Persistence of Energy Savings in Industrial Retrocommissioning Projects

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ABSTRACT

Pacific Gas and Electric (PG&E) and Nexant, Inc. are implementing an Industrial Retrocommissioning (IRCx) program in Northern California. The first of its kind in the PG&E service territory, IRCx is focused on the entire manufacturing sector and has built-in requirements intended to promote savings persistence.

All major utilities have retrocommissioning (RCx) programs in their energy efficiency portfolios, most of them focused on commercial buildings and systems. One daunting challenge of these programs has always been savings persistence.

This paper will show how the Industrial RCx program is employing different measures to address the typically short useful life of RCx measures. The program incorporates advanced measurement and monitoring techniques into each facility's operation and maintenance procedures to enhance the average measure life. The program is also demonstrating effective collaboration among multiple consultants and service providers. An example of the IRCx approach is part of this paper.

The Need for a New Approach

Retrocommissioning programs have been part of all major utilities' portfolios for the past many years. These programs were developed to promote better operation and maintenance (O&M) practices primarily among facility personnel in the commercial buildings sector. Likewise state and federal agencies that administer energy efficiency incentive programs have RCx in some form included in their portfolios. RCx programs are popular with businesses as well, because they provide energy efficiency solutions with low cost/no cost measures and the effect, in cost savings, in many cases is almost instantaneous. These attributes are especially beneficial for many end users in a slowly recovering economy.

A major limitation on the success of these programs, however, is that RCx measures have a relatively short life. Since many of them are programming changes to control systems, it is easy for someone unaware of the reason behind the new setting to re-adjust the controls back to pre-RCx conditions (e.g., resetting supply air temperature in an air-handling unit). In the long run, this vulnerability reduces the effectiveness of RCx programs. Consequently, various utilities/agencies have tried to incorporate some form of persistence in their programs by providing a detailed systems manual and by training facility staff at the end of the project. Although this is a good starting point, in many cases the manuals are not consulted and training is not converted to standard practice for reasons ranging from lack of resources to a shift in priorities to a change in personnel.

Monitoring Based Commissioning and Continuous Commissioning

Most of the existing retrocommissioning programs do not require either the implementation of a process for data monitoring and analysis or an external service contract (Friedman, Potter, Haasl, & Claridge, 2003). Recently, however, a few utilities and state agencies (e.g., PG&E, California State University, NYSERDA[1]) have initiated Monitoring Based Commissioning (MBCx) to address the issue of savings persistence. These programs differ from conventional RCx programs because they involve extensive monitoring of facility subsystems to create a better understanding of system operation. This installed permanent monitoring also helps to increase the persistence of RCx measures, as the data log provides real-time evaluation of how efficiently the system is working. Currently all MBCx programs are being implemented only in the commercial sector.

The MBCx model is based on the Continuous Commissioning™ practices created by the Energy Systems Laboratory at Texas A&M University (Mingsheng, Claridge, & Turner, 2002). Continuous Commissioning obtains long-lasting energy savings through ongoing system evaluation (Haasl, Friedman, & Potter, 2004). Once the facility has been commissioned, the building energy usage and important parameters (e.g., temperatures, flow rates) are monitored, and if the consumption increases significantly or any of the parameters fall out of range, the facility is visited again by retrocommissioning personnel, to analyze the cause and implement a remedy.

Persistence of Commercial RCx Savings

There have been no studies related to savings persistence in industrial retrocommissioning projects, because there are very few Industrial RCx programs being implemented. However, several studies on the persistence of retrocommissioning measures in commercial buildings have been completed in the last ten years (Toole & Claridge, 2006). These studies were completed on buildings which participated in the traditional RCx programs that do not include an ongoing evaluation and on buildings that participated in Continuous Commissioning™.

In general, Continuous Commissioning™ results in greater energy savings persistence than traditional retrocommissioning, in which proactive maintenance of the optimized system is not part of the program. A few examples are instructive:

- In 1996-1997, ten buildings located on the Texas A&M campus were part of a Continuous Commissioning project (Claridge, et al., 2003). Persistence was studied after four years (Turner, et al., 2001) and again after eight years (Claridge & Toole, 2007). After four years, the average chilled water and hot water savings were 90% and 100% of the first-year savings respectively. After eight years, the chilled and hot water savings were 81% and 74% of the first-year savings for eight of the ten buildings. Follow-up after commissioning included monitoring the energy usage on a regular basis and recalibrating the Energy Management System based on the information obtained.
- In 2004, Lawrence Berkeley National Laboratory completed a persistence study of eight participants in the Sacramento Municipal Utility District Retrocommissioning program (Bourassa, Piette, & Motegi, 2004). This research showed that although approximately

[1] New York State Energy Research and Development Authority

80% of the energy efficiency measures were still present three to four years after the retrocommissioning, at four of the studied sites the aggregated energy savings had fallen to 65% of the post-retrocommissioning savings.

- In 1999 and 2000, Intel retrocommissioned the HVAC systems in nine buildings on two Oregon campuses through Portland General Electric's Existing Building Commissioning program. In 2004, a study was completed to analyze how the energy savings identified during retrocommissioning persisted after four years (Peterson, Ho, & Lai, 2005). Persistence was reported for only three buildings, as the remaining six buildings yielded mixed and non-quantifiable results. For these three buildings, 89% of electric savings and 0% of natural gas savings persisted after four years. Had the remaining buildings been included, the persistence of aggregate electric savings would have been significantly lower.
- Unusual results were found in a single office building located in Boulder, Colorado that participated in a comprehensive RCx project. A study conducted after eight years (Selch & Bradford, 2005) found that more than 83% of the originally estimated savings had persisted, a high level of long-term persistence. However, the report noted that close to 100% of the energy savings would have been maintained if ongoing support had been provided to the building staff as part of the RCx work.

How IRCx Differs

The Industrial RCx program is the first of its kind in PG&E's service territory. Not only does it serve the industrial manufacturing sector rather than the commercial sector but it has built-in requirements designed to promote savings persistence. In 2003, the California Public Interest Energy Research (PIER) program published a list of strategies for improving the persistence of commissioning benefits for commercial buildings (Friedman, Potter, Haasl, & Claridge, 2003). Three of the strategies are included in the IRCx program: operator training, trend analysis, and, most important, measurement and monitoring.

The following sections will explain how this program is promoting and incentivizing the incorporation of advanced measurement and monitoring techniques into facilities' O&M procedures to extend the average life of RCx measures, as well as providing incentives to customers who may need to hire external resources to enhance savings persistence.

The Industrial RCx Program

IRCx is a PG&E third-party program implemented by Nexant, Inc.[2] Marketing and implementation began with the start of PG&E's 2010-2012 Energy Efficiency Portofolio. The program seeks to benefit the customer by focusing on energy savings that do not require major capital investment but that will lower energy bills and reduce maintenance time and expenses. The program goals are to improve equipment life, equipment reliability, productivity, and—most importantly—knowledge of preventive maintenance techniques and maintenance technology.

IRCx first helps customers identify system deficiencies through a no-cost audit. Program participants may receive financial incentives to offset the cost of repairs and optimization and for

[2] The program is funded by California utility ratepayers under the auspices of the California Public Utilities Commission. With few exceptions, industrial businesses that receive gas or electric service from PG&E and pay the Public Goods Charge or Public Purpose Program Surcharge can participate.

measures that sustain the results of retrocommissioning via proactive, preventive maintenance. Common, eligible IRCx measures include:

- Leak repairs and maintenance (compressed air, steam, compressed gases)
- Combustion efficiency optimization
- Insulation repair
- Belt drive upgrades
- Sequencing and compressor controls
- Heat transfer surface cleaning and maintenance
- Process optimization through system tuning

A maintenance plan is required. It can consist of either a computerized maintenance management system (CMMS) or a multi-year contract with a preventive maintenance contractor (typically three years). If the facility already has a CMMS installed, flags and parameters related to the IRCx measures can be added to the existing system. While this requirement does increase the implementation cost of the IRCx program, the cost of a new or an upgraded CMMS or the vendor contract can be part of the total project cost and the incentives are capped by 50% of this cost.

Either the CMMS (several are available off the shelf) or the preventive maintenance contract will ensure that the performance of the involved equipment and/or system is tracked following implementation. This tracking is vital, as it provides O&M personnel with valuable intelligence on how to operate the systems in the most efficient manner and alerts them to developing problems.

Since the IRCx program has a built-in proactive maintenance requirement, it is expected that the persistence results will be closer to those of Continuous Commissioning projects than to traditional RCx projects.

Industrial Sector Challenges

Range of Expertise

Providing proactive maintenance services and achieving savings that persist over time in industrial facilities is challenging. In the commercial sector, the list of parameters that are considered important in building diagnostics is well defined; this list does not change drastically for different sites. In the industrial arena, however, each plant is unique, even within one industry type. In glass manufacturing, for example, a facility that produces flat glass is very different from one that produces bottles. In addition, for each subsystem within the plant (e.g. compressed air, combustion) different expertise is required, along with a different proactive maintenance plan. In general, companies providing services for compressed air systems do not have in-house experts on combustion systems.

The IRCx program thus provides the ideal setting for engaging a host of different subject matter experts to provide the auditing and, if needed, maintenance services. Nexant is currently working with *eight* different service vendors and consultants to provide coverage of the different systems encountered in the program to date. The IRCx program is proving to be a good example of how multiple consultants and service providers can work together in providing industries the most comprehensive energy solutions available from their utility.

IRCx is also ideal for increasing collaboration between different incentive programs. During the IRCx audits, retrofit measures are routinely identified and are referred to other retrofit incentive programs. Similarly many projects have been referred to IRCx by retrofit programs. This collaboration is very helpful for the customer, who receives maximum benefits in an efficient manner.

Assessing Efficiency

The operating performance of industrial facilities, unlike that of commercial buildings, cannot be determined by analyzing the energy consumption of the plant or even of a system or subsystem. For example, in a compressed air system, a reduction in compressed air consumption will not translate to a similar reduction in compressor demand, because the compressor demand depends on production parameters such as daily throughput and type of product. Thus just measuring the energy consumption of the system will not provide a good handle how well the system is being controlled. For such a system, a better way to achieve optimal performance is either to contract with a service vendor to provide periodic leak audits and system tune-up services or to install an extensive monitoring system to monitor compressed air consumption at end uses and trigger alarms or flags at the central monitoring system to initiate investigation. The following case-study illustrates how this works.

Case Study: Glass Bottle Manufacturing

One of the first participants in the IRCx program has been a large manufacturer of glass bottles in the Central Valley of California. The plant produces wine bottles from molten glass. Much of the bottling and packaging machinery requires compressed air for operating actuators, robotic arms, vacuum valves, and other components. The facility operates 24 hours per day year round and has an extensive compressed air distribution system that supplies process lines throughout the plant.

As is typical in any industrial facility using a large volume of compressed air, leaks continually develop in the equipment and supply lines. When neglected, the accumulation of a large number of leaks results in major compressed air losses and severely reduces the efficiency of the compressor system. In addition, numerous leaks result in an artificially high system air demand, causing the compressors to work harder than necessary and shortening their working life.

Before implementing its IRCx project, the glass manufacturer did not have a systematic procedure for identifying and repairing leaks or to maintain the optimum control of the compressed air system. The practice—common in industry—was to repair leaks and replace valves after equipment failure or when large leaks were slowing production. Air leak loads and faulty controls, however, can contribute 20% or more of the total compressed air demand in a facility. Consequently there is great energy savings potential in facilities of this type. The IRCx program is especially well suited for developing sustainable retrocommissioning practices for compressed air systems.

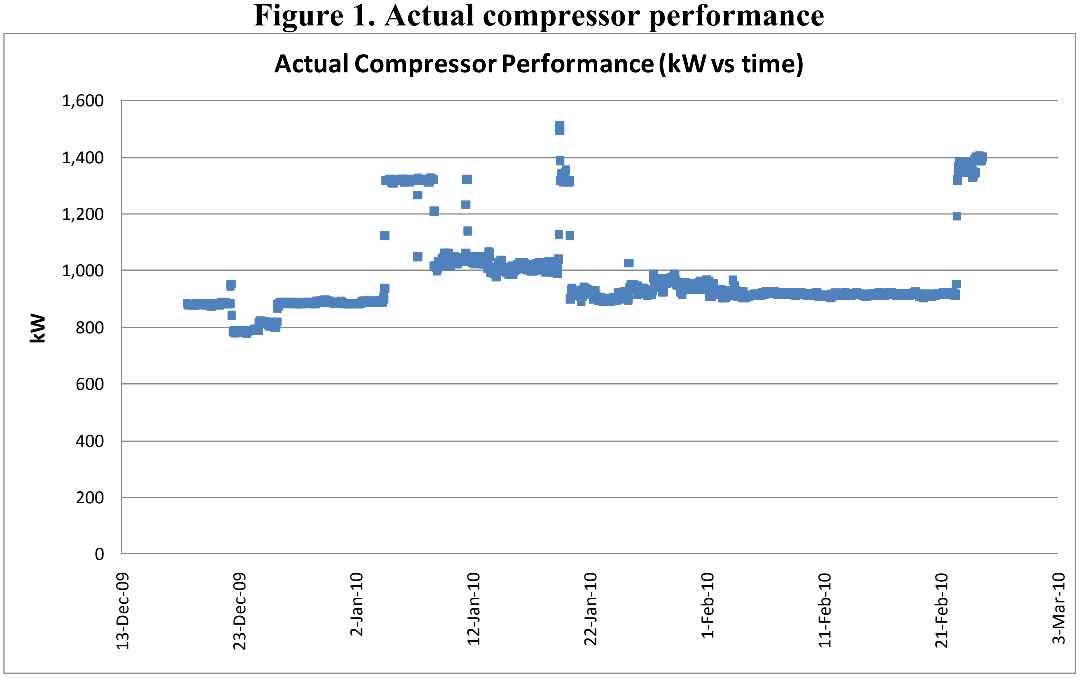
The Compressed Air System

More than 40 machines at the glass plant utilize compressed air. Three rotary screw compressors supply over 4,500 scfm of compressed air at 85 psig throughout the facility. Because the plant's operation is continuous, it is easy for substantial air leaks to go unnoticed. The high noise level makes it difficult to audibly detect leaks without special equipment. Trending was performed for a two-month period to establish the baseline average compressed air production and compressor system load. Figure 1 shows the average compressor loads for those two months; the trends show a pretty steady base load at approximately 900 kW with a peak of almost 1400 kW. With this level of demand on the compressor system, it is very easy to overlook the energy being lost because of the leaks or malfunctioning controls.

In addition to air loss from the compressed air system, inefficient machinery components are wasting air throughout the plant. Old style vacuum valves are being used on many machines that use compressed air for generating suction. These traditional valves use much more air than newer high efficiency valves. In addition to repairing leaks, compressed air savings can be realized through establishing a practice of replacing old vacuum valves with high efficiency units.

Through the IRCx program, a comprehensive audit was performed to locate air leaks. Leaks were located during production using ultrasonic air leak detectors and were tagged for identification with estimated flow rates. A sample of leaks was also measured to calibrate the estimation of the scfm assumed for the remaining leaks. A total air leak loss of 630 scfm was estimated for the identified leaks. This corresponds to approximately 13% of the total compressed air production of the plant.

Figure 1. Actual compressor performance



After providing the compressed air audit, the plant's energy manager was provided assistance in creating a comprehensive plan for systematically repairing the air leaks, replacing valves, and installing meters. As the plant has enough staff availability for performing maintenance work and repairs, the leaks repair work, the installation of the monitoring system and the vacuum valve replacement was completed in-house. The majority of the identified leaks were repaired by maintenance personnel over several months. After this first phase of repairs was completed, it was verified that compressed air usage had been reduced by approximately 10% relative to the pre-implementation demand, corresponding to approximately 100 kW of compressor power savings.

Savings Persistence Plan

Due to the complexity of the compressed air system at this plant, the two feasible options for achieving savings persistence were either to enter into a three-year contract with a service provider or to install an elaborate monitoring system with the capability of monitoring compressed air consumption at each end use.

The customer chose the monitoring option. More than 40 compressed air flow meters have been installed on the major end uses. The measurements are logged and then are routed back to the plant manager's computer, where they can be trended to analyze the performance of each machine. The compressed air consumption of each end use during idling ranges from 8 scfm to 20 scfm depending on the machine. So if the logged data show more consumption at any of the 40 locations, a quick leak detection survey can be conducted and the problem fixed within a reasonable time. This plan provides an almost real-time diagnostic solution.

Figure 2 shows 6 of the 40 flow meters that have been installed, and Figure 3 shows sample data depicting how compressed air flow is being monitored.

Figure 2. Installed air flow meter displays

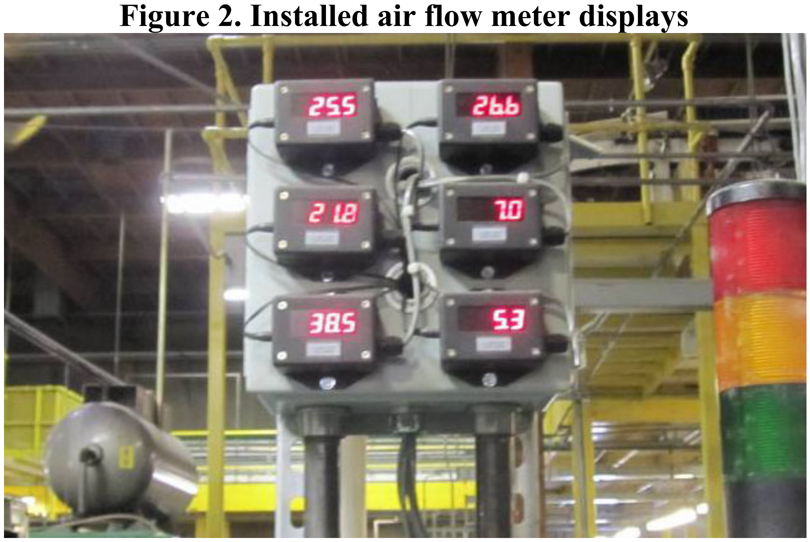
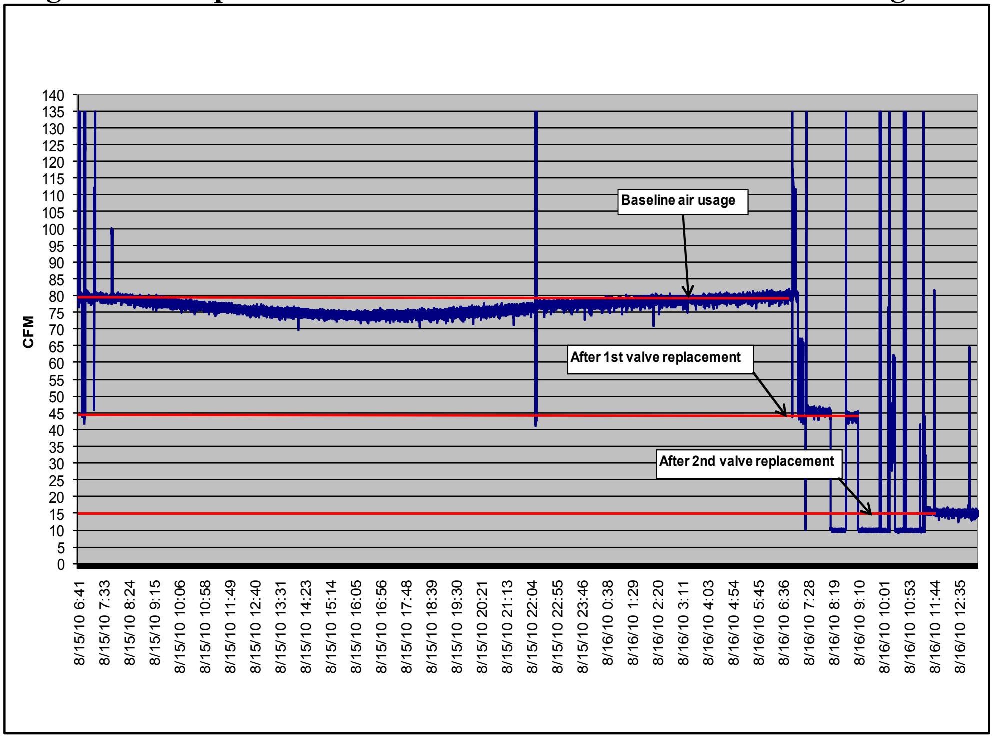


Figure 3. Compressed Air Flow Measurements at a Case Packing Line



The project cost includes the cost of leak repairs, new vacuum valves, compressed air flow meters, and data loggers. The program will provide incentives to the customer for up to 50% of the total cost. Compared to a conventional RCx project, the total first cost of this project was 2.5 times higher. If the monitoring system is excluded, the simple payback for just fixing the compressed air leaks and installing vacuum valves would have been 1.5 months (including incentives). The addition of the monitoring system will increase the simple payback to 3 months. This is not a huge impact as the incentives have increased as well. Also the installation of the monitoring system will assist the end-user in operating However, the incorporation of the monitoring system will increase the persistence of savings so the increase in simple payback has minimal effect on the overall cost effectiveness of this project.

This monitoring system is in operation since the last five months and the customer has been successful in keeping a continuous log of compressed air consumption and the 100 kW reduction achieved at the time of implementation is still being maintained. Phases II and III of this project are in implementation and comprehensive trended data will be available later in 2011 which will further support the successful implementation of this persistence strategy. The corporate is pleased with the results and has approved an additional $350,000 for the plant to invest in monitoring equipment for compressed air, electric and natural-gas sub-metering which will assist in providing savings persistence for the remaining two phases of the project.

This is just one example of how the IRCx program is trying to promote persistent savings from RCx measures. Different measures will require different solutions. Currently this program has more than 25 active projects which are using either monitoring techniques or service vendors to increase the useful life of the measures being implemented.

Conclusions

Even though the cost of each project under this RCx program will be substantially greater when compared to a conventional RCx program, the overall benefit from implementing better maintenance practices and utilizing real-time monitoring of important parameters will outweigh the increased costs. Given our early experience with IRCx, we expect that targeting industrial facilities and promoting better maintenance protocols by incorporating them as a program requirement will:

- Increase the efficiency of the entire process.
- Increase the effective useful life of industrial RCx measures.
- Promote energy efficient O&M practices in manufacturing facilities.
- Involve service vendors, consultants, and other energy efficiency programs to provide a streamlined, consolidated incentive package to the customer.
- Create a benchmark for future implementation of RCx programs targeted toward industrial applications.

The short-term results from the presented case-study do show that the persistence strategy utilized and funded through the IRCx program is assisting the facility in improving the energy foot-print, operation and maintenance of the plant.

References

Bourassa, N. J., Piette, M., & Motegi, N. (2004). Evaluation of Retrocommissioning Persistence in Large Commercial Buildings. *National Conference on Building Commissioning.*

Claridge, D. E., & Toole, C. (2007). *A Follow-up Study on the Persistence of Savings from the Retrocommissioning of Ten Buildings on a University Campus: Preliminary Results.* Energy Systems Laboratory, Texas Engineering Experiment Station, Texas A&M University System.

Claridge, D. E., Turner, W., Liu, M., Deng, S., Wei, G., Culp, C., et al. (2003). *Is Commissioning Once Enough?* California Energy Commission Public Interest Energy Research Program.

Friedman, H., Potter, A., Haasl, T., & Claridge, D. (2003). *Strategies for Improving Persistence of Commissioning Benefits.* Department of Energy and California Energy Commission Public Interest Energy Research.

Haasl, T., Friedman, H., & Potter, A. (2004). Strategies for Improving Persistence of Commissioning Benefits: Making Lasting Improvements in Building Operations. *ACEEE Summer Study on Energy Efficiency in Buildings.* Pacific Grove, California.

Mingsheng, L., Claridge, D. E., & Turner, W. D. (2002). *Continuous Commissioning Guidebook: Maximizing Building Energy Efficiency and Comfort.* Federal Energy Management Program, U.S. Department of Energy.

Peterson, J., Ho, B., & Lai, H. (2005). Evaluation of Retrocommissioning Results After Four Years: A Case Study. *National Conference on Building Commissioning.*

Selch, M., & Bradford, J. (2005). Recommissioning Energy Savings Persistence. *National Conference on Building Commissioning.*

Toole, C., & Claridge, D. E. (2006). Review on Persistence of Commissioning Benefits in New and Existing Buildings. *Building Commissioning for Energy Efficiency and Comfort.* Shenzhen: ICEBO.

Turner, D., Claridge, D., Deng, S., Cho, S., Hagge, T., Darnell, C., et al. (2001). *Persistence of savings Obtained from Continuous Commissioning.* California Energy Commission Public Interest Energy Research Program.