800	$160	0.0	2.0%
	Yes	NWTC-01	Recondition RTU-2 Economizer	11,278	0	$586	$1,660	2.8	0.1%
	Yes	NWTC-02	Remove RTU-1 Pre-filters	1,677	0	$447	$220	0.5	0.0%
	Yes	NWTC-04	Data Shed Programmable Thermostats	24,996	0	$1,300	$4,400	3.4	0.1%
	Yes	S&R-01	Radiant Heater Programmable Thermostats	0	1,760	$827	$480	0.6	0.1%
	Yes	S&R-02	De-lamp Office Area Lights	3,130	0	$145	$80	0.6	0.0%
	Yes	S&R-03	Lower Storage Area Occupancy Sensor	1,423	0	$23	$235	10.2	0.0%
	Yes	VC-01	Lockout Compressor Operation	11,694	0	$1,116	$120	0.1	0.1%
	Yes	VC-02	Video Monitor Timeclocks	3,879	0	$101	$260	2.6	0.0%
Total Recommendation Package as Selected by PECI				314,601	56,962	$33,615	$9,655	0.3	3.3%
	5%	Measure interaction of total package		298,871	54,114	$31,934	$9,655	0.3	3.2%
Total Recommendation Package as Selected by Owner				314,601	56,962	$33,615	$9,655	0.3	3.3%
	5%	Measure interaction of total package		298,871	54,114	$31,934	$9,655	0.3	3.2%

Note: Measures with an (*) in the title are mutually exclusive with other measures

CAPITAL IMPROVEMENT MEASURES

Recommendation Selection Owner	PECI	Finding Number	Energy Conservation Project Title	Electric Energy Saved (kWh/Yr)	Natural Gas Saved (Therm Per Year)	Annual Cost Savings	Implementation Cost	Simple Payback (Years)	%Total Cost Savings
	Yes	SERF-01	Install Indirect Evaporative Cooling	93,524	0	$4,022	$40,000	9.9	0.4%
	No	SERF-02	Reduce Process Chilled Water Flow	32,496	0	$1,397	$28,800	20.6	0.1%
	Yes	SERF-03	Exhaust Fan VFD	154,462	0	$6,642	$55,200	8.3	0.7%
	Yes	NWTC-03	RTU-1 Supply and Return Fan VFDs	39,986	0	$2,079	$8,668	4.2	0.2%
Total Recommendation Package as Selected by PECI				320,468	0	$14,140	$132,668	9.4	1.4%
	5%	Measure interaction of total package		304,445	0	$13,433	$132,668	9.9	1.3%
Total Recommendation Package as Selected by Owner				320,468	0	$14,140	$132,668	9.4	1.4%
	5%	Measure interaction of total package		304,445	0	$13,433	$132,668	9.9	1.3%

Note: Measures with an (*) in the title are mutually exclusive with other measures

TOTAL PROJECT SUMMARY (O&M and Capital Improvement Measures)

		Electric Energy Saved (kWh/Yr)	Natural Gas Saved (Therm Per Year)	Annual Cost Savings	Implementation Cost	Simple Payback (Years)	%Total Cost Savings
Total Recommendation Package as Selected by PECI		635,069	56,962	$47,755	$142,323	3.0	4.7%
5%	Overall measure interaction of total package	603,316	54,114	$45,367	$142,323	3.1	4.5%
Total Recommendation Package as Selected by Owner		635,069	56,962	$47,755	$142,323	3.0	4.7%
5%	Overall measure interaction of total package	603,316	54,114	$45,367	$142,323	3.1	4.5%

FTLB-03 Reset Condenser Water Temperature

Finding Description

It was noted during the site visit that the condenser water return temperature was being controlled at 75ºF. Spot measurements of chilled water supply and return temperature, chiller input power, and condenser water supply temperature indicated that the chiller was operating at approximately 50% load and 0.72 kW/ton efficiency with the 75ºF condenser water temperature. Manufacturer's data indicates the chiller would operate at approximately 0.5 kW/ton at 50% load with 67ºF condenser water temperature. The spot measurements observed during the site visit were validated using trend data that has been collecting since the initial site visit occurred.

Recommendation

The recommendation is made to lower the condenser water temperature setpoint to be 10ºF above current outside air wet-bulb temperature, with a minimum temperature of 67ºF. The chiller will operate more efficiently with lower condenser water temperature, however the cooling tower fans will operate more frequently to satisfy the new temperature setpoint. But the minimal increase in fan energy will be offset by the reduction in chiller energy. For our analysis, we have assumed that mechanical cooling will be minimal below 60ºF Tdb due to extensive use of direct evaporative cooling and energy recovery. The Twb + 10ºF control strategy is recommended because this will minimize the additional cooling tower fan operation necessary to achieve the lower setpoint. Adequate time delays will also have to be programmed in to prevent the system from short cycling and hunting as the outside air conditions vary. Chiller energy savings have been calculated using local bin weather data for the hours the chiller is actually operating (6 am to 6 pm 7 days per week based on current schedule) and data gathered during the site visit and through trending. It is recommended that the condenser water temperature sensor be calibrated prior to implementing the measure to maximize the savings potential. A detailed calculation for this measure is provided in the spreadsheet entitled *FTLB 03 – Reset Condenser Water Temperature* located in Appendix B – Savings and Cost Estimates.

Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	48,769	kWh/yr	Estimated Annual Cost Savings	$2,097
Estimated On-peak Demand Savings	18.2	KW/mo	Estimated Implementation Cost	$80
Estimated Annual Natural Gas Savings	0	Therm/yr	Simple Payback (years)	0.0

Implementation Plan

Implementation of this measure consists of making programming changes to the Delta building automation system. We have estimated that in-house staff can make the necessary changes to the control sequences in approximately two hours at a labor rate of $40 per hour.

FTLB-07 Heat Recovery Control Modifications

Finding Description

All four fan systems serving the FTLB have the capability to recover thermal energy from the exhaust stream and pre-treat the incoming outside air prior to entering the evaporative cooling section and the heating/cooling coils. It was noted during the site visit that the thermal recovery control sequences for the Penthouse and Center fan systems were not programmed to enable the system to recover energy during heating conditions (i.e. below 50°F outside air temperature) and control sequences for the East and West fan systems were not programmed to enable the system to recover energy during cooling conditions (i.e. above 75°F outside air temperature).

Recommendation

The recommendation is made to modify the control sequences so that thermal energy can be recovered from the exhaust air stream for all systems throughout the year. For our calculations, we have assumed that each thermal recovery system will have a constant effectiveness and energy savings are based on actual system flow rates for both the "occupied" and "unoccupied" hours. The thermal recovery control strategy should not allow the leaving air temperature of the exhaust stream to drop below approximately 40ºF to prevent moisture and possible frost build-up on the coil (40ºF is the approximate dew point temperature of exhaust air at 74ºF and 30% relative humidity). Based on our analysis, a 40ºF leaving air temperature would occur when the outside air temperature was approximately 0ºF. We have assumed the three-way control valve will modulate to maintain a constant exhaust air leaving temperature when the outside air temperature is below 0ºF, hence the amount of heat recovery from the exhaust air stream will be constant below this temperature. Note that the actual on-peak demand savings for this measure will vary depending on outside air temperature. For example the demand savings will be larger during the summer months when the energy recovery has the greatest impact on chiller savings. A detailed calculation for this measure is provided in the spreadsheet entitled *FTLB 07 – Heat Recovery Control Modifications* located in Appendix B – Savings and Cost Estimates.

Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	6,181	kWh/yr	Estimated Annual Cost Savings	$19,800
Minimum On-peak Demand Savings	2.9	KW/mo	Estimated Implementation Cost	$160
Estimated Annual Natural Gas Savings	54,263	Therm/yr	Simple Payback (years)	0.0

Implementation Plan

Implementation of this measure consists of making programming changes to the Delta building automation system. We have estimated that in-house staff can make the necessary changes to the control sequences in approximately four hours at a labor rate of $40 per hour.

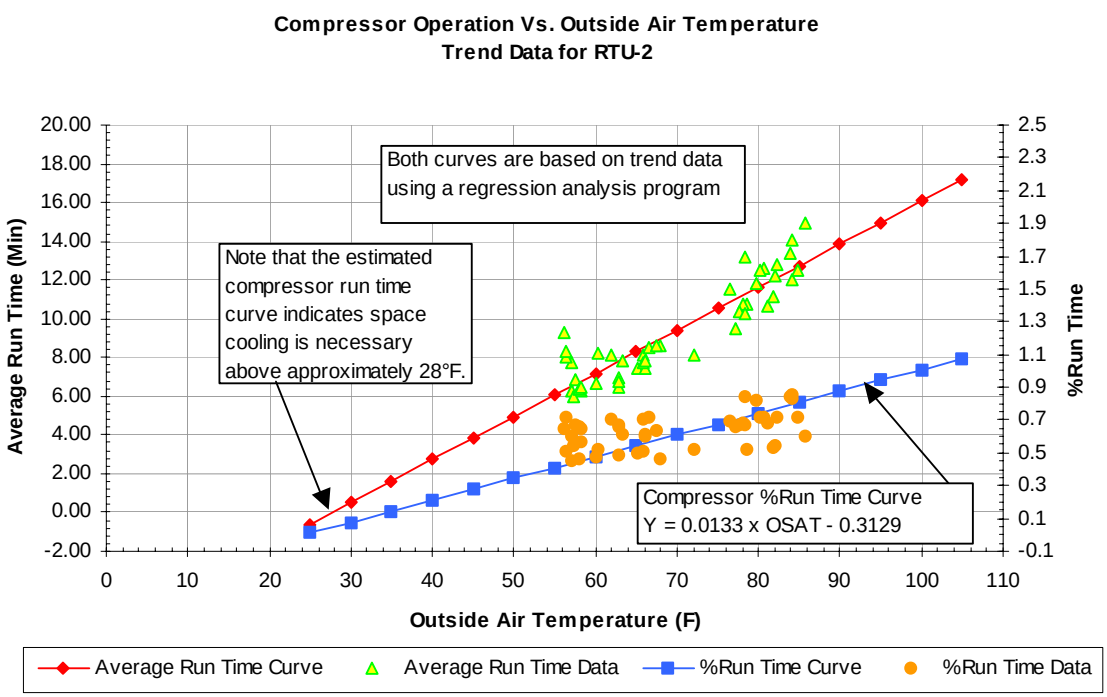
NWTC-01 Recondition RTU-2 Economizer

Finding Description

Building 251 located at the NWTC site is served by two roof-top packaged HVAC units. RTU-2 serves a computer room and operates 24 hours per day due to the constant load on the system. It was noted during the site visit that the economizer for RTU-2 is bolted shut, yet most of the economizer components (i.e. sensors, controller, actuator, etc) appear to be in place. A functioning economizer will use outside air to satisfy a cooling load when the outside air conditions are right rather than operating the compressor. Since RTU-2 operates 24 hours per day there are many hours in which free economizer cooling would be available to satisfy the load in the space. It is assumed that the outside air brought into the building through RTU-2 will eventually migrate out into the rest of the building and eventually be exhausted through RTU-1.

Recommendation

The recommendation is made to recondition the economizer so that outside air can be used to satisfy space cooling load when conditions are applicable. Energy savings have been calculated using bin weather data and trend data collected for RTU-2. The computer room is located within the core of the building and the heat load generated by the computers is assumed to be fairly constant. Trend data was used to develop a relationship between compressor operation and outside air temperature, as illustrated in the following graph.



Based on the curves illustrated above, we have assumed that a cooling load exists whenever the outside air temperature is above approximately 28°F. The outside air and return air dampers will modulate in order to maintain the mixed air low limit cut-out temperature (approximately 50°F – depending on installed sensor) whenever the outside air temperature is below the low limit temperature. The outside air dampers will then remain 100% open until the outside air temperature is higher than the return air temperature, at which point the outside air damper will close to a minimum position. Mechanical cooling will be enabled to supplement economizer operation should the outside air temperature be unable to completely satisfy the cooling load, and mechanical cooling will be used to meet the entire cooling load when the economizer high limit cut-out temperature is reached. Since the space is considered unoccupied, the minimum outside air damper position can be fully closed. Control of the economizer and compressor operation should be performed by the Honeywell economizer controller located within RTU-2 and not the Delta building automation system.

It should be noted that the computer room does not have a dedicated exhaust system to relieve the outside air introduced to the space through the economizer. Hence, the air from the computer room will migrate out into the rest of the building and eventually be exhausted through RTU-1 and bathroom exhaust fans. This should not be problematic since the volume of air from RTU-2 is small compared to RTU-1 and the temperature of the air emanating from the computer room will be approximately the same temperature as the rest of the building. If relief from the space is necessary, the recommendation is to install a barometric relief damper in the return air duct at the unit. A detailed calculation for this measure is provided in the spreadsheet entitled *NWTC 01 – Recondition RTU-2 Economizer* located in Appendix B – Savings and Cost Estimates.

Estimated Economic Impact Summary

Estimated Annual Electrical Energy Savings	11,278	kWh/yr	Estimated Annual Cost Savings	$586
Estimated Electrical Peak Demand Savings	0	KW/mo	Estimated Implementation Cost	$1,660
Estimated Annual Natural Gas Savings	0	Therm/yr	Simple Payback (years)	2.8

Implementation Plan

As stated above, much of the necessary economizer control equipment is already installed on the unit – a Honeywell controller, Honeywell actuator, outside air enthalpy sensor, and low temperature cut-out air temperature sensor. The recommendation is made to set up the economizer to function based on a differential enthalpy between the return air and outside air, meaning that 100% outside air will be used if the outside air enthalpy is less than the return air enthalpy. In addition we recommend relocating the low temperature cut-out temperature sensor to the mixed air stream rather than in the discharge air stream. Relocation of the low temperature cut-out sensor will allow the economizer and compressor to be fully integrated (i.e. the economizer can remain at 100% open until the differential temperature locks out the damper and the compressor operates as a second stage of cooling). When the sensor is located in on the downstream side of the cooling coil, the discharge air temperature could drop below the cut-out

temperature when the compressor comes on to provide second stage cooling, thus defeating the control strategy of economizer-compressor integration.

Therefore, implementation of this measure will require installation of new outside air dampers, connection of the return air and outside air dampers to each other, connection of the outside air dampers to the actuator, installation of a new return air enthalpy sensor (the same sensor-type should be used to measure both air streams), and movement of the low temperature cut-out temperature sensor to the mixed air stream. In addition, control of the economizer and compressor operation should be completely performed by the Honeywell economizer controller located within RTU-2 and not the Delta building automation system.

Appendix H: Sample Diagnostic Monitoring and Trending Plans

These plans are developed by the commissioning provider. Building staff may assist in their implementation, depending on the scope of work. The examples provided are intended to give the reader a sense of the level of rigor involved in the retrocommissioning process.

- **Datalogger Plan**

Appendix H contains two pages of a sample datalogger plan for a typical commercial office building. The datalogger plan lists all of the dataloggers for the project, their location and what information they are recording.

- **EMCS Trending Plan**

Appendix H also contains a sample EMCS trending plan for implementation by either building staff or the controls contractor.

Datalogger Plan for Short-Term Diagnostic Monitoring

Project Name: _____

Brand Name of dataloggers: _____

Run-Time Parameters:

Start Date _____

Start Time _____

Stop Date _____

Stop Time _____

Duration_____

Sampling Frequency _____

Storage Frequency _____

Total Loggers _____

Total Points _____

Each logger has four separate modules. Each module can be programmed separately to gather data on temperature, pressure, or current. Below are the first two pages of the logger plan for Building One.

Logger 1:

Equipment Name	Point Name	Measurement	Type module	Units	Min.	Max.
Chiller - 1	Leaving Chill. Water	Water	Temp.	^{o}F	32	212
Chiller - 1	Entering Chill. Water	Water	Temp.	^{o}F	32	212
Chiller - 1	Chil. Pump -1	Current	400 mV AC	Amps	0	0
Chiller - 1	Cond. Pump -1	Current	400 mV AC	Amps	0	0

Logger 2:

Equipment Name	Point Name	Measurement	Type module	Units	Min.	Max.
Chiller - 2	Leaving Chill. Water	Water	Temp.	^{o}F	32	212
Chiller - 2	Entering Chill. Water	Water	Temp.	^{o}F	32	212
Chiller - 2	Chil. Pump -2	Current	400 mV AC	Amps	0	0
Chiller - 2	Cond. Pump -2	Current	400 mV AC	Amps	0	0

Logger 3:

Equipment Name	Point Name	Measurement	Type module	Units	Min.	Max.
AC-13	Hot Deck	Temperature	Temp.	^{o}F	32	212
AC-13	Cold Deck	Temperature	Temp.	^{o}F	32	212
AC-13	Mixed Air	Temperature	Temp.	^{o}F	32	212
AC-13	Return Air	Temperature	Temp.	^{o}F	32	212

Logger 4

Equipment Name	Point Name	Measurement	Type module	Units	Min.	Max.
Cooling Tower	Primary Fan Motor	Current	400 mV AC	Amps	0	0
Cooling Tower	Pony Motor	Current	400 mV AC	Amps	0	0
Cooling Tower	Sump	Water	Temp.	^{o}F	32	212

Logger 5:

Equipment Name	Point Name	Measurement	Type module	Units	Min.	Max.
Ambient Outside	Outside Air Temp.	Temperature	Temp.	^{o}F	32	212
Ambient Outside	Outside Humidity	Relative Humidity	Humidity	RH	0	100

Logger 6

Equipment Name	Point Name	Measurement	Type module	Units	Min.	Max.
Boiler -1	Pump	Current	400 mV AC	Amps	0	0
Boiler -2	Pump	Current	400 mV AC	Amps	0	0
Boiler -1	Forced Draft Fan	Current	400 mV AC	Amps	0	0
Boiler -2	Forced Draft Fan	Current	400 mV AC	Amps	0	0

Sample EMCS Trending Plan

Building staff is responsible for entering and initiating the trends using the building's energy management control system (EMCS) per this plan. Some projects may require assistance from an outside controls contractor for these tasks. Calibration of critical sensors should be completed no more than two weeks prior to initiating trends. Trending and the short-term datalogging are done simultaneously. The trend data are then compared to the data gathered by the portable dataloggers to determine whether the EMCS is working correctly. Trend data are also used to augment the short-term diagnostics for verifying sequences of operation and schedules. This trend plan will be used during both pre-implementation of the improvements and during post-implementation. Any changes to the plan for post-implementation are noted in *italics.* The following outlines the trend plan for Office Building One.

Sample EMCS Trends			
Issue or Equipment	Points to Trend	Sampling Interval	Analysis Summary
Identify unnecessary equipment operation (chillers, air handlers, pumps, exhaust fans, lights, etc.)	Change of value (COV), another indicator or an ON condition Time-series also works well.	COV or time-series 15 min.	Make sure HVAC is not unnecessarily on outside of occupancy periods. Verify that lighting on times match HVAC.
Chiller start	Turn ON parameter (cooling coil valve position, outside air temperature (OSAT), etc.)	15 min.	Make sure chiller is not on unless the parameter requirement is met.
Chiller loading	Chiller current, OSAT	15 min.	Make sure the chiller current draw goes up with OSAT
Chilled water reset	Chilled water supply temperature, reset parameter (OSAT, valve position, etc.)	15 min.	Graph chilled water supply temperature (CHWST) against OSAT or valve position and compare to reset schedule, or analyze columnar data.

Sample EMCS Trends			
Issue or Equipment	Points to Trend	Sampling Interval	Analysis Summary
Chiller efficiency	Primary chilled water and condenser flow (or values in TAB or start-up report), entering and leaving chilled water and chiller kW (or current, if no kW). For reference, also trend entering and leaving condenser water temperatures.	15 min. for 2 weeks	Calculate the kW/ton of cooling for all points and add this column to the data. Plot the kW/ton (Y-axis) against the chiller % load. Save this graph as a benchmark. During similar weather the next season, repeat the trend and graph and see if the kW/ton generally remains the same or is degrading (possibly indicating fouling). Compare, by interpolation, to manufacturer's kW/ton data. Tons = 0.0417 x gpm x (CHWRT – CHWST). kW = Volts x Amps x 1.732 x power factor/1000. Get PF from start-up report or spot-check it (PF = W / (V x A x 1.732)).
Cooling tower operation (fans, mixing valve and entering condenser reset)	Fan stage, valve position, tower sump, entering and leaving condenser water temperature, reset parameter (OSA WB, DB), fan stage parameter.	5 min.	Compare the fan staging with the schedule, compare the entering condenser temperature with its schedule and compare valve operation to expected (closed when entering condenser water ≤ setpoint).
Simultaneous heating and cooling	Heating element enable or valve position, supply temperature, cooling coil valve position	2 min.	Make sure that when the cooling coil valve is open, the heating coil is closed.
Supply air reset	Supply air temperature, reset parameter (OSAT, zone demand, etc.)	2 min.	Graph SAT against OSAT or zone demand and compare to reset schedule, or analyze columnar data similarly.
VAV duct static pressure control	Duct static pressure (and reset parameters if its reset)	2 min.	Observe, for fixed static pressure systems, that the pressure remains the same during the monitoring period and for reset, that the static pressure follows the reset schedule.
Short cycling	COV for on / off issues	2 min.	View columnar data for analysis.
Hunting	Actuator position or command or COV	2 min.	Plot against time and observe hunting.

Sample EMCS Trends			
Issue or Equipment	Points to Trend	Sampling Interval	Analysis Summary
Terminal unit	Zone temperature, heating coil valve position and command, air cfm or damper position, cfm setpoint (for applicable controllers). The OSAT and the duct static pressure may also need to be trended.	2 min.	Plot with two Y-axes for resolution (valve position on right axis). Observe that the zone temperature remains within 1°F of the deadband range, that the cfm is not over- or undershooting its setpoint or hunting, that the heating valve is not hunting and that the cfm is at minimum before the heating valve opens, etc.
Compressor staging	Compressor stage, OSAT, RAT, SAT	2 min.	Observe that the stages are not short cycling, that the minimum ON/OFF times are not violated, and that the staging is reasonable relative to the causal conditions (OSAT and RAT).

Plant Equipment

Description of Trend Point	Number of Points Per Trend
Outside air temperature	(1)
Outlet or leaving water temperature from the tower for both chillers (cond. water return)	(2)
Chilled water supply temp from both chillers	(2)
Hot water converter for secondary loop - entering and leaving water temperatures for each	(4)
Hot water converter steam valve position for each	(2)
Sub-Total	**11**

Air Handlers

Name	Tag Number	Description of Trend Point	Number of Points Per Trend
East AC	1	Mixed air temp	(1)
East AC	1	Supply air temp	(1)

East AC	1	Preheat valve position	(1)
East AC	6	Supply air temp	(1)
West AC	13	Hot deck and cold deck temp (multizone)	(1)
West AC	15	Supply air temp	(1)
West AC	15	Chilled water valve position	(1)
Sub-Total			**(7)**

Appendix I: Sample Functional Performance Tests

Appendix I contains a sample functional test for a centrifugal chiller and a variable frequency drive (VFD) on a pump. These tests are developed by the retro-commissioning service provider and can be more or less detailed and comprehensive depending on budgets and project objectives. Facility staff may assist with the hands-on operation of the equipment tested.

Sample Functional Test for Centrifugal Chiller

Functional Performance Test

Building:	**Commissioning Provider:**	**Phone:**
Date:	**Mfg. or Contractor:**	**Phone:**

Special Instructions:

Before performing this test, make sure that the normal PM tasks have been completed for the chiller and the following related equipment has been observed or functionally tested to prove proper operation:

- Chilled water pumps
- Condenser water pumps
- Cooling towers

Be sure all related pumps and cooling towers are operable and enabled.

Set leaving chilled water temperature to specified temperature.

If test is not being performed on or near design-day temperatures, false load the chiller.

If an energy management control system (EMCS) interfaces with this chiller, make sure all sensors are calibrated and properly located.

Use monitoring (dataloggers) and EMCS trend logging whenever possible to demonstrate proper operation of the equipment (this can be used in lieu of manual functional testing) and attach the output to this form.

Electrical

Check for voltage imbalance. Maximum allowable imbalance is 2%.

At the main disconnect for the compressors, measure the voltage of each phase and use the following method to determine the percent imbalance:

Phase A + Phase B + Phase C / 3 = Average Voltage

The percent voltage imbalance is then:

100 (Avg. Voltage – Lowest Phase) / the Average Voltage = % of Imbalance

Measured Voltage for Compressors

Phase A:	Phase B:	Phase C:

Percent Imbalance _____ The percent imbalance is acceptable Yes/ no

Comments and Calculations:

General

Check operation or status of each. Enter comment number if deficient, and document comments by number in form provided below checklist. Use N/A for not applicable and N/O for not obtainable or available.

Checklist Item	Number
Test condenser water flow and chilled water flow	
Test interlocks to pumps	
Test starter for dynamic limits and timers	
Oil heater safety inhibits starting	
Check chilled water recycle mode (if applicable)	
Chilled water pump stays on	
Other (list):	

Number	Comment

Test control panel for manual function.

- **Do readouts match actual values? ..... ☐Yes / ☐No**
- **Is refrigerant alarm and room ventilation adequate? ..... ☐Yes / ☐No**

Confirm energy performance over load range. Compare results to manufacturer's data using the attached table. If using dataloggers for this test, attach the readouts and explanation verifying proper performance. Otherwise proceed with manual test as follows:

Take three sets of data at 10-minute intervals. Tolerances from specified values should not exceed 1 degree F for temperature and 5% for flow. Repeat if necessary until system stabilizes and the differences between the three readings are less than the limits.

Chilled Water	Interval 1	Interval 2	Interval 3
LWT (F)			
EWT (F)			
Delta T			
Flow in GPM			
EW Pressure (PSI)			
LW Pressure (PSI)			
Evap. Leaving Refrigerant Temp.			

Condenser Water	Interval 1	Interval 2	Interval 3
LWT (F)			
EWT (F)			
Delta T			
Flow in GPM			
EW Pressure (PSI)			
LW Pressure (PSI)			
Condenser Leaving Refrigerant Temp.			

Electricity	Interval 1	Interval 2	Interval 3
Watt meter output			

Calculate the average test data and enter the results into the following table along with the manufacturer's performance data:

Based on the average test data, calculate the capacity using the following formula:

CAP in cooling tons = (chilled water delta T) * (chilled water flow rate) / 24

Check operation or status of each. Enter comment number if deficient, and document comments by number in form provided below checklist. Use N/A for not applicable and N/O for not obtainable or available.

Chilled Water	Manufacturer's Data	Average Test Data	Comment #
LWT (F)			
EWT (F)			
Delta T			
Flow in GPM			
EW Pressure (PSI)			
LW Pressure (PSI)			
Evap. Leaving Refrigerant Temp.			
LWT (F)			
EWT (F)			
Delta T			
Flow in GPM			
EW Pressure (PSI)			
LW Pressure (PSI)			
Condenser Leaving Refrigerant Temp.			
KW			
BTU/h or Cooling Tons			
kW per Ton =			

Number	Comment

- **Was any unusual noise or vibration observed?..... ☐Yes / ☐No**
- **Were amperage fluctuations observed?..... ☐Yes / ☐No**
- **Vane steady (not hunting)? ..... ☐Yes / ☐No**
- **Capacity is according to design? ..... ☐Yes / ☐No**
- **kW per ton is according to design? ..... ☐Yes / ☐No**

Part Load Test

Confirm energy performance over load range. Compare results to manufacturer's data using the attached table. If using dataloggers for this test, attach the readouts and explanation verifying proper performance. Otherwise proceed with manual test as follows:

Chiller may need to run for one hour with temperature and flow rate stabilized before performing this test. Watch amperage readings while load is being reduced. Amperage should be steady when recorded.

Take three sets of data at 10-minute intervals. Tolerances from specified values should not exceed 1 degree F for temperature and 5% for flow. Repeat if necessary until system stabilizes and the differences between the three readings are less than the limits.

Chilled Water	Interval 1	Interval 2	Interval 3
LWT (F)			
EWT (F)			
Delta T			
Flow in GPM			
Evap. Leaving Refrigerant Temp.			

Condenser Water	Interval 1	Interval 2	Interval 3
LWT (F)			
EWT (F)			
Delta T			
Flow in GPM			
Condenser Leaving Refrigerant Temp.			

Electricity	Interval 1	Interval 2	Interval 3
Wattmeter Output			

Calculate the average test data and enter the results into the following table along with the manufacturer's performance data:

Based on the average test data, calculate the capacity using the following formula:

CAP in cooling tons = (chilled water delta T) * (chilled water flow rate) / 24

Chilled Water	Manufacturer's Data	Average Test Data
LWT (F)		
EWT (F)		
Delta T		
Flow in GPM		
EW Pressure (PSI)		
LW Pressure (PSI)		
Evap. Leaving Refrigerant Temp.		
LWT (F)		
EWT (F)		
Delta T		
Flow in GPM		
EW Pressure (PSI)		
LW Pressure (PSI)		
Condenser Leaving Refrigerant Temp.		
KW		
BTU/h or Cooling Tons		
KW per Ton =		

- **Was any unusual noise or vibration observed?..... ☐Yes / ☐No**
- **Were amperage fluctuations observed?..... ☐Yes / ☐No**

Chilled Water Reset

If a reset strategy is employed, a test should be developed to demonstrate that the strategy works correctly. Use monitoring equipment or EMCS trend logging whenever possible and attach output demonstrating the reset strategy.

Training

- **Are the staff responsible for operating the chiller adequately trained?..... ☐Yes / ☐No**

Explain:

O&M Plan

- **Has an acceptable O&M Plan been put into place? ..... ☐Yes / ☐No**

Briefly describe the O&M plan:

The following items need correction:

- **Are eddy current tests conducted every 5 years? ..... ☐Yes / ☐No**

Variable Frequency Drive (VFD) Pump

Secondary Hydronic Pump Application

Functional Performance Test

Commissioning Team:

Commissioning Provider: _____

EMCS operator: _____

VFD technician: _____

HVAC technician: _____

Owner's rep.: _____

Pump ID:_____

____**Chilled water** (CHW) **secondary** ___**Hot water secondary** (HW)

Design max.: Hp: ____ GPM: _____ Head _____ Ft

VFD brand and model: _____

The following functional performance test is for a VFD controlling a variable flow hydronic system to a **constant** differential pressure (DP). ***A checkmark denotes compliance.***

I. Documentation Verification

___ Review the design documents and the specifications if available.

___ Verify that the VFD ___description, ___specifications, ___technical and troubleshooting guide and the installation, ___programming record and ___balance reports are on-site. From the design documents determine: Location for the DP measurement:

_____

Control strategy for the pump:_____

_____

II. VFD Installation

Differential Pressure Sensor

Actual location of DP measurement_____

The measurement should ideally be taken across the coil of the last branch.

Complies?

_____

Pressure Offset (Po) Conversion: psi x 2.31 = ft H_2O

DP pump is being controlled to: _____feet [A].

Pressure rise across pump at design conditions (from balance report): _____feet
[B]. Pressure offset, Po, [A] ÷ [B]= _____.

Optimally, Po should be 0.3 or less in order for the VFD and pump to be able to respond to small pressure changes and realize adequate energy savings. If Po is greater than 0.4, the DP sensor is probably located too close to the pump.

Complies? _____

Balancing to Lowest Pressure

Review the HVAC balance report and verify that the system was balanced so the VFD controls to the lowest possible DP (from the capacity test). The controlling DP from the balance report is _____feet. At design, the corresponding VFD frequency or pump RPM from the balance report is: Pump-1 _____; Pump-2 _____; Pump-3 _____. The corresponding flow from the balance report is_____GPM. Refer to the capacity test at the end of this form for details.

Balanced to lowest DP?
_____

General Issues

___ Verify that any power quality mitigation measures required from the specifications have been completed.

___ Verify that there are no three-way coil valves that may negate the value of the VFD by allowing flow to bypass the coil.

___ Verify that the acceleration and deceleration ramp time of the VFD is between one and four minutes. Actual ramp time: up _____min. down _____min. (short ramp times will result in "hunting" and excess modulation by the VFD; typical ramp times are 1 to 4 minutes)

___ Verify that each VFD has been integrated into the EMCS as per specification.

___ Verify that the EMCS monitors the DP.

___ Verify that minimum flow bypass of two-way valve, if present, has flow less than 2% of design flow.

III. Functional Performance Test

This test is not intended to verify that the coil valve is functioning properly, but rather that the VFD is functioning properly.

1. Design Flow by Test and Balance (TAB). Record in Condition 1 in Table 1 the speed, DP, and total supply flow at design conditions from the TAB report.

2. Intermediate Flow (coil valves partially open). Intermediate flow will occur when current conditions are such that the system is not in full cooling or full heating, nor at minimum flow. Read the speed, DP, and the total supply flow in the secondary loop and record in Condition 3 in Table 1.

   If the conditions are not in an "intermediate" position, change all space temperature set points to 4 degrees below the actual temperature in the space, for CHW pumps, or four degrees above for HW pumps (circle one) to simulate an approaching of thermostat satisfaction and take readings.

3. Design Flow (coil valves full open). Using the (EMCS) or other means, change all space temperature set points to at least 10 degrees below the current space temperature for CHW pumps, or 10 degrees above for HW pumps, so that the entire HVAC system supplied from these pumps is in full cooling (or heating, as appropriate, circle) in all zones. Observe that all coil valves are to their design maximum position (from the TAB report). Wait at least 20 minutes for lag time while observing:

   ___ Does the first lag pump turn on (after a delay) when the lead pump exceeds its _____ gpm design flow?

   ___ Does the 2nd lag pump turn on (after a delay) when the sum Lead + Lag 1 exceeds the sum of their design, *AND* the DP drops to 80% or _____ feet?

   Read the speeds, DP and the total supply flow and record in Condition 2.

4. Minimum Flow (Coil valves shut). Change all space temperature set points to be equal to the actual space temperatures to simulate a satisfied condition, driving the boxes to their minimum and the coil valves closed. Wait at least 25 minutes.

   ___ Do the lag pumps sequentially turn off (with a delay) when the flow is less than the design of all *running* pumps?

   ___ Does the last pump shut off appropriately?

   Take the frequency, pressure and flow readings and record in Condition 4.

IV. Analysis

Table 1.

Condition	Secondary Pump No.	Speed (Hz or RPM)		DP at Sensor (psi)		Total Flow (gpm)
		Reading	Average	Reading	Average	
1. At design flow by TAB	**Lead**					
	Lag-1					
	Lag-2					
2. At design flow (during commissioning)	**Lead**					
	Lag-1					
	Lag-2					
3. At intermediate flow (during commissioning)	**Lead**					
	Lag-1					
	Lag-2					
4. At no flow (during commissioning)	**Lead**					
	Lag-1					
	Lag-2					

Conversion: 0.434 x ft H_2O = psi

2.31 x psi = ft H_2O

1. In Table 1, average the speed and the DP for all pumps at each of the four conditions.

2. If the speed at Condition 1 (TAB test) is not within 10% of the current test at Condition 2, all the boxes may not have been driven wide open during the commissioning test, or the readings were taken before the lag time was complete. Investigate and repeat tests as appropriate.

   ___Less than 10% variance?

3. During operation of lead-lag pump combinations, the average DP readings at all four conditions should remain within 10% of each other. If there is more than a 10% variance, the sensor may be faulty. Note that during lead-lag pump transition, the DP may appropriately vary by as much as 20%.

   ___Less than 10% variance?

4. **___At no flow, Condition 4, is the flow and DP zero?**

5. **___For the total flow readings in Table 1, are the values in Condition 2 > 3 > 4?**

6. ___**Collaborative Trending**

The system operation will, will not (circle) be trended to further verify the proper operation of the VFD. Points to be trended are listed in the Trending Request Form.

___**From studying the trends, is the VFD is functioning properly?**

7. **Additional tests.** Refer to the chilled water systems sequence of operations tests for further collaboration on the VFD performance.

V. Training

___The building staff are adequately trained to operate and maintain the VFD. Comments:

VI. O&M Plan

___An acceptable O&M plan has been put into place. Describe:

VII. Capacity Test

To ensure that energy use is minimized, the hydronic system must be balanced at design conditions at the lowest possible differential pressure (DP) possible. This requires that the lowest possible DP at the sensor be found that will allow the delivery of design flow through the valve most difficult to satisfy. This system minimum DP is what the VFD should control to. This is accomplished by changing the temperature setpoint for all zones to 55F for cooling coils or 85F for heating coils, causing all AHU coil valves to be calling for full cooling or heating, as applicable. Each coil's flow is then measured against the design flow. The coil that is receiving the lowest fraction of design is identified. The current DP at the controlling sensor is noted. A calculation is made, giving the DP required at the sensor to allow the identified most critical coil to meet its design flow. The equation is $DP_2 = DP_1 \times Q_2^2 / Q_1^2$. Where Q_1 = actual or fraction of design flow during capacity test. Q_2 = design flow or 1.0 if using fractions. DP_1 = DP at sensor. DP_2 = DP to control to. It is noted that if all coils were calling for full cooling simultaneously, the pump could not maintain the new DP_2 value, due to diversity pump size reduction having been made by the design engineer.

<u>Summarize findings and possible improvements on Master List</u>

Appendix J: Commissioning Resources

Commissioning Overviews and Case Studies

Building Commissioning: The Key to Quality Assurance. USDOE Rebuild America / PECI., 1998. *[RCX]*
Commissioning retrofits and existing buildings: overview, process and case studies. 68 pgs.
1-800-363-3736.

Beyond Lighting DSM: Life After Green Lights, Urban Consortium Energy Task Force of Public Technologies, Submitted by Montgomery County Government, MD, Div. of Facilities and Services, 1998.
Existing building commissioning case study with sample process and detailed procedures. 70 pgs. 301-217-6000.

Continuous Commissioning[SM] of Texas Tech University, Final Report; *Energy Systems Laboratory Technical Report 76 pages. Order document # ESL0TR-01/09-02 at* http://www-esl.tamu.edu/CATALOG.htm

Commissioning For Better Buildings in Oregon. Oregon Office of Energy / PECI, 1997. *[rcx]*
New construction overview, benefits, process and case studies. 44pgs. (see web site below).

What Commissioning Can Do For Your Building. PECI, 1997. *[rcx]*
Commissioning overview and report of 175 building case studies. 12pgs. 503-248-4636.

Commissioning Four New Science Laboratory Buildings (U. of WA). Bonneville Power Admin. / Phoebe Caner, 1997.
Commissioning case studies with detailed "lessons learned" information in all sections. ~70 pgs. 503-230-7334.

Commissioning the Physics/Astronomy Building Control System (U. of WA). Bonneville Power / Phoebe Caner, 1996.
Commissioning case study and report with lessons learned. ~110 pgs. 503-230-7334.

Four case studies. Seattle City Light.
http://www.ci.seattle.wa.us/seattle/light/conserve/business/bdgcoma/cv6_bcam.htm.

Procedural Guidelines, Specifications and Functional Tests *Last Updated: 12/05/02*

* Denotes documents available on electronic disk. *[RCX]* = dedicated solely to retrocommissioning; *[rcx]* = contains some data on, retro-commissioning.
D = for design phase, C = for construction phase. All CAPS denotes document is more comprehensive than lower case.

Source	Guide-lines	Guide Specs	Sample Tests
Building Commissioning Guidelines. Energy Design Resources, 2002. Available at www.energydesignresources.com.	YES	No	Some
AABC Commissioning Guideline. Associated Air Balance Council. Available for order at www.aabchq.com	YES		
Appendix VII Idaho New Building Commissioning Guidelines. State of Idaho, 2000. Available at: http://www2.state.id.us/adm/pubworks/archengr/commgl97.htm	YES	No	No
Building Commissioning Assistance Handbook Appendices. Seattle City Light, 1999. (standardized functional test procedures http://www.ci.seattle.wa.us/seattle/light/conserve/business/bdgcoma/cv6_bcam.htm.	No	No	*YES
Procedural Standards for Building Systems Commissioning, National Environmental Balancing Bureau (NEBB), 1999. 301-977-3698	Yes d, c	Some d, c	Some
A Practical Guide for Commissioning Existing Buildings, PECI and Oak Ridge National Labs (ORNL), 1999. NTIS 1-800-553-6847 [RCX]	YES	No	No
Model Commissioning Plan and Guide Commissioning Specifications, USDOE/PECI, 1997. NTIS: # DE 97004564 1-800-553-6847. Http://www.peci.org/cx/mcpgs.html.	*Some D, c	*YES D, C	*YES

Source	Guide-lines	Guide Specs	Sample Tests
Building Commissioning Guide, U.S. GSA. & USDOE, 1995, revised in 1998 (Ver. 2.2). Ver. 1 by Enviro-Management & Research, Inc. Version 2.2 available on the web: http://www.eren.doe.gov/femp/techassist/bldguide.pdf	*Yes D, C	No	No
The HVAC Commissioning Process, ASHRAE Guideline 1-1996, 1996. ASHRAE Publications Dept., 1791 Tullie Circle, NE, Atlanta, GA 30329.	Yes d, C	Some d, c	No
The Building Commissioning Handbook, The Association of Higher Education Facilities Officers (APPA), written by John Heinz and Rick Casault, 1996. APPA, 1643 Prince Street, Alexandria, VA 22314.	YES d, C	YES C	No
Beyond Lighting DSM: Life After Green Lights, Montgomery Co., MD, 1995. [RCX] Existing building commissioning case study with sample process and detailed procedures. 70 pgs. 301-217-6000.	Yes	No	Yes
Engineering and Design Systems Commissioning Procedures, U.S. Army Corps of Engineers, 1995 (ER 1110-345-723). Dept. of the Army, U.S. Army Corps of Engineers, Washington, DC 20314-1000.	Some d, c	Some d, c	No
Commissioning Specifications, C-2000 Program, Canada, 1995. C-2000 Program, Energy Mines & Resources, Energy Efficiency Division, 7th Floor, 580 Booth St., Ottawa, Ontario, Canada K1A 0E4.	No	*YES C	No
Model Construction Document Specifications and A/E Services Contract Clauses. Bonneville Power Administration/John Heinz, U. of WA, 1995. 503-230-7334. Also available on the Univ. of Washington web site below.	No	*YES C	Some
Commissioning Guidelines, Instructions for Architects & Engineers, State of WA., 1995. Dept. of General Admin., Div. of Engin. & Arch., (360) 902-7272.	Yes d, c	No	No
Commissioning of HVAC Systems, seminar/workshop training materials, Univ. of Wisconsin, Madison, 1994. 800-462-0876 or 608-262-2061	Some C	Some C	Some
Laboratory HVAC Systems: Design, Validation and Commissioning, ASHRAE collection of 11 papers, 1994. And,	*Yes C*	*No*	*No*
Commissioning Smoke Management Systems, ASHRAE Guideline 5-1994. ASHRAE Publications Dept., 1791 Tullie Circle, NE, Atlanta, GA 30329.	*Yes d, c*	*No*	*No*
Standard HVAC Control Systems Commissioning and Quality Verification User Guide, U.S. Army Const. Engineering Research Labs, 1994. Facilities Engineering Applications Program, U.S. Army Engineering and Housing Support Center, Ft. Belvoir, VA 22060-5516. FEAP-UG-GE-94/20.	*No*	*No*	*Yes*
Contractor Quality Control and Commissioning Program—Guidelines and Specification, Montgomery Co. Gov., St of Maryland, 1993. 301-217-6071.	**Yes c*	**YES C*	**Some*
HVAC Systems Commissioning Manual, Sheet Metal and Air Conditioning Contractors' National Association (SMACNA), 1993. SMACNA, 4201 Lafayette Center Dr., Chantilly, VA 22021.	*Yes c*	*Some c*	*Some*
Commissioning Guide, Public Works Canada, Western Region, 1993. 403-497-3770.	*Some d, c*	*Yes d, C*	*No*
Guide Specification for Military Construction—Commissioning of HVAC Systems, Dept. of the Army, U.S. Army Corps of Engineers, 1993. Washington, DC 20314-1000	*No*	**Some c*	**YES*
Building Commissioning Guidelines, Bonneville Power Administration/PECI, 1992. 503-230-7334.	*YES d, C*	Some c	Some
HVAC Functional Inspection and Testing Guide, U.S. Dept. of Commerce and the General Services Administration, 1992. NTIS: 800-553-6847.	*No*	No	YES

Source	Guide-lines	Guide Specs	Sample Tests
Thermal Energy Storage (TES) Commissioning Guidelines, California Institute for Energy Efficiency, San Diego State University, 1991. San Diego State University, Energy Engineering Institute, San Diego, CA 92182.	*Yes C*	No	Yes
AABC Master Specification, Associated Air Balance Council. (Primarily for how the TAB fits into the commissioning process) AABC National Hdqrs, 202-737-0202.	*No*	*Yes d, C	No

Web Sites Containing Commissioning Documents

American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)	**http://www.ashrae.org/**
Building Commissioning Association	**http://www.bcxa.org/**
California Commissioning Collaborative	**http://www.cacx.org/**
Continuous Commissioning	**http://www-esl.tamu.edu/cc/index.html**
Energy Design Resources	**http://www.energydesignresources.com** (case studies, design briefs, guidelines)
Florida Design Initiative	**http://www.state.fl.us/fdi/index.html** (ongoing articles & forum)
NYSERDA	**http://www.nyserda.org/commissioning.html**
NEBB	**http://www.nebb.org/search.htm** (certification program and manuals)
Oregon Office of Energy	**http://www.energy.state.or.us/bus/comm/bldgcx.htm** (benefits of Cx, case study, the full text of *Commissioning for Better Buildings in Oregon*) *[rcx]*
PECI	**http://www.peci.org/** (Cx conference announcement, downloadable *Model Cx Plan and Guide Specifications*, Cx information sources, Cx & O&M training locator database)
Texas A&M Energy Systems Lab	**http://www-esl.tamu.edu/** (retro-commissioning process and software, for purchase) *[RCX]*
University of Washington	**http://depts.washington.edu/fsesweb/fdi/index.html** Univ. Cx guide specs distributed throughout the specs. Vol's 1-4)
USDOE / FEMP	**http://www.eren.doe.gov/femp/** (full text of GSA/USDOE *Building Commissioning Guide;* early version of *Model Cx Plan and Guide Specifications*)
USDOE	**http://www.eren.doe.gov/** (Links to commissioning doc's. Search on "commissioning.")
Seattle City Light	**http://www.ci.seattle.wa.us/seattle/light/conserve/business/bdgcoma/cv6_bcam.htm** (standardized test procedures and case studies)
Total Building Commissioning (NIBS)	**http://sustainable.state.fl.us/fdi/edesign/resource/totalbcx/index.html** National Institute of Building Sciences (find commissioning information by searching on "commissioning"
Whole Building Design Guide (National Institute of Building Sciences)	**http://www.nibs.org/projwbdg.html**