

Retrocommissioning Final Report

Owner Y Building X

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Table Of Contents

Introduction.....	1
Approach.....	1
Building Description.....	1
Summary of Findings Selected For Implementation	2
General Information.....	2
Findings and Implementation Summary Table Including Savings And Costs	3
Recommendations And Conclusions	5
Appendix A – Implementation Details	
<u>Group 1 Findings</u>	
Findings 2, 3, and 5 – Heating Water Pump Modifications	A.2
Finding 7 - Reduce Condenser Water Flow When Only One Chiller is in Use	A.2
Finding 8 – Excessive Condenser Water System Head.....	A.2
Finding 19 - Filter Performance Improvements	A.3
<u>Group 2 Findings</u>	
Finding 31 – Reset Schedule Programming Error	A.3
Finding 32 – SF1 and SF2 have no Hard Wired Static Safeties or Pressure Relief Doors	A.3
Finding 33 – Chilled Water Pump May Not Run for Freeze Protection Cycles	A.3
Finding 34 – Fans SF1 and SF2 do not have a Mixed Air Low Limit Cycle	A.4
<u>Group 3 Findings</u>	
Findings 9 and 10 – Chilled Water Flow is in Excess Of Design Requirements	A.4
<u>Group 4 Findings</u>	
Finding 22 – Building Static Pressure Control Problems.....	A.4
Finding 23 – Minimum Outdoor Air Settings are Approximate and may be Too High	A.5
Findings 27 and 29 – Improvements in the SF1 and SF2 Discharge Temperature and Discharge Static Pressure Control Routines are Possible via the New DDC Terminal Units.....	A.5
Finding 30 – Improved Condenser Water Temperature Control Sequence Possible	A.6
Finding 36 – Improved Economizer Lock-out Set Points May Save Energy.....	A.6

New Findings

Finding 47 – Eliminate Prefilters in SF1 and SF2..... A.6

Calculation Appendices

- Appendix B - Findings 2, 3, and 5 Calculations
- Appendix C – Findings 7 and 8 Calculations
- Appendix D - Finding 19 Calculations
- Appendix E - Finding 32 Calculations
- Appendix F - Finding 33 Calculations
- Appendix G - Finding 34 Calculations
- Appendix H - Findings 9 and 10 Calculations
- Appendix I - Finding 22 Calculations
- Appendix J - Finding 23 Calculations
- Appendix K - Findings 27 and 29 Calculations
- Appendix L - Finding 30 Calculations
- Appendix M - Finding 36 Calculations
- Appendix N - Finding 47 Calculations

Validation Appendices

- Appendix O – Purchase Order for the Work Associated with Findings 2, 3, and 5
- Appendix P – Purchase Order for the Extended Surface Area Filters Associated with Findings 7 & 8
- Appendix Q – Purchase Orders for the Labor and Materials Associated with Finding 19.

Drawings

- Appendix R - Heating Hot Water System Flow Diagram

Introduction

Retrocommissioning Building X belonging to Owner Y has been a coordinated effort between Portland Energy Conservation Inc (PECI), Owner Y's Engineering and Operations groups and Utility. In the course of the project, building documentation was reviewed, interviews and field investigations were conducted, and systems were analyzed and tested. An initial assessment report was prepared and presented in August. The parties involved in the project then met, reviewed the report and selected the findings that were appropriate for additional consideration and/or implementation. Between September and November, these targeted findings were further evaluated and/or implemented. The purpose of this report is to summarize the final results of this effort. For additional information regarding all of the findings identified by the retrocommissioning study, please refer to the Building X Initial Assessment Report dated August 16, 1999.

Approach

The project began with a scoping study, during which preliminary interviews were held and a preliminary walk-through of the facility was conducted. This information resulted in a scoping report, which identified target areas for the focus of the project. The next step in the process was the development of a commissioning plan. This document more fully developed the approach and served as a framework under which the remainder of the project was conducted. Implementation of the plan resulted in more detailed analysis of the existing building documentation and systems via field investigations, interviews, monitoring, testing, and calculations. The results of this effort were presented in the Initial Assessment Report in August of 1999. After reviewing the report, all parties met and selected 18 of the 43 findings for further investigation and/or implementation. A cooperative effort between Owner Y, PECI, and Utility focused on implementing the majority of the energy conserving measures by the end of the 1999 calendar year. Operational and maintenance issues were primarily related to control system programming modifications and were deferred until the next control contractor service visit in early 2000. One energy conservation measure will required significant capital and control system modification for full implementation. This project was also deferred into the year 2000. When implemented it will save significant heating energy, save some electrical energy, improve building comfort conditions and help alleviate the low heating system capacity problem. Details of the implemented findings are summarized in a table in a subsequent section and discussed in Appendix A.

Building Description

Building X is a 261,000 square foot office building located in downtown City Z that was constructed in the 1970/1971 time frame. In addition to the office building, there is a retail/parking structure associated with the building. The retail/parking structure was not a focus of this study but may represent another retrocommissioning and energy conservation opportunity as detailed in Finding 24 of the Initial Assessment Report.

In the office building, a central chiller plant containing 2 centrifugal water-cooled chillers provides primary cooling. This plant is supplemented by an air-cooled chilled water system owned and operated by one of the tenants to cool critical areas in their lease space. Supplemental cooling is also provided to the computer rooms of another tenant by a closed loop dry cooler type system. There are also some water-cooled direct

expansion type computer room units that reject heat to a domestic water stream, which then wastes to the drain.

The heating plant consists of 2 packaged type, gas fired sectional boilers that generate hot water for use in perimeter heating loops and in heating coils located in some of the air handling systems. There are also two reheat coils served by this system. Operational experience and our analysis both indicate that the existing boiler plant size may be marginal. Implementing Finding 22 will help alleviate this problem since the infiltration load on the building heating system will be reduced in the winter. A capital project aimed at replacing the existing plant with high efficiency boilers with more capacity than the existing equipment may also be an economically viable alternative with a reasonable payback. Both of these issues are discussed in detail in the Initial Assessment Report.

The majority of the building is cooled by two large variable volume air handling systems which serve pneumatically controlled induction terminal units. These terminal units will soon be replaced with VAV and fan terminal units with DDC controllers. Two small package air handling systems provide conditioning for the lobby areas of the building on the first floor. As mentioned previously, there are also some stand alone tenant owned air handling systems scattered through out the building serving specialized cooling needs.

The original control system has been upgraded to a Siebe Network 8000 DDC system equipped with a Signal front end. In general, the original pneumatic actuation was retained but the new VAV and fan terminal units with DDC controllers will use electric actuators.

Summary of Findings Selected for Implementation

The Initial Assessment Report identified 43 findings, some of which had the potential to save energy. Of these findings, 18 were targeted for further analysis and/or implementation. These findings were further subdivided into groups. As with any retrocommissioning process, not all of the targeted findings were related to energy conservation. Some of them dealt with life safety issues, operational issues, and failure mode issues. However, many of the findings, when implemented will result in significant energy or other resource savings, and will improve the over-all performance and reliability of the building systems. The following table summarizes the findings and their savings potential, implementation costs, and paybacks. More detailed information regarding the specific steps taken to implement the findings can be found in Appendix A. Calculations supporting the savings and costs indicated below can be found in the Calculation and Validation Appendices.

Shading indicates items that have been implemented as of this time.

Group 1 Findings – Findings targeted for 1999 implementation to meet UTILITY energy conservation goals.

Finding No.	Description	Annual Savings Potential						Projected Cost to Implement \$	Simple Payback years
		Electricity		Gas		Other			
		kWh	\$	Therms	\$	Item	\$		
7	Reduce condenser water flow when only one chiller is in use	61,566	\$2,685	0	\$0	N/A	N/A	\$5,000	1.86
8	Excessive condenser water system head	18,862	\$823	0	0	N/A	N/A	\$0 if testing and repair done in house	Immediate
19	Filter performance improvements	171	\$7	0	0	Filters	\$2,807	\$0; simply install a different filter at the next change-out cycle	Immediate
2, 3, and 5	Heating Water Pump Modifications	52,816	\$2,303	0	\$0	N/A	N/A	\$2,611	1.13

Group 2 Findings – Findings targeting operational, maintenance, and failure mode issues.

Finding No.	Description	Annual Savings Potential						Projected Cost to Implement \$	Simple Payback years
		Electricity		Gas		Other			
		kWh	\$	Therms	\$	Item	\$		
31	Reset schedule programming error	0	\$0	0	\$0	0	\$0	\$450 or less	N/A
32	SF1 and SF2 have no hard wired static safeties or pressure relief doors	0	\$0	0	\$0	0	\$0	\$14,950	N/A
33	Chilled water pump may not run for freeze protection cycles	0	\$0	0	\$0	0	\$0	\$450 or less	N/A
34	SF1 and SF2 do not have a mixed air low limit cycle	0	\$0	0	\$0	0	\$0	\$0 - \$4,600 depending on how it is done.	N/A

Group 3 Findings – Findings targeted for 1999 implementation but which will not result in energy savings until 2000 due to seasonal nature of the system operation.

Finding No.	Description	Annual Savings Potential						Projected Cost to Implement \$	Simple Payback years
		Electricity		Gas		Other			
		kWh	\$	Therms	\$	Item	\$		
9 and 10	Chilled water flow is in excess of design Option 4 – Throttle pumps to design and run 2 pumps	1,628	\$71	0	\$0	N/A	\$0	\$0	Immediate

Group 4 Findings – Findings targeted for 2000 implementation.

Finding No.	Description	Annual Savings Potential						Projected Cost to Implement \$	Simple Payback years
		Electricity		Gas		Other			
		kWh	\$	Therms	\$	Item	\$		
22	Building static pressure control problems	9,927	\$437	11,716	\$6,198	N/A	N/A	\$20,058	3.02
23	Minimum outdoor air settings are approximate and may be too high or too low	0	\$0	0	\$0	N/A	\$0	See Note	N/A
27 and 29	Improvements to the discharge temperature and pressure reset routines are possible via the new DDC terminal units	7,507	\$330	0	\$0	N/A	N/A	\$380	1.15
30	Improved condenser water temperature control sequence possible	32,643	\$1,436	0	\$0	N/A	N/A	\$760	0.53
36	Improved economizer lock-out set points may save some energy	13,331	\$673	0	\$0	N/A	N/A	\$760	1.13

Note: Testing performed on November 30, 1999 revealed that the return fans actually pressurize the mixing box when the systems are on minimum outdoor air and air flows out the minimum outdoor air dampers rather than in the dampers. See Appendix A for details.

New Findings – Findings identified and developed subsequent to the Initial Assessment Report.

Finding No.	Description	Annual Savings Potential						Projected Cost to Implement \$	Simple Payback years
		Electricity		Gas		Other			
		kWh	\$	Therms	\$	Item	\$		
47	Eliminate prefilters in S1 and S2	5,149	\$453	0	\$0	Filters	-\$453	\$0	Immediate

Summary Table

Description	Annual Savings Potential						Projected Cost to Implement \$	Simple Payback years
	Electricity		Gas		Other			
	kWh	\$	Therms	\$	Item	\$		
TOTAL by category evaluated and ready to implement to date; Does not include Group 2 Findings	203,601	\$9,219	11,716	\$6,198	0	\$2,354	\$29,568	1.66
TOTAL by category implemented to date	138,564	\$6,272	0	\$0	0	\$2,354		
TOTAL dollar value of savings evaluated and ready to implement to date							\$17,770	
TOTAL dollar value implemented to date							\$8,625	

Recommendations and Conclusions

The implementation work associated with the 18 targeted findings is well underway, with 6 already completed. The additional details regarding the status of these findings are reported in Appendix A. It is our recommendation that this effort continue until the targeted findings are fully implemented. (PECI will be available for follow-up and consulting as required to complete the implementation work per our previous discussions.) All selected findings, when implemented, will result in annual energy savings of 5% of the current utility bill. While this is somewhat less than was originally anticipated during the scoping study, it is still a significant reduction with an over-all payback of less than 2 years. It is also our recommendation that the findings that were not selected for implementation at this time be revisited in the future, especially those that deal with the heating system capacity and the addition of terminal equipment under the current induction unit replacement project.

Building X is already very well run and maintained. Equipment and lighting control systems are used to schedule the equipment they serve to be off or in a minimal state of operation anytime this is possible. The Operations and Engineering staff are diligent in their efforts to keep the building in good operating shape, maintain comfort to the best of the ability of the equipment, and minimize operating costs to the extent possible without degradation of the systems and equipment. Prior to this study, Owner Y had initiated projects to improve comfort and/or system efficiency. The most significant of these is the retrofit installation of Direct Digital Control (DDC) Variable Air Volume (VAVs) and DDC Fan Terminal Units (FTUs) to replace the existing induction units. In addition to replacing worn out equipment with state-of-the-art equipment, this retrofit will improve building comfort conditions and allow reduced energy consumption by shutting down zones that were not in operation while allowing the air handling systems to remain in operation to serve the remaining zones. Our assessment of this activity was reported under

finding 25 of the Initial Assessment report. The DDC technology made available by the retrofit project makes possible the control sequence changes proposed by findings 27 and 29 to optimize discharge temperature and pressure. Without this technology, these recommendations would have been difficult, if not impossible, to implement. Finding 14 of the initial assessment report contains some additional considerations regarding the selection of the terminal equipment that the Owner may wish to consider as the project expands from the 11th floor to other floors of the building. These recommendations were discussed in the initial assessment report meeting in early September.

The capacity of the existing heating system requires that the air handling and lighting systems be operated more than necessary during winter weather to maintain building comfort conditions. Additional energy savings could be realized through a more rigorous scheduled control of the lighting and air-handling systems once the capacity issue is addressed.

Some of the findings that are going to be implemented by Owner Y were not related at all to energy consumption. These Group 2 findings in the preceding table focus on operational and maintenance issues. While implementation of these findings will not result in any direct savings to the building operating or energy costs, they will help avoid potentially costly equipment failures and repairs.

The remainder of this report provides details and documentation to support our recommendations and conclusions.

Appendix A

Implementation Details

The following paragraphs detail what was/is involved in the implementation process associated with each of the findings which were targeted for implementation subsequent to the Initial Assessment Report. The finding numbers and descriptions in the headers are those that were used in the Initial Assessment Report. In many cases, similar findings were grouped together for evaluation and implementation.

Group 1 Findings

Findings 2, 3, and 5 – Heating Water Pump Modifications

The issues involved in findings 2, 3 and 5 turned out to be interactive. Finding 2 dealt with the problems associated with high head pumps piped in parallel with low head pumps. Finding 3 dealt with the fact that the pumps were pumping against throttled discharge valves; energy was being put into the system at the pump motor and dissipated immediately at the pump discharge. Finding 5 dealt with excessive boiler circulation pumping capacity. The result was more water was circulated than was required and more energy was used than necessary. The excess capacity problem associated with finding 3 was addressed by trimming the pump impellers so that only the required capacity was produced. Trimming the impellers also addressed the parallel pump mismatch problems associated with finding 2. Since the final calculations required for the impeller trims for the system circulation pumps (HWP1 through 4) were completed in the early fall, the actual impeller trim work was deferred until the next summer to minimize the impact of the work on the ability to heat the building. As a temporary measure, the pumps were throttled to their design flow rates, which achieved the energy savings projected in the initial assessment report. Additional savings will be achieved by trimming the impellers in the summer of 2000. Savings for the boiler circulation pumps (finding 5) were achieved by installing variable speed drives and slowing down the pumps so that they only pump the capacity that is needed.

Finding 7 – Reduce Condenser Water Flow When Only One Chiller is in Use

The building chilled water system is served by two independent and nearly identical chillers. It is usually only necessary to run one chiller. However, due to the piping arrangement, it is necessary to run both condenser water pumps regardless of the number of chillers that are operating. This results in condenser water flow rates significantly higher than what would be required most of the time, which in turn results in wasted pump energy and unnecessary operating expenses. The finding proposes installing an automatic valve for each chiller and controlling the valve so that it opens when the chiller runs and closes when the chiller doesn't run. This will allow one pump to operate when one chiller is operating. The building operates for a significant number of hours in this mode during the year and so significant savings will be generated by not operating the second pump when only one chiller is running. Currently a contract is in place to make the necessary modifications prior to the start of the 2000 cooling season.

Finding 8 – Excessive Condenser Water System Head

Field tests and estimates of the required head for the condenser water pumps indicate that the pumps were operating at a higher head or differential pressure than would be expected. This indicates that there must be a restriction in the system at some point. Subsequent testing by the operating staff revealed that the condenser water pump strainers and the cooling tower spray tree nozzles had become fouled. The fouling was due to debris generated when the recently installed replacement fill and new epoxy coating placed on the tower started to delaminate and fail. The manufacturer made repairs under warranty which including replacing the tower fill. The new fill improved tower efficiency due to better wetting and the cleaned

strainers and nozzles reduced the pump head. The savings were generated because less pumping energy was needed with the lower system head and because of the improved tower efficiency.

Finding 19 – Filter Performance Improvements

This finding deals with replacing the existing final filters with newer technology filters that have lower pressure drops and higher dust holding capabilities. The savings are generated primarily by longer filter life cycles (fewer filters to purchase, install and dispose of) but the newer technology filters also save fan energy due to the lower pressure drop.

Group 2 Findings

Finding 31 – Reset Schedule Programming Error

In reviewing the program code for the S1 and S2 air handling systems, a potential programming error was found that could restrict the action of the chilled water valve. This is an operational issue and there is no energy savings associated with correcting this item. The control contractor will correct the item on the next site visit.

Finding 32 – SF1 and SF2 have no Hard Wired Static Safeties or Pressure Relief Doors

Field investigations revealed that there are no hard-wired static pressure safety systems on air handling systems SF1 and SF2. There are some blow out panels in place to protect equipment from excessive pressure, but not all locations are protected. The only existing safety system is software based and uses the information from the discharge static pressure sensor to provide a safety shut down. The problem with this technique is that if the existing sensor fails, the control loop that controls fan static pressure would lose its input and go “open loop” or out of control, which could cause a duct over-pressurization problem. But, since the sensor that failed also provides an input to the software based safety system, the software based safety system would not function. It is also quite likely that this safety system is not fast enough to detect over pressurization caused by an accidental fire or smoke damper closure in time to shut down the fan system and prevent duct work damage. If a fire or smoke damper in the main duct system were to fail closed, it is possible for the duct system to be blown apart from the resulting pressure surge. This pressure surge could be higher than the peak of the fan curve and could propagate very quickly down the duct system. A pressure relief door or blow out panel is usually more effective in dealing with this type of problem; the blow out panel or relief door creates a designed in, controlled failure point in the system. There are also certain unusual (but not impossible) failure modes for the economizer dampers that could result in duct system and air handling casing failure due to extreme pressures. This was an operational issue and there were no energy savings associated with correcting this item. The control contractor will correct the item on the next site visit.

Finding 33 – Chilled Water Pump May Not Run During Freeze Protection Cycles

In reviewing the program code for the building chilled water system, it was discovered that the chilled water pump may not be commanded on during a freeze protection cycle. This makes the protection provided by the cycle incomplete since it relied on the pump moving water through the chilled water coil as a part of the freeze protection scheme. This was an operational issue and there were no energy savings associated with correcting this item. The control contractor will correct the item on the next site visit.

Finding 34 – SF1 and SF2 do not have a Mixed Air Low Limit Cycle

In reviewing the program code for SF1 and SF2, it was discovered that these units are not provided with a mixed air low limit cycle. This can present an operational problem during periods of low load/system air flow when they occur in combination with subfreezing temperatures. The results can be nuisance freeze stat trips and difficulty in restarting the system after a freeze stat trip or a scheduled shut down. Up until now this potential problem has not been an issue, but it may become more evident as the DDC boxes are installed throughout the building and scheduled operation by tenant or floor is incorporated into the system operating strategy. This is an operational issue and there were no energy savings associated with correcting this item. The control contractor will correct the item on the next site visit.

Group 3 Findings

Findings 9 and 10 – Chilled Water Flow is in Excess of Design

Field investigations, calculations and testing revealed that the existing chilled water pumps are capable of pumping flow rates in excess of design when both pumps are operated. The chiller evaporators are piped in series and the current operating practice is to run both pumps any time either or both chillers are operating. The excess flow represents wasted pumping energy. However, if the flow rates are reduced too much, there will be operational problems associated with running the chillers including the potential to frost or even freeze the tubes. Several experiments were performed to determine how to best address this issue. Running only one pump provided marginal performance and was not recommended as a normal operating mode by the chiller manufacturer. Trimming the impellers in both pumps to provide the required flow rate with both pumps running was investigated but eliminated because it eliminates the possibility of running on one pump if the other were to fail. (While running on one pump currently is marginal and not recommended, it is a feasible operating mode in an emergency if the performance of the machinery is carefully monitored.) Installing larger impellers on the existing pumps so that one pump would provide sufficient flow on its own is a viable option but has a high initial cost. Throttling the pumps so that the design flow is produced with both pumps running saves the least amount of energy but has the lowest initial cost since the work can be done by in-house staff. This was the option selected and is reflected in the attached summary table.

Group 4 Findings

Finding 22 – Building Static Pressure Control Problem

The following issues result in a building static pressure control problem that is especially evident during cold weather:

- The current arrangement for controlling the supply and return fan volumes,
- The variable air volume (VAV) design of the existing air handling system,
- The method of controlling the air handling unit relief dampers, and
- The stack effect associated with the height of the building.

Modifications and improvements to the existing control system could alleviate and/or eliminate this problem. The modifications are significant and relatively costly, but they generate savings because return fan energy and heating system load are reduced. The load on the heating system is reduced because the

infiltration load that exists with a negatively pressurized building (air is sucked into the building through cracks and openings especially at windows and doors) is converted to an exfiltration problem (air is blown out of the building at cracks, etc.). This air is now heated by being brought into the air handling systems through the economizer cycle and mixed with warm air rather than being heated by the perimeter heating system as it is drawn into the occupied space. Mixing the return air with outside air to achieve the desired supply temperature is essentially a heat recovery strategy (the return air has been warmed by the building loads). Addressing this finding will help alleviate the sizing problem that exists with the building heating system since the infiltration load will be removed from the system, thus making more capacity available to offset transmission losses through the building walls.

Finding 23 – Minimum Outdoor Air Settings are Approximate and May Be Too High or Too Low

The settings currently used for minimum outdoor air regulation are based on a percentage of damper actuator travel rather than a true measurement of air flow. Testing in the field revealed that under some conditions, the minimum outdoor air flow is actually reversed; i.e. air flows out of the mixing chambers on the air handling system rather than into the mixing chambers. This observation implies several things. For one thing, it implies that there could be some indoor air quality problems in the building during the periods of time when the system is on minimum outdoor air. Typically, this would only occur in the summer (currently above 76°F) or during extremely cold weather. Another implication is that it is quite likely that the building tends to run negative in this mode. This means that the extra air that the return fans are bringing back to the return plenum and forcing out of the building via the outdoor air dampers is infiltrating into the building at cracks and doors. Solving the building pressurization problem (finding 22) will tend to help address this issue. Currently the return vanes are positioned with the same signal that positions the supply fan vanes. The phenomenon we observed during the test tends to demonstrate that this is not the best way to operate since the system characteristics that the supply fan sees as flow varies are considerably different than what the return fan sees. It may be possible to correct this by applying a series of correction factors to the signal to the return fan assuming it is an independent output from the DDC system. The system could be tested and adjusted in several modes to be sure that the return flow was always less than the supply flow by the minimum outdoor air quantity. If the systems use a common output, then a bias relay could be installed to put a fixed differential between the return fan vane command and the supply fan vane command. The best approach would be to implement the Finding 22 recommendations, which provides an independent output and control loop for the return fan vanes. Fixing this problem will actually cause some energy to be used at the chiller plant in the summer to condition the minimum outdoor air that is currently not being brought in. However, this will be offset by the reduction in return fan energy (the fans are moving more air than they need to) and the elimination of the infiltration load. We anticipate that the net impact on the operating costs for the building will be 0.

Findings 27 and 29 – Improvements in the SF1 and SF2 Discharge Temperature and Pressure Reset Routines are Possible with the New Direct Digital Control (DDC) Terminal Equipment

Currently, the existing pneumatically controlled induction style terminal equipment are being replaced with conventional VAV and VAV/fan terminal units using DDC equipment. The distributed intelligence associated with the DDC equipment provides the opportunity to optimize the temperature and pressure settings for the air handling equipment based on what is going on at the zone level. This will result in some additional energy savings and can be accomplished with relatively minor programming modifications to the software running on the existing Network 8000 DDC control system. The control contractor will perform this work at the time of the next site visit.

Finding 30 – Improved Condenser Water Reset Control Sequence Possible

A review of the cooling tower control code indicated that set point adjustment and sequencing improvements could result in energy savings. Specifically, the system set point could be adjusted to optimize the overall tower fan energy/chiller compressor energy picture. In addition, sequencing would be arranged to assure that water was not bypassing the cooling tower when the cooling tower fans were in operation. These improvements can be accomplished with relatively minor programming modifications to the software running on the existing Network 8000 DDC control system. The control contractor will perform this work at the time of the next site visit.

Finding 36 – Improved Economizer Lock-Out Set Points may Save Additional Energy

A review of air handling systems SF1 and SF2 program code indicates that the set points used to switch from economizer mode (free cooling using as much outdoor air as possible) to recirculation mode (use minimum outdoor air as required for ventilation purposes) could save energy. The improvement can be made with minor programming modifications to the software running on the existing Network 8000 DDC control system. The control contractor will perform this work at the time of the next site visit.

New Findings

Finding 47 – Eliminate the Prefilters In Air Handling Systems SF1 and SF2

Air handling systems are typically equipped with final filters that are selected to provide the quality of air required for the occupied space in the building. Since these filters are relatively expensive, it is also common practice to provide roughing filters or prefilters ahead of the final filters. The prefilters can be replaced at a small fraction of the cost of final filters and remove many of the larger particles that would normally be caught by the final filters, thus extending the life of the final filters. The prefilters do nothing to make the air that is supplied to the building any cleaner. Despite their advantages, prefilters add a pressure drop to the system they are installed in. This pressure drop translates into fan energy over the life of the filter since the fans must do more work to move the required airflow through additional resistance. In addition, the prefilters, while inexpensive in comparison to the final filters, do add cost, and must be installed and disposed of. Thus, facility operators and engineers are always juggling the trade-off of prefilter and additional energy cost vs. final filter cost.

Recent advances in filter technology have reduced the cost of filters and increased their dust holding capacity to the point where the choice to eliminate the prefilters becomes easier. When the prefilters are eliminated, the pressure drop is removed from the system and energy is saved. On the negative side, the final filters will now load up more quickly since they must capture and retain all particles in the air stream, not just the ones that were not handled by the prefilters. An analysis for the Building X systems SF1 and SF2 showed that savings can be achieved by eliminating the prefilters and changing the final filters more frequently. The cost of filters will probably increase since more frequent changes of the final filters will be required. However, the energy savings will pay for this increase with the result being a net reduction in operating cost. Implementation of this measure while some-what radical is also low risk because if the new operating mode proves to be unsatisfactory the prefilters can simply be reinstalled.

The operating staff are experimenting with this option in combination with the extended surface area filters associated with Finding 19. SF1 and SF2 are two nearly identical systems. The staff have installed the extended surface area filters on both systems, but retained the prefilters on only one system. This will allow them to track the advantages and disadvantages of not using the prefilters and make a more informed decision at the time of the next filter replacement cycle. If the final filters last two years or longer before they need to be changed when no prefilters are installed, then it should be more cost-effective to eliminate the prefilters. The savings projections in the report reflect eliminating the prefilters on only one system.