The Importance of Retrocommissioning Measured, Identified or Greatly Modified Subsequent to the RCx Assessment

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Synopsis

Building operators and owners are accustomed to energy audits that provide a list of potential retrofits accompanied by the expected cost and savings for each measure. They then select the measures they wish to have implemented based on this listing. Our experience indicates that the initial RCx assessment can effectively identify the overall savings expected from a retro-commissioning project, but may not effectively provide a good estimate of the savings from individual measures. In fact, some effective measures emerge only during the RCx process. This paper examines the results of eight RCx projects where at least one of the significant measures implemented was not identified during the initial assessment or represented a significant change or modification of a measure identified during the assessment. This paper has examined nine RCx projects in which project savings were increased by up to 40% with an average increase of 19% due to implementation of measures that were not originally identified. This suggests that there can be significant benefit in permitting the RCx provider to thoroughly investigate each facility, rather than restricting the investigation to the rapidly determined list of potential RCx measures identified during the assessment.

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Introduction

Building owners and operators are widely accustomed to the retrofit process for improving the energy efficiency of buildings by installing new, more efficient energy-using equipment. This process typically begins with a walk-through energy audit that provides a rapid overview of potential energy savings in the building and potential payback of measures that may be installed. If the retrofit potential is deemed sufficiently attractive, the initial walk-through audit is typically followed by a more detailed investment-grade audit that provides a considerably more thorough evaluation of the savings from retrofit measures and of the potential cost of installing these measures. The owner or the owner's representative then selects the measures that will be installed for final design, installation and (ideally) commissioning.

The retro-commissioning process typically starts with the RCx equivalent of the walk-through audit – we call it an "assessment" to distinguish it from a normal energy audit (Liu et al., 2002). This assessment provides sufficient information to give the owner a firm cost proposal for the RCx process and provide an estimate of potential savings that is almost always met. The process then typically involves a much more detailed assessment of each potential commissioning measure to enable it to be successfully implemented.

In recent years, we have observed more customers who wish to apply the normal retrofit model to the commissioning process; they wish to define the scope of the commissioning job by requesting separate payback values for individual measures in the commissioning job and then picking the measures to be given a detailed evaluation and be subsequently implemented. This paper examines the results of eight RCx projects in which at least one significant measure was implemented that was not identified during the RCx assessment, or represented a modification of a measure identified during the assessment. These examples suggest that the application of the normal retrofit procedures to the RCx process will at least sometimes substantially decrease the impact of the RCx project.

Example # 1: Large Computing Facility in Texas

During the assessment phase RCx on a 481,000 ft^2 computing facility in Texas, it was noticed that steam consumption was suspiciously high during the summer months, particularly since the main uses of steam during this time were for domestic hot water and kitchen uses (Zhou et al. 2005). There should be no use of hot water except for a very limited area. The hourly steam consumption data showed a minimum steam consumption rate of about 500 lb/hr (or 0.5MMBtu/hr) during the summer. Six single-duct VAV units that serve exterior zones also have separate hot decks to provide heating. The heat to all of these units was observed to be off during the assessment. It was suspected that there was substantial steam/hot water leakage and/or heat loss within the loop system. However, it was not possible to propose an RCx measure to reduce steam usage, since the source for the steam consumption was not identified during the assessment.

Steam is delivered to the site at 225 psi by a district heating and cooling provider. The high pressure steam is first reduced to lower pressure steam through PRVs. Low pressure steam is then converted to heating hot water and domestic hot water through heat exchangers. Low pressure steam is also delivered to the kitchen. During the RCx process, the higher-than-expected steam consumption was traced to a pressure-relief valve (pop-up valve) that was operating frequently (as much as twice a minute sometimes) and releasing large amounts of steam into atmosphere. Subsequent investigation determined that one of the PRVs was malfunctioning and could not maintain the preset pressure (the output pressure was about 40 psi while set for 25 psi), which caused the excessive steam venting and increased the baseline consumption. The PRV was subsequently repaired by a mechanical contractor, and the summer steam usage was largely eliminated.

It was estimated that fixing this broken device itself was responsible for a reduction in steam consumption of about $40,000/yr.

One of the major findings identified during the assessment was excessive outside air flow. Field observations during summer indicated that many of the 14 major AHUs had their return dampers closed (or nearly closed) while the relief dampers were wide open (or nearly wide open). CO_2 levels measured at the return air were very low (around 500 ppm). Although outside air flows were not measured, there was little doubt that the building was taking in an excessive amount of outside air at the time, representing a major energy saving opportunity.

During the RCx implementation phase, it was not possible to replicate the apparent outside air levels observed during the field assessment. It took considerable investigation before the problem was diagnosed. The problem was related to a characteristic of the particular older controller in use. When the field tests were conducted during the assessment, a laptop was plugged into the controllers to get EMS readings for comparison with field measurements. Neither the ESL engineers nor the very experienced building engineers realized that whenever the controllers were “hijacked” by local plug-ins, the communication to the supervisory controller was lost. In this case, the local control that drives the return dampers closed and the relief dampers open was normally disabled during summer by the supervisory controller, but when the communication was lost, the local controller took over, resulting in the high amounts of outside air observed. The direct result was an overestimate of savings possible from adjustment in outside air control.

Coincidentally, the over-estimate of savings from outside air reduction was approximately compensated by the failure to identify the PRV failure in the same building during the assessment, so the overall results from RCx implementation were consistent with the predictions during the assessment.

The savings from the pressure relief valve repair increased the project savings by about 15%. In addition, this discovery stimulated further analysis that lead this site to install local boilers and eliminate the district steam supply at 225 psi, saving another $100,000/year. This then to analysis of losses in the steam line to an adjacent site that lead to additional savings of $250,000 per year! If the “ripple effect” savings are counted, savings at this site and the adjacent one increased by 200% due to the discovery of this pressure-relief valve malfunction!

Example # 2: Large Medical Research Facility: Modify Measure During the RCx Process

In a relatively new 4-story, half-million square-foot medical research facility, most of the first floor and part of the ground floor are used for office and meeting space. Laboratories and offices are found throughout the rest of the building and are used to conduct research on infectious diseases, chemical and biological defense, sleep studies, clinical trials, etc. The 1500 building occupants mostly work from 8:00 am to 5:00 pm but the labs must remain conditioned 24 hours a day because of the experiments being conducted.

During the assessment, it was determined that air-to-air heat exchangers installed in the building in many of the 100% OA zones were not being used due to problems like frozen actuators, partially functional actuators, leaking dampers, etc. This was not only causing excessive energy use – the chillers did not have sufficient capacity to cool the outside air without benefit of the heat exchangers, and some supply air temperatures were as high as 65ºF, causing comfort problems in the labs.

The heat exchangers were designed with bypass dampers so the pressure loss caused by the heat exchangers could be avoided when the outside air temperatures were mild. The bypass dampers would be opened, and dampers would be closed to prevent flow through the heat exchangers. The operational staff attempted to make the non-functional dampers operational as originally intended by adjusting the pneumatic controls, lubricating and realigning dampers, and replacing some of the actuators. The operation of the dampers was much improved, but the dampers that controlled flow through the heat exchangers still would not fully open and close, due to a poor design. It was then decided to permanently keep these dampers open so air could always flow through the heat exchangers and close the bypass dampers when the heat exchangers are needed.

This solution increased the energy savings in this project by at least 40% compared with what it would have been without this measure, in addition to reducing capacity requirements sufficiently that the existing chillers are able to meet peak summer load and maintain comfort in the spaces.

Example # 3: Medical Facility #1

The initial assessment of a 1.2 million square foot medical facility identified a typical mix of RCx measures. The facility contains operating rooms, labor and delivery, clinics, emergency services, laboratories, patient rooms, administrative offices, conference and classrooms. Again, a measure identified during the assessment had considerably smaller savings than anticipated, while a measure undiscovered during the assessment produced substantial savings. This facility operated with two separate chilled water loops. The critical services (Operating Room, Intensive Care Unit and Labor and Delivery) are served by the critical loop, and other units by the non-critical loop. The loops are operated separately during daytime hours and combined during nighttime hours when possible to reduce the number of chillers that must be operated. The assessment identified an opportunity to optimize the operation of these loops, develop a formal and well-defined chiller operating procedure, and to program the loops for conversion from manual control to automatic control. The detailed implementation study revealed that optimization opportunities were considerably more limited than originally estimated.

The original assessment did not identify any operational improvements for the boilers, but the implementation study found there was opportunity to reduce the operating pressure from 90 psi to 75 psi and change the boiler operation from having a hot standby boiler to a lag lay-up arrangement. These measures accounted for an increase of about 10% in the RCx savings for the project.

Example # 4: Medical Facility #2

In a 400,000 ft^2 hospital, several AHUs that are equipped with VFDs were essentially being operated at a fixed speed of 57 Hz. Many of the zones supplied by these VFD equipped units were observed with reheat valves 100% open through the cooling months. The extensive use of reheat indicated too much cooling air flow was being supplied by these units.

In August 2007, an investigation was launched to determine the feasibility of VFD control using existing sensor inputs. The AHUs were not equipped with duct static pressure sensors. High priority units, such as those serving the operating room were not considered candidates for VFD control. Flow tests were conducted on six other units to determine the amount of OA supplied based on fan speed. The results were compared to ventilation requirements detailed in ASHRAE standard 62.1 and each of the six AHUs tested provided adequate OA to the space at a fan speed of 30 Hz. All six units were placed on VFD operation during occupied hours, with speed control based on reheat valve position and varied from 30 Hz to 57 Hz.

This measure increased the RCx savings realized in this hospital by approximately 15%.

Example # 5: Airport Terminal Building

In a large airport terminal building, static pressure reset was implemented. After implementation, it was discovered that with both supply and return fans running at minimum speed of 20 Hz in numerous AHUs, the static pressure set point was exceeded during periods of low occupancy. These AHUs have had terminal box setbacks that made the AHU exceed its unoccupied/lightly occupied static pressure set point even when the supply and return fans were running at minimum. In a couple of cases, the static pressure would actually rise during the night setback even though the fans slowed down. A return fan cutoff point was created in the controller and linked back to EMCS that allows the return fan to turn off when the supply fan speed falls below a certain value.

This measure saved several thousand dollars per year, but did not result in a large percentage increase in the project savings that are considerably in excess of $1,000,000 per year.

Example # 6: Community College

At a community college campus, the original assessment identified RCx measures to improve chiller operations and implement chilled water supply temperature reset (Deng et al., 2004). Automating this reset required a small controls gateway upgrade to connect chiller controls to the EMCS. At the end of the project, the controls upgrade had not been implemented, so it was not possible to implement the chilled water supply temperature reset.

Meanwhile, the assessment had identified minor savings potential from the heating hot water system but these were not expected to be large since there was no VFD on the pumps. During RCx implementation, two 500 BHP main boilers were shut off for the most time after thorough engineering survey and calculation and we were able to run the 150 BHP “pony” boiler for most of the winter fully loaded. Also, all three boilers were tuned up. The 50 HP HHW circulation pump was turned off, and the 15 HP broken pump was fixed and served the building the whole time, greatly improving ΔT and saving pumping energy. Encouraged by this series of HHW RCx measures and activities, the in-house team self identified and implemented Christmas break HHW aggressive reset and shutdown and achieved significant savings and morale.

The practice, prior to implementation of RCx measures, was to run a small 150 BHP boiler in the summer (May to September) to heat the swimming pool, and run the two 500 BHP boilers for both pool heating and heating hot water for the remaining months. Further, the practice was to alternate the larger boilers twice daily, running the more reliable one at night and then turning on the second boiler when operating personnel arrived on campus the next day. This practice was not energy conserving in that the boilers were being started and each was run for about 12 hours per day. The RCx engineers noted that even in January weather, the larger boiler was typically running at about 20%-25% capacity. Operating a boiler at such a small load is not efficient, and cycling it daily is not optimum. Load calculations determined that the smaller boiler could handle the entire building’s heating needs and swimming pool heating about 90% of the time during the winter and it was recommended that it become the lead boiler. One large boiler would then be used in a standby mode to provide the extra capacity when needed. The RCx engineers also recommended that the small boiler be tuned up for maximum efficiency, which was done.

In the course of assessing the hot water needs of the campus, it was noted that too much water was being pumped throughout the system. The temperature difference between the supply and return hot water on a day with outside temperatures of 20ºF was only 2ºF - 3ºF. The hot water pump was a 50 hp constant speed pump. It was noted that a “standby” 15 hp pump was not being used and recommended that it become the lead hot water pump. It had the same pressure as the 50 hp pump. A variable frequency drive on the larger pump would be preferable, but no capital budget was available for this project. The 15 hp pump had not been used in seven years, but it was refurbished and placed in service. This change saved 35 hp over the year, i.e. about 2000 operating hours for the hot water pump.

It is estimated that the energy cost savings achieved on this campus by the RCx process were increased by 25% - 40% by these measures.

Example # 7: University Central Plant: Condenser Water Pump

In a small university central plant, it was observed in the assessment that condenser water flow through one cooling tower was too low. It was thought that pump capacity was too low because the cooling tower was originally designed for ground level positioning and later moved to the rooftop. During implementation, field measurements were conducted using an externally mounted ultrasonic flow-meter, and found the condenser water flow-rate was 1,361 GPM when chiller #1 was running. The chiller #1 design flow specifications call for 1,545 GPM. Field testing and ultrasonic flow-meter measurements also found that when both chiller #1 and chiller #2 are operating, the condenser water flow rate for chiller #1 was 1,232 GPM, which is even lower than when chiller #1 only is running. These results confirmed that chiller #1 does not have enough condenser water flow. A detailed condenser water loop study was conducted and it was found that the design point of CWP-1 is actually 10 feet more than the other three pumps, and the chiller #1 condenser pressure drop is 12.8 feet more than that of chiller #2. Both of the chillers are located in the same equipment room. Chiller #2 has performed well and therefore suggests an adequate design. Further investigation found that a valve on the condenser water pump 1 outlet side was 75% shut. It was also confirmed that the valve in question could be used as a balancing valve and this was needed to ensure that chiller #1 gets enough condenser water flow.

This discovery produced only small energy savings, but also saved the cost of a larger pump.

Example # 8: Semi-Conductor Processing Facility

At a large semi-conductor processing facility, the assessment noted that chilled water from both the Central Utility plants is fed into a common 42” header. Since Building A requires a very stable chilled water temperature supply for wafer production, the decision has been made not to use the available plate/frame heat exchanger. This precludes several months of “free cooling” during the winter and “swing” seasons. Building B (another wafer processing facility) and Building A, the two primary process loads, could be fed from the second plant, by changing the piping arrangement. Making this change would allow the non-critical loads to be fed from the plant with the plate-frame heat exchanger and would allow the use of chilled water temperature reset schedules as well as the plate/frame heat exchange for these non-critical loads. It was noted that more analysis would be required before implementation. Subsequent to the assessment, it was determined that the piping changes required were more extensive than originally thought, precluding implementation of this recommendation.

However, a major opportunity to improve boiler operation was discovered during implementation. The boilers were being operated by continuously running an extra boiler, keeping the average load near 50%. Upon observing this, the boiler operation was immediately changed during from five operating boilers to four. The boiler loading went up to about 65%, producing immediate savings of 10-15 MMBtu/hour and increasing the RCx savings at this site by approximately 25%.

Conclusions

This paper has examined eight RCx projects in which project savings were increased by an average of 18%, with the largest increase being approximately 40% due to implementation of measures that were not originally identified. If the "ripple effect" savings of Example 1 were included, the average savings increase would be nearly 40%! This suggests that there can be significant benefit in permitting the RCx provider to thoroughly investigate each facility, rather than restricting the investigation to a rapidly determined list of potential RCx measures.

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