Retrocommissioning Investigation Study of the Sheraton Chicago Hotel & Towers Cityfront Center

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Synopsis

The Sheraton Chicago Hotel & Towers Cityfront Center, owned by Tishman Hotel Corporation and operated by Starwood Hotels and Resorts Worldwide, is a 1.2 million square foot hotel and conference guestroom facility located in the heart of Chicago, and is the venue for the 2007 National Conference on Building Commissioning. The hotel includes 1,209 guest rooms and suites, conference and meeting room facilities, exhibition space, promenade reception space, a business center, a health club, retail stores, offices, multiple kitchens and dining services, and a laundry facility.

A recent dramatic utility rate increase and change in the utility rate structure will cause the hotel's utility bills to skyrocket from $2.4 million a year to an estimated $3.8 million a year. In an effort to mitigate this large operating cost increase, Tishman decided to pursue retrocommissioning of the building, and Architectural Energy Corporation was hired by Tishman to perform retrocommissioning investigation services in support of this effort, including short-term diagnostic monitoring, targeted functional performance testing, energy modeling, and economic analysis of energy conservation measures.

The retrocommissioning investigation of the hotel completed in September of 2006 identified a host of energy saving opportunities, including the low cost, no cost activities commonly associated with retro-commissioning as well as ones that have a higher capital cost, such as improvements to the energy management system and installation of variable speed drives. The study also looked at operational considerations, such as outsourcing the laundry.

In the end, the Tishman Hotel Corporation selected a group of measures to implement generating an estimated total annual cost savings of $1.2 million, representing a 32 percent reduction in anticipated annual energy costs. The implementation cost estimate for these measures is estimated at $1.9 million, resulting in a simple payback period of 1.6 years. This paper summarizes the techniques used and energy conservation measures identified during this retrocommissioning investigation effort.

About the Author

Tracy Phillips is the team leader for AEC's Building Energy Evaluation Services Team, and manages a variety of projects, including retrocommissioning, energy savings performance contract support, demand-side management support, load research studies, and measurement and verification. In addition to staffing and managing projects within his Business Team, Mr. Phillips performs detailed energy auditing, building baselining and energy modeling, energy conservation measure analysis, system diagnostics and short/long-term monitoring, and functional performance testing. Mr. Phillips is currently leading the technical oversight effort of three retrocommissioning programs in California, overseeing the quality control of 41 retrocommissioning providers spanning over 450 buildings statewide.

Sustainability

"Seventh Generation" was a precept developed as part of the Gayanashagowa or Great Law of Peace, the oral constitution of the Six Nations of the Iroquois Confederacy. This maxim, which served as a major inspiration to Benjamin Franklin and James Madison in their writing of the U.S. Constitution, directed chiefs to consider the impacts of their decisions on the seventh generation to come, an idea remarkably ahead of its time.

Since the development of this concept, and the writing of the Constitution over 300 hundred years ago, few leaders have seriously thought in these terms. It was not until the oil embargo of 1973 when the U.S. recognized its tenuous relationship with oil that the idea of energy efficiency truly began to take hold. And over the decades, the seventh generation ideals, particularly regarding sustainability, have slowly developed a foothold in the American psyche.

The built environment has long been recognized as a significant user of energy resources, and as such represents a tremendous opportunity to reduce energy consumption. Many programs and practices have been developed, with increased emphasis in the last couple of decades in particular, to address these energy saving opportunities, notwithstanding the highly effective more recent practices of commissioning (new construction), recommissioning (commissioning of an existing building that has been previously commissioned), and retrocommissioning (commissioning of a building that has never undergone the formal commissioning process).

The Project

Starwood Hotel and Resorts Worldwide, Inc. is one of the world's largest hotel and leisure companies. They conduct their hotel and leisure business both directly and through their subsidiaries. They are primarily focused on the operation of hotels and resorts in the luxury and upscale segment of the lodging industry. Their brand names include St. Regis®, The Luxury Collection®, Sheraton®, Westin®, and Four Points® by Sheraton. Through these brands, they are well represented in most major markets around the world.

Starwood is committed to excellence and leadership. As part of these corporate goals, Starwood is focused on providing an energy-efficient operation of its well-appointed environment. To this end, Starwood Hotels hired AEC to perform RCx investigation activities on the Sheraton Chicago Hotel & Towers Cityfront Center in 2006. The objective of the RCx investigation was to identify operational and capital improvements that would decrease energy consumption of the facility and improve the quality of the indoor environment.

The Stakes

As a first step in the RCx investigation process, AEC's engineering team spent a week on site, collecting equipment data, interviewing facility personnel, installing short-term data logging equipment, and performing functional performance tests on various pieces of equipment.

Using the information gathered on site, and from other resources such as as-built building plans and TAB reports, AEC developed a DOE-2.2 energy model of the hotel. The energy model was subsequently calibrated to historical energy bills, and further calibrated to the performance data analyzed as part of the short-term diagnostic process, as well as from the resulting functional performance tests. This step in the process represents a robust approach toward energy simulation calibration, and illustrates the integration of "traditional" energy study methodology (utility bill calibration) with RCx practices (functional performance testing and short-term monitoring).

The first important use of the model was to develop a baseline for the facility. What followed was a jaw-dropping realization. Historical utility billing information had illustrated that the hotel spent about $2.4 million a year in utility bills. However, recent increases in the utility rates were input into the energy model, and the results indicated an estimated annual utility cost of $3.8 million, a 58% increase in costs! With this realization, the importance of identifying energy saving opportunities was solidly driven home.

Table 1 Utility Rates and Annual Costs

Year	Electric Usage Charge ($/kWh)	Gas Usage Charge ($/therm)	Total Electric Costs	Total Gas Costs	Total Energy Costs
2003	$ 0.0603	$ 0.5747	$ 1,995,816	$ 281,620	$ 2,277,436
2004	$ 0.0623	$ 0.8241	$ 2,037,906	$ 391,312	$ 2,429,218
2005	$ 0.0585	$ 1.0746	$ 1,962,137	$ 560,304	$ 2,522,441
Average	$ 0.0604	$ 0.8237	$ 1,998,620	$ 411,079	$ 2,409,698
New Rates[1]	$ 0.1056	$ 1.2357	$ 3,214,735	$ 632,106	$ 3,846,841

1 The rates listed are blended rates that include fixed and demand costs

Table 2 Utility Costs, Historical Average vs. Energy Model Predictions

	Average Historical Cost	DOE2 Model with New Rates	% Increase
Electric Usage Charge	$ 1,998,620	$ 2,957,137	48%
Electric Demand Charge	$ -	$ 257,598	*n/a*
Gas Usage Charge	$ 411,079	$ 632,106	54%
Total Energy Cost	$ 2,409,698	$ 3,846,841	60%

The Setting

The Sheraton Chicago Hotel & Towers Cityfront Center, owned by Tishman Hotel Corporation and operated by Starwood Hotels and Resorts Worldwide, is a 1.2 million square foot hotel and conference guestroom facility located in the heart of Chicago. The hotel includes 1,209 guest rooms and suites, conference and meeting room facilities, exhibition space, promenade reception space, a business center, a health club, retail stores, offices, multiple kitchens and dining services, and a laundry facility. As a hotel, the facility operates continuously year round, with an average annual guestroom occupancy of 74%.

The heating needs of the building are served by electric resistance heating elements. The main large air handling units (AHUs) have large capacity coils for heat, and the variable-air-volume (VAV) terminal boxes have electric reheat coils. The coils have limited staging and high minimum airflow requirements. Electric baseboards supplement the heating in a few locations.

Three centrifugal 800 ton water-cooled chillers provide chilled water to the AHU cooling coils. The chilled water loop is a primary constant-flow arrangement. Heat rejection for the chillers is provided by two constant-speed multi-cell (two and three cell) cooling towers, served by a constant-volume condenser water loop. All the chillers and cooling towers are the original equipment installed in 1992.

Air distribution and ventilation is provided by eight main AHUs serving the building’s public spaces. All these AHUs contain a mixing/filter section, chilled water coils, electric heat, and airside economizing ability. Most of these units utilize inlet guide vanes to vary air volume, while a few are constant-volume units.

An additional 18 built-up AHUs serve various support spaces, corridors, and mechanical spaces. Half of these units contain mixing dampers, chilled water coils, face and bypass dampers, and electric heat, while the other half utilize direct expansion (DX) cooling. Four of the units serving the corridor spaces provide ventilation air, which is subsequently exhausted through the toilet exhaust risers serving the guestrooms.

Each of the guest rooms contains a two pipe fan vertical coil unit (FCU) with a chilled water coil and electric heating. The FCUs have a three speed fan (low, medium, high) with heating or cooling control and temperature selection which are controlled by the occupants.

The Findings

Short-term diagnostic analyses, as well as the targeted functional performance tests, were used to help identify opportunities for improved performance and energy savings, and in some cases to provide proof or dispel assumptions made about existing system operation. The energy model was subsequently used to perform economic analysis of proposed energy saving opportunities, and packages of measures were run simultaneously to account for the potential interactive affects between measures.

The resulting findings were separated into two categories: corrective measures, which were deemed necessary to return the building to proper operation, and energy savings measures. A meeting was subsequently held between AEC engineers, facility engineers, and the building owners and managers, to discuss each finding in detail, and determine whether or not each would be considered for implementation. Selection of each measure for inclusion in the final package was determined on a number of key factors, including economic performance, first cost, non-energy related benefits, and implementation barriers.

Corrective Measures

Two corrective measures were identified, primarily through the use of short-term monitored data analysis, and accepted for implementation. The building's baseline was subsequently revised to reflect implementation of these measures, and all savings estimates for the energy saving measures were subsequently calculated using this revised baseline model incorporating these corrections.

- *Correct Outside Air Fractions and Economizer Operation* – in many cases, AHUs were discovered to have malfunctioning economizers, and excessive minimum outside air fractions (OAFs). This measure involved correcting malfunctioning economizer operation, and restoring the design minimum OAFs.

- *Correct Supply Air Temperature and Heating Control* – 10ºF to 15ºF variations in supply air temperatures from the set points were witnessed in the monitored data for some AHUs. Most of these control issues were due to heating element control problems which was identified by temperature data collected before and after the heating elements, cooling coils, and at the unit discharge. The recommendation involved correction of this heating element control and supply air temperature set point through system troubleshooting, sensor recalibration and placement assessment, and review of the operation of the cooling coil valve and heating element staging.

Energy Saving Measures

A number of energy saving measures were identified and analyzed at the hotel, dealing with the central heating and cooling plants, the public area air distribution systems, the guestroom fan coils, and the building lighting systems.

Direct Digital Control System

- *Incorporate a Central DDC System* – all equipment is currently controlled by stand-alone pneumatic controls. The addition of a state of the art comprehensive control system will provide the building with an intelligent ability to manage energy usage, provide greater comfort conditions, and increase response time. It will enable a variety of installed mechanical systems to work in unison and react to the shifting parameters of building occupancy and weather variations. The control strategies recommended (and modeled) as part of this new system included:

- Unoccupied public space zone temperature set points
- Unoccupied VAV terminal box minimum airflow scheduling
- AHU scheduling
- Unoccupied minimum outside air fraction set point
- Demand controlled ventilation
- Differential enthalpy economizer control
- Supply air temperature reset based on average terminal box damper position
- Mixed air temperature set point reset
- Chilled water temperature reset based on outside air temperature
- Condenser water temperature reset based on ambient wet-bulb temperatures
- Automated chiller plant enable based on outside air temperatures

- *Incorporate Networked Guest Room HVAC Controls* – this recommendation involves the installation of "smart" digital thermostats that incorporate a cooperative control between an infrared occupancy sensor and a door lock sensor in the guest rooms with the ability to sense whether the room is occupied or unoccupied and adjusting the zone temperature set point accordingly. This networked option involves integration of these digital thermostats to the proposed DDC system to allow for even more aggressive setbacks when the room is un-booked for an extended period of time. Zone set points are reset +/- 5ºF when unoccupied, and typically an additional 3ºF to 5ºF when the room is not rented.

Air Handling Units

- *Add Variable Frequency Drives* – this recommendation involved replacing the existing inlet guide vane control (fixing them in place) with variable frequency drive (VFD) control of the AHU fan motors. A static pressure reset strategy was also recommended as part of this measure, utilizing the functionality of the proposed DDC system. Conversion of the existing constant-volume AHUs to VAV control, and DDC control of the terminal boxes was also considered as part of this recommendation, but was ultimately not included due to significant implementation cost increase, and the potential disturbance to regular hotel operations.

- *Replace Heating Elements with Steam Coils* – this measure involves replacing the electric resistance heating elements on the main AHUs with steam coils, including additional steam piping from the existing boiler to these new coils, as well as necessary valves and associated controls. These steam coils will allow for better control and better efficiency than the electric heating elements, allowing for better matching of the reheat provided by the coils, saving energy and improving supply air temperature control.

Chilled Water Plant

- *Replace Existing Chiller with Pony Chiller* – the chiller plant has excess capacity. This measure involves replacement of one of the three 800 ton chillers with a new 400 ton "pony" chiller. This would allow for greater flexibility regarding accurately matching cooling loads, and greater efficiency since the smaller chiller would operate closer to its full load capacity than the larger units during times of a low building cooling load.

- *Waterside Economizing* – this measure involves installation of a heat exchanger between the condenser water loop and the chilled water loop, as well as isolation valves, the required piping between the condenser water loop and the chilled water loop, and associated controls. This configuration allows the condenser water to be used to cool the chilled water loop (instead of the chillers) when the outside air wet bulb temperature is adequately less than the chilled water loop set point. This measure would allow necessary cooling to be provided at lower outside air temperatures to hotel rooms on the south exposure without operating the chillers.

Hot Water Plant

- *High Efficiency Heating Domestic Hot Water Boilers* – this measure involves replacement of the aging five atmospheric boilers with a rated peak efficiency of 80%, with high efficiency condensing boilers at a rated peak efficiency of 94%. The measure would require retrofitting the flues with a suitable material for condensing type applications.

- *High Efficiency Pool Boiler* – hot water is generated by a 45 kW boiler with a rated peak efficiency of 75%. This measure involves the replacement of the aging boiler with a new boiler with a rated peak efficiency of 95%.

Guestroom Exhaust

- *Exhaust Fan and Damper Control* – although the exhaust dampers are interlocked with the bathroom light switch in each guestroom, it was found that many of these exhaust dampers are no longer operating correctly and have failed open. This measure involves installation of two-position actuators on the exhaust air dampers, commissioning of all of the guestroom exhaust dampers, and the installation of VFDs on the four exhaust fans and the makeup air fans serving this exhaust system.

- *Exhaust Heat Recovery* – the fresh air corridor units (makeup air) and toilet exhaust fan system operate continuously, resulting in a large amount of wasted energy. This measure involves the addition of a run around coil between these exhaust and make up air units, and associated controls, to provide energy recovery from the exhausted air.

Lighting

- *Parking Garage Lighting Retrofit* – this measure involves replacing the T-12 lamps and magnetic ballasts with more efficient T-8 lamps and electronic ballasts in the parking garage, in addition to de-lamping some of the fixtures, as many areas are overlit.

- *Guestroom Lighting Retrofit* – the guestrooms incorporate a compact fluorescent lamp in the entry and bathroom, a T-12 fluorescent strip in the bath vanity, and three 100 Watt incandescent lamps in the table and bedside lamps. This measure involves replacing the incandescent lamps with more efficient compact fluorescent lamps and replacing the T-12 fixture with a T-8 lamp and electronic ballast.

- *Illinois Board Room Lighting Retrofit and Control Adjustment* – the Illinois Board Room is constantly too warm. This measure involves replacement of the existing lighting lamps and ballasts with more efficient lighting, to reduce internal heat gain, and commissioning of the air delivery system to ensure that adequate airflow is being delivered to the space. The commissioned system and lower internal heat gains will result in a higher allowable supply air temperature set point for the AHU, and additional energy savings.

Measures Considered, but Not Selected

A number of additional measures were also considered, but were ultimately not selected for implementation or were not recommended by AEC due to potential disruption to hotel operations, high first costs, longer simple payback periods, or other factors. These included:

- Stand-alone guestroom HVAC controls (networked option provided greater savings and better simple payback period)
- Automated guestroom lighting control (unacceptable simple payback and perceived operating problems)
- VAV retrofit of constant-volume AHUs and DDC control of terminal boxes (first cost)
- Replacement of all existing chillers with high efficiency models (first cost)
- Conversion of the single loop chilled water loop to primary/secondary arrangement, with a variable-flow secondary loop (first cost)
- Addition of VFDs on the cooling tower fans (unacceptable simple payback)
- Lighting retrofit and controls in public spaces (unacceptable simple payback)
- Fuel cells (lack of local incentive money)
- Repairing laundry heat recovery system (laundry now outsourced)

Results and Conclusions

The total estimated savings potential for the measures selected is 12,193,366 kWh, although the natural gas consumption is estimated to increase by 3,376 therms for this package of measures. This results in a total estimated annual cost savings of $1,192,517, representing a 32% reduction in predicted annual energy costs. The implementation cost estimate for these measures was estimated at $1,861,200, resulting in a simple payback period of 1.6 years.

Although these savings predictions and the simple payback period is very impressive, these measures have not been implemented to date. Why?

For projects in which the study is initiated by a building owner or manager, implementation almost always poses a challenge. When the study is funded by a utility-sponsored or government-sponsored program, or by a performance contract, there may be more incentive to implement the measures, either contractually or in the way of incentive monies. But even in these types of projects, implementation can prove difficult.

In some cases, this is due to lack of available funding, but in most cases, it is simply due to lack of time, particularly regarding the facility personnel who are usually charged with soliciting bids and managing the implementation effort. These personnel are almost always already over-taxed in their efforts to manage building operations, and despite their intimate and thorough understanding of the needs for these improvements, for not only energy savings but also for improved controllability, they simply do not have the time to dedicate to motivating this effort.

So what can be done? The answer: implementation assistance.

What is needed is a champion for the cause, someone to shepherd the process entirely, and make it a reality. Implementation assistance can fulfill this need. Typically performed by the engineering firm that conducted the RCx investigation, implementation assistance involves some or all of the following: clarification of the owner's project requirements and basis for design; development of specifications and detailed control sequences; review of contractor bids; submittal review; construction management; commissioning; and training.

Implementation assistance not only helps motivate implementation. The unbiased consulting services and representation provided by the third-party helps maximize energy savings and system performance, and ensures that the needs of the building owner are faithfully being met. It is a critical next step that is just beginning to be defined and understood, and should eventually be integrated seamlessly into the projects like this one.