

Retro-Commissioning Phase I Demonstration Project Shanghai, China

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Synopsis

In July of 2004, our firm was contracted to complete the initial phase for a typical retro-commissioning process conducted on three high-rise commercial buildings in Shanghai, China. This work was sponsored by the U.S. Environmental Protection Agency (EPA) eeBuildings program and our retro-commissioning team included representatives from the EPA and three student participants from the Department of Facilities Engineering & Management at Tongji University in Shanghai.

The scope of work for this project included a cursory review of all available documentation, interviews with the building operations staff, physical inspections of all HVAC and lighting control related systems and limited functional testing and data-logging of HVAC related performance parameters. Once the inspections and tests were completed, we met with the building owner representatives to discuss our findings and make recommendations for potential low and no cost improvements that would result in reduced energy consumption and improved indoor air quality.

The aim of this paper will be to describe our experiences during this demonstration project and discuss how this approach might be further refined and applied to other locations. We will emphasize the value of incorporating local participants into our project team in an effort to better “seed” the practice of building commissioning and to promote a longer term commitment to completing and sustaining the improvements identified through our demonstration project.

About the Author

Peter Keithly is a 1975 graduate of the University of Washington with over 25 years of experience in the field of facilities engineering. As a principal owner of KBA, Pete has spent the last nine years as a full-time building commissioning authority, with extensive experience in commissioning related specifications writing, design document review, commissioning plan development and functional performance testing on a wide variety of facilities and building systems. Pete has also taught technical college level courses on HVAC controls, and has presented on the subject of Building Commissioning at numerous conferences and workshops. He is a founding member and served for six years on the Board of Directors for the Building Commissioning Association (BCA). Pete is also a LEED Accredited Professional and an active advocate of high performance and sustainable building practices. You can email Mr. Keithly at: pete@keithlybarber.com.

INTRODUCTION

Building Commissioning & Retro-Commissioning Defined

For the purposes of this paper, building commissioning (Cx) shall be defined as follows:

“A formal quality assurance process designed to verify that building systems provided during new construction are designed, installed, functionally tested and capable of being operated and maintained to perform in conformity with the design intent.”¹

Therefore, building retro-commissioning (RCx) can most easily be defined as:

“The process of commissioning existing building systems that were either not commissioned when originally constructed or have been substantially altered from the original design. RCx is a process designed to identify and correct existing building system operational and performance deficiencies and to confirm functionality in compliance with the building owner’s current design intent and operational needs”.

Note: “design intent” refers to the ideas, concepts and criteria defined by the building owner to be important, and typically include facility function, desired performance and environmental needs.

A Typical Retro-Commissioning (RCx) Scope of Work

For the purpose of providing a common understanding for the readers of this paper, the following brief narrative describes a fairly typical² retro-commissioning approach and scope of work:

RCx Phase I – Planning & Qualifying

At the start of the typical retro-commissioning process, a specific “Commissioning Authority” (CA) is identified to lead the project team and an initial commissioning plan is developed that defines the project goals and desired approach. The CA must have a strong understanding of building commissioning procedures and the time available to sustain the commissioning process through completion.

Once the commissioning plan is in place, an initial qualifying investigation should first be conducted in order to determine if a particular building meets the screening criteria and a reasonable potential exists for functional improvements that might be identified and realized through completion of the retro-commissioning process. These evaluation procedures might include the following components:

- A familiarization review of all available building plans and maintenance documentation.
- Research and identification of the original building systems design intent.
- Interviews with building managers, operators and occupants.
- Review of maintenance work-request records.

- Review of energy consumption (billing) data, analysis of the energy usage index (BTUs per square meter of conditioned building space) and data comparisons to similar buildings.
- Random spot checking and short-term data-logging of indoor environmental quality conditions.
- A general physical condition review of major building system components.

At this point, the information collected is analyzed by the CA. A report is provided to the project team listing the issues and recommendations thus far identified, and a decision is made whether or not to continue with a more in-depth investigation and analysis of the building systems. If the project team determines there is good potential for functional improvements to be gained, the process will continue with the following procedures:

RCx Phase II – Comprehensive Systems Investigation & Analysis

- A more in-depth review of all existing documentation (plans, specifications, manuals etc.) related to those systems and equipment scheduled for retro-commissioning.
- Establishment and documentation of the building owner's current desired building operations and functional performance requirements.
- Analysis of the current (in-effect) operational procedures and control system sequences.
- Additional building system inspections and functional performance testing with the intent of identifying specific required repairs and additional suggested improvements.

Once the above procedures are completed, the CA again reviews all the relevant information and develops a report that lists specific required repairs and suggested improvements to the particular building systems being commissioned. This list should be segregated into those repairs and improvements the CA deems to be critical to the operation of the building system, and those that might be considered non-critical yet beneficial. Often these suggested repairs and improvements include the CA's budget estimates. This report is then presented to the project team for review and discussion, and decisions are made as to which repairs and improvements will be completed as part of Phase III.

RCx Phase III – System Repairs and Improvements

Once a decision has been made regarding specific repairs and improvements, a firm action plan and budget are developed. In some cases these repairs and improvements are scheduled and managed entirely by the building management staff, and in other cases the CA provides at least some level of project oversight. When the work is complete, the CA then conducts a site review to verify resolution of the previous issues and readiness for the final comprehensive functional testing of the specific building system.

RCx Phase IV – Comprehensive Functional Testing

When the CA is satisfied that all desired repairs and improvements are complete and operational, a final comprehensive functional testing plan is developed and conducted. The purpose of this functional testing is to verify compliance with the operational and performance criteria now established and defined by the current design intent document. All remaining issues discovered during this comprehensive functional testing process are documented and assigned for resolution as appropriate.

RCx Phase V – Final Issues Resolution and Turnover

Most often the CA remains involved in tracking the resolution of issues. In some cases this involvement includes active participation in developing, implementing and testing suggested solutions. Once the issues are resolved to the satisfaction of the client, the CA then compiles the record documents for the entire retro-commissioning process and provides a final retro-commissioning report. This report is presented for review and final approval by the building owner.

The commissioning plan might also include some level of additional training for the maintenance and operations staff. In addition, the CA may be contracted to provide follow-up reviews and testing at a later date to insure system performance is sustained over time.

THE SHANGHAI PROJECT

Background

In the Spring of 2003, our firm was contacted by David Hathaway from ICF International to discuss the possibility of providing building operations consulting in Shanghai, China, as part of EPA's on-going eeBuildings program. The eeBuildings program is a voluntary market transformation initiative developed by the U.S. EPA with the intention of providing developing countries with "lessons learned" from the EPA ENERGY STAR Buildings Program. Previous to this time, the EPA had been working closely with various Shanghai building owners and managers of large commercial buildings to help them identify low-cost and no-cost measures for reducing building energy use, operating costs and greenhouse gas emissions. Gary McNeil (who runs the program at EPA) and his supporting staff were interested in how elements of the formal building retro-commissioning process might be applied to help achieve this goal.

Over the course of the discussions, it was determined that the most reasonable and cost-effective approach might be to initially solicit interested building owners and managers for potential buildings, and then proceed to narrow the selection down to the three buildings for the demonstration project. In addition, it was determined that best approach for this project would be to design and implement a building retro-commissioning plan that would provide for what might be typically referred to as the "Planning and Qualifying" scope of work (Phase I) only. In the Spring of 2004 a site review of seven potential building sites was undertaken and subsequently narrowed down to the three buildings for this project. The following criteria were used:

- Availability and clarity of related systems design, operations and maintenance documentation.
- Level of expressed interest in participation from building owners and operators.
- Our familiarity with the particular building control (EMS) system.
- Estimate of potential for low and no cost improvements.

The three Shanghai buildings chosen for the demonstration project were:

1. Lippo Plaza Building (35 floor commercial office building managed by Jones, Lang LaSalle, opened in 1999)
2. COSCO International Shipping and Financial Building (50 floor commercial office building managed by FPDsavills, opened 2000)
3. Huadu Mansion Building (30 floor commercial office building managed by CBRE, opened in 1995)



Lippo Plaza Building



COSCO Financial Building



Huadu Mansion Building

Shanghai Project Approach

Because our retro-commissioning demonstration project budget only allowed for limited number of working days in Shanghai, it was important to design a project approach that maximized our effectiveness. As noted earlier, we selected our three project buildings based on information gained during our initial visit to Shanghai in May of 2004. We then assigned specific project responsibilities to three KBA engineers. One engineer was to concentrate on the building automation control system, another was to concentrate on the HVAC related equipment (air handlers, chillers, cooling towers etc.) and the third engineer was assigned responsibility for the interior lighting systems. The scope of our services was to be limited to the RCx planning & initial investigation phase only, and our specific aim was to identify and document a list of low and no cost suggestions for improving the operational performance of the HVAC and lighting related systems at each building. With assistance from Maria Chen, Don Anderson and other members of the EPA eeBuildings team, we were able to garner some limited documentation related to our project building systems and we spent a fair amount of time reviewing this information at our office in Seattle, in order to be better prepared once we arrived in Shanghai.

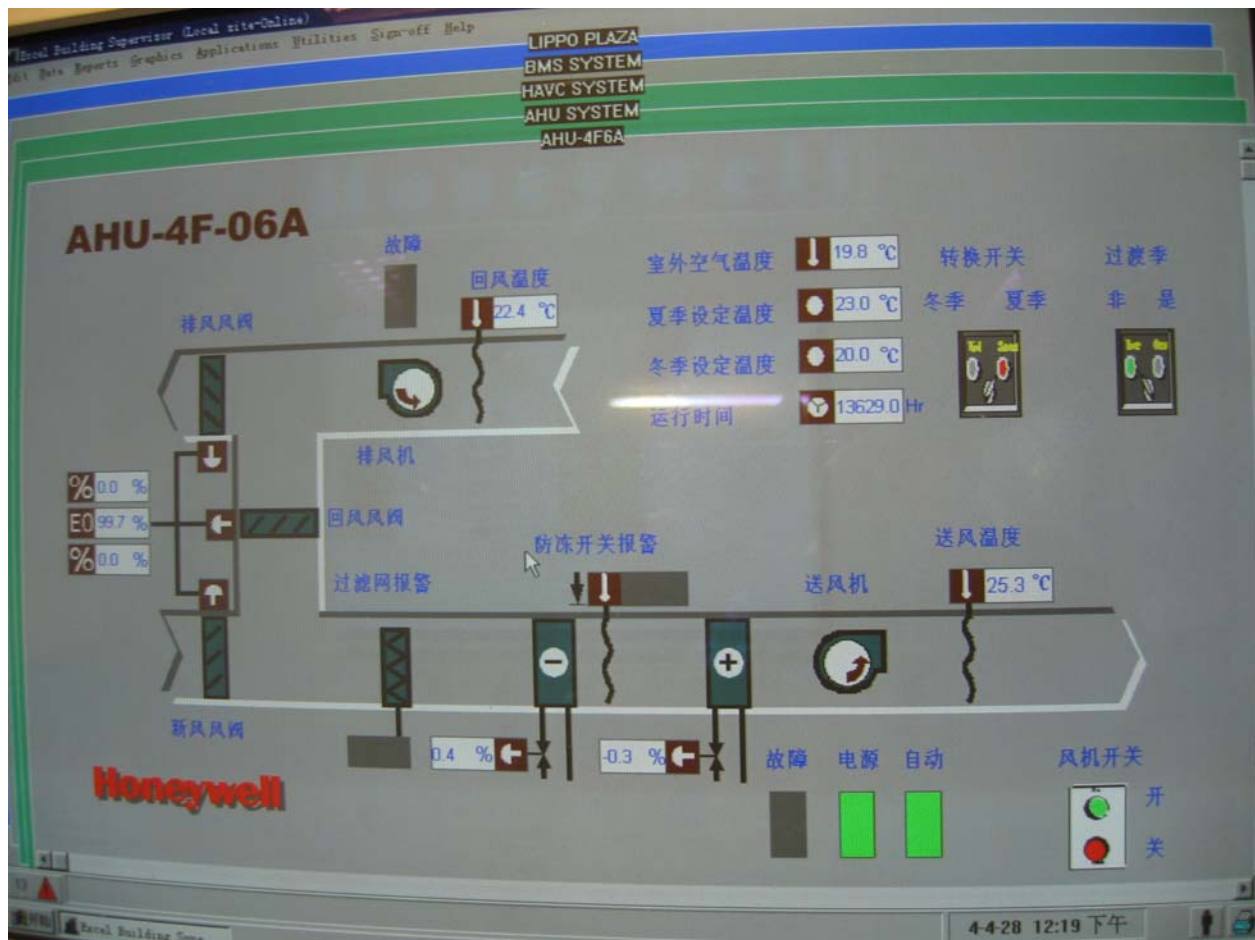
Our final project plan called for us to work a total of three days at each site in Shanghai. Because of a previous collaborative relationship between the EPA eeBuildings team and Professor Shirley Pan from the Department of Facilities Engineering & Management at Tongji University, it was also arranged for one English speaking engineering student to be assigned to work with each of our KBA commissioning engineers. The help and support from these students was very useful and it was also an opportunity for them to observe and learn something about the formal building retro-commissioning process. In addition, Maria Chen from the EPA eeBuildings team acted as the main liaison between our engineers and the project building managers, and she was

responsible for the majority of the scheduling and coordination required for our project to go forward.

Our first order of business at each site was to meet with the building management and operations staff to explain our retro-commissioning plan and solicit information regarding their knowledge of specific issues related to the actual maintenance and operations of these building systems.

Note: Appendix “A” includes a list of some questions asked during these initial interviews. We were then provided with a comprehensive tour of the buildings to gain a better level of familiarity with the building layout and the location of the various system components. Once these tours were completed, we then broke into three separate groups and began to concentrate on a more in-depth investigation. In most cases we were assigned one of the building operations staff to help “guide” us around the building as necessary, and our Tongji University engineering students were able to provide a reasonable level of translation when questions were asked. During this period of time we inspected all the major systems equipment and documented physical issues such as broken damper linkages, dirty coils, disconnected wiring etc.

Over the course of the three days at each site we were able to gain a fair level of understanding regarding the fundamental design intent of each building system. Because our engineering team had a strong background in the operation and commissioning of similar building systems, we encountered very little difficulty in recognizing typical HVAC components and configurations. As you can see from the picture below, even the energy management control system interface graphics were basically familiar, and we were able to use these systems to conduct a reasonable review of real-time HVAC system performance.



Typical HVAC Control System Graphical Interface Screen – Shanghai RCX Project

In addition to the document reviews, visual equipment inspections and discussions with the building operators, the team also conducted some limited functional testing and independent data-logging of four indoor environmental quality indicators in randomly selected occupied zones throughout the buildings. These indicators included:

1. Space Air Temperatures
2. Carbon Dioxide (CO₂) Levels
3. Relative Humidity Levels
4. Task Lighting Levels

The goal in gathering this data was to get a general sense of the overall HVAC and lighting performance throughout the building, rather than trying to identify specific areas of concern. Once this data was reviewed, the team developed a list of some specific issues and recommendations for appropriate resolution. Appendix “B” and “C” include samples of the data collected and Appendix “D” includes a sample of the issues identified and recommended actions.

Common Issues and Recommendations

At the conclusion of our project, we assembled all the information we had collected and compiled both a list of building specific recommendations, and also a list of general program recommendations we felt were appropriate for all three buildings. For this paper, we have provided a summary of several recommendations we believe might be most appropriate to consider for similar building applications.

- Without exception, we felt that all three of our project buildings could do a better job of using outside air effectively for “free” cooling applications and adequate ventilation. Even in a climate as warm and humid as Shanghai, there are typically many hours of the day and night where outside air temperature and humidity conditions would permit the use of ambient air to reduce the overall building cooling load. In addition, we also suggested the increased use of outside air during the early morning hours, prior to occupancy, to pre-cool the building interiors and improve the air quality of the indoor environments. Most of the economizer related AHU equipment we inspected was not fully functional, and the control systems were not programmed for optimum energy efficiency in this regard. We also saw no indication that CO₂ demand ventilation strategy was being employed, and we felt as though implementation of this control strategy could also help to significantly reduce energy usage during the heating season.
- Our random measurements of task lighting levels in the three project buildings indicated that many zones were over-illuminated, and many zones were illuminated when the areas were not occupied. Reducing the task lighting to adequate levels could provide a significant reduction in energy usage. We also recommended the use of occupancy sensors and zone lighting controllers to turn off lighting in unoccupied zones. Because of the low labor costs in Shanghai, we recommended that it would be prudent and very cost-effective to simply assign the responsibility for continuously roaming the building and shutting off unnecessary lighting (and other electrical appliances) to one building operations staff person.
- Review of the building HVAC automation control systems indicated that a number of the original control and monitoring points were not providing accurate data, and many of the major HVAC system components were being run in a substantially manual mode. A complete retro-commissioning process would call for identifying and restoring these faulty control points. We also recommended a complete review of the operating control system software with potential revisions and upgrades in order to bring it into compliance with the current operational needs and design intent.
- Active management of building energy consumption requires that usage data be available on a timely and accurate basis. We also recommended that energy (electricity and natural gas) meters be read and recorded on a regular (hourly) basis in order to gain a better understanding regarding the specific energy usage profiles for each building. This data can then be analyzed in more depth by individuals qualified in energy

management techniques, and various energy saving strategies can be tested and the results better verified.

Recommendations for Future RCx Demonstration Projects

Based on the success of effort in Shanghai, we would suggest that future RCx demonstration projects be structured to allow for active participation by both representatives from the in-house building operations staff and at least one representative from a local university level engineering program. This level of local participation adds several distinct values to the RCx process:

- The in-house staff gains a better operational knowledge of their systems, and they more clearly understand the logic behind particular design features.
- The in-house staff has a direct sense of accomplishment having participated in the identification and resolution of issues that may have been causing chronic operational problems for some time.
- Knowledge of typical RCx procedures is acquired by the in-house staff and this increases the likelihood of future re-commissioning applications as part of an effective preventive maintenance program.
- The participation of local engineering students helps to “seed” the potential for building commissioning procedures being performed on future projects and also allows students to better understand how actual systems work (and perhaps don’t work!) in real world applications.

Another recommendation we would make for future RCx demonstration projects would be to concentrate our efforts and funding on completing the entire RCx scope of work (all five phases) at one location. We believe it is important to provide some level of experienced guidance through the entire process so that the final resolution of significant issues can be realized. When the positive results of a well designed and effectively implemented retro-commissioning process can be demonstrated and documented, it becomes much easier to convince other building owners and managers to invest in the process.

Shanghai Project Summary

The overall experience was very informative and rewarding. We learned that building managers and operators in Shanghai face similar challenges to those in other countries in regards to providing comfortable conditions for occupants while maintaining reasonable levels of building energy usage. We also learned that a formal retro-commissioning process is very transferable to all buildings, regardless of location.

One recent study indicates that completing the retro-commissioning procedures on an existing building can yield energy savings of more than 15%.³ The success of this program will be measured not so much by the energy savings realized at any particular building as by the increased understanding of how building commissioning procedures can be applied to existing buildings and new building projects. The adoption of building commissioning procedures into

the mainstream building construction, maintenance and operations effort has the potential to dramatically improve the quality and performance of building systems worldwide.

Appendix A

SAMPLE of BUILDING OPERATORS AND MANAGERS INTERVIEW QUESTIONS

QUESTION:
1. Who is the Chief Operating Engineer for the building?
2. How many O&M Staff?
3. Normal working schedule?
4. What types of training do the M&O staff have?
5. What outside contractors are used for M&O?
6. Is building cleaned by in-house staff or contractors?
7. What is the normal cleaning schedule?
8. Is there a central HVAC controls system?
9. Who is responsible for the M&O of this HVAC control system?
10. Can you monitor and control from an offsite location?
11. Is there a lighting control system?
12. Who is responsible for the M&O of the lighting control system?
13. Can you monitor and control from an offsite location?
14. What is the normal occupancy schedule for this building?
15. What is the normal operating schedule for the HVAC system?
16. What is the normal operating schedule for the lighting?
17. In what areas of the building do you have problems with controlling temperature?
18. Are you planning any major system repairs or replacements?
19. Do you have any energy usage data for this building?
20. Do you have any M&O documentation? As-built plans?

Appendix B

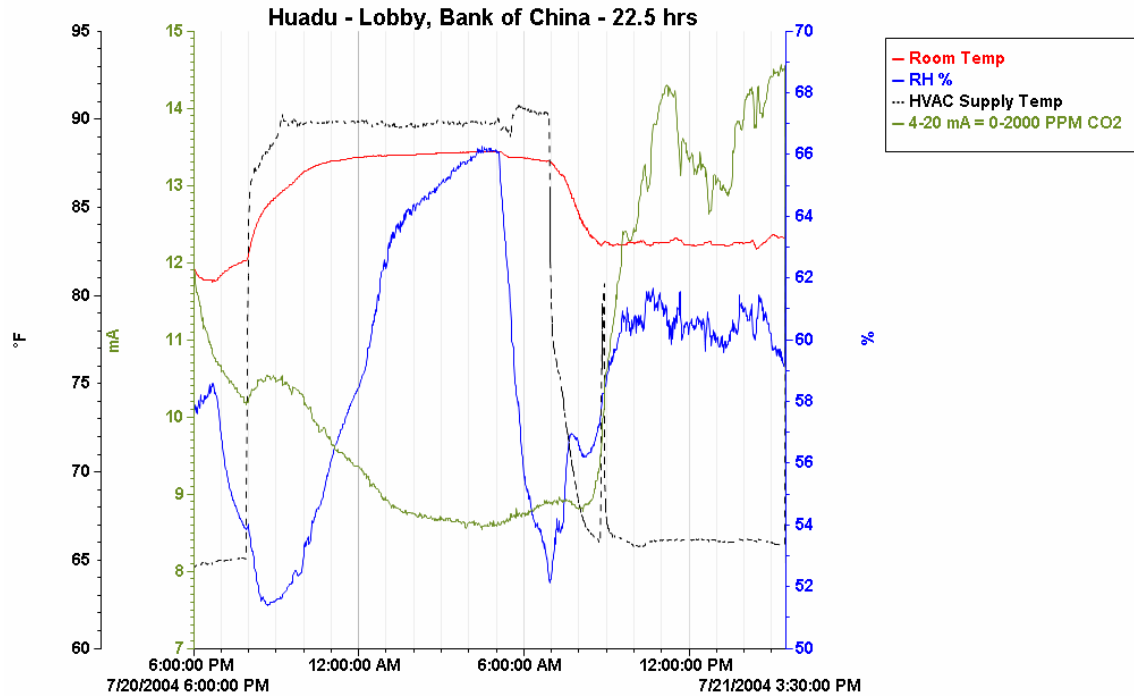
SAMPLE of DATA COLLECTED DURING QUALIFYING INVESTIGATION

Temp (degrees C), Relative Humidity, Task Lighting Levels (Lumens), CO2 (PPM)

TIME	FLOOR &	LOCATION	TEMP	%RH	LITE(? Units	CO2
13:56	20#	Fac Mgmt Office	23.4	59.6	268	1175
13:55	1#	Hall – North	27.1	62.3	1160	800
13:56	1#	Hall – East	26.8	64.1	2455	654
13:57	1#	Hall – South	26.6	66.6	2210	612
13:59	1#	Hall- West	27.0	63.6	609	617
14:02	2#	Restaurant	27.8	58.8	5014	631
14:03	2#	Restaurant	27.6	51.8	961	612
14:04	2#	Arrail Dental	26.6	54.1	339	635
14:05	2#	Singular Image Design	27.0	55.1	318	743
14:06	12#	Lift	28.2	62.0	1844	792
14:07	3#	Coffee Bar / Planet Shanghai	26.3	64.1	514	616
14:08	3#	Tenant space	26.6	67.1	62	566
14:20	5#	Tenant space	26.6	51.1	451	649
14:22	5#	Passage	26.3	62.9	358	712
14:24	5#	Tenant space	26.1	52.1	611	694
14:26	6#	Passage	26.7	58.8	350	876
14:28	6#	Tenant space	26.2	59.5	611	992
14:32	6#	Tenant space	26.1	54.9	570	954
14:36	7#	Passage	26.7	54.4	134	881
14:36	7#	Tenant space / Catholic	25.0	57.2	435	1170
14:37	7#	Tenant space / Catholic	24.5	59.5	420	1123
14:38	7#	Tenant space / Air Waten	24.3	61.3	520	701
14:39	8#	Passage	25.2	57.6	340	835
14:39	8#	Tenant space	25.3	58.8	490	887
14:40	8#	Tenant space	25.2	56.9	680	886
14:42	9#	Passage	26.2	61.2	118	663
14:42	9#	Tenant space / Rolls-Royce	25.0	53.7	580	590
14:43	9#	Tenant space	26.1	54.8	721	629
14:44	9#	Tenant space / 905#	25.5	60.0	370	579
14:45	10#	Passage	26.1	61.7	114	598
14:45	10#	Tenant space / Hartung Consult	25.9	60.2	450	669
14:46	10#	Tenant space	25.6	58.6	395	676
14:47	11#	Passage	25.8	57.0	208	659
14:48	11#	Tenant space / Arusta Life Science	25.5	52.4	556	940
14:49	11#	Tenant space	25.3	59.4	580	666

Appendix C

SAMPLE of PLOTS FROM RANDOM DATA-LOGGING IN VARIOUS LOCATIONS



Comments Related to Above Data: Profile indicates good temperature control during occupied periods. Zone temperature setpoint was maintained very high during the occupied period due to energy reduction constraints enforced by the local jurisdiction. Note: High occupied CO2 levels as would be expected in a bank lobby. Ventilation rates should be further investigated for this zone. HVAC supply air temperature spike at 9 AM seems curious and should be further investigated.

Appendix D

SAMPLE of BUILDING FINDINGS AND RECOMMENDATIONS LIST

Overview

In general, this building in very good condition with the majority of all equipment being well maintained. In addition, the random measurement of space temperature, relative humidity, CO₂ and task lighting levels would indicate that the building environment is being maintained at a satisfactory level during periods of occupancy. The building operations staff is very aware of the need to manage energy usage and has begun to keep records of kWh consumption on a daily basis. The following list includes specific findings, observations and recommendations for potential energy savings and/or improved systems operation.

1. **ISSUE:** One of the first issues we encountered was the apparent short-circuiting of air flow out of the cooling towers. Because of the aesthetic architecture built at the peak of the building, the cooling tower fans discharge is significantly blocked, and this causes the exhaust air to be recycled back into the intake side of the cooling tower. The result of this air flow blockage is that the cooling towers capacity is significantly reduced, and this forces the associated cooling tower fans and pumps to work harder in order to keep the condenser water loop temperatures within design limits. This not only uses more energy, but it also forces the building operators to introduce excessive make-up water in order to run all the chillers on the hottest of days. **RECOMMENDATION:** That an HVAC engineering firm be consulted to review possible improvements to the discharge airflow on the cooling towers. While this may involve some additional ducting, the improvement in cooling tower efficiency would likely provide a very fast payback on the investment.
2. **ISSUE:** Currently it appears that the potential for cooling with outside air is not being utilized to the fullest extent possible. While the air temperatures were probably too high for effective use during the time we were conducting our work (mid July), there should be many days during the year when the potential for cooling with outside air is significant, and this would reduce energy usage by avoiding use of the mechanical chilled water system (chillers and associated pumps) when they may not be necessary. **RECOMMENDATION:** A review of all air handling unit (AHU) economizer control sequences and current operations to verify use of outside air whenever the potential for effective use exists. In addition, the use of AHU systems for night cooling be attempted. This is a strictly operational change which basically calls for running all the AHUs in the 100% outside air mode during the early morning hours, whenever a general cooling load is anticipated for the next day, and the outside air temperature is lower than the average indoor air temperature. If the building space and internal structure (including furniture etc.) temperature can be lowered with the use of outside air only, this “heat sink” can provide a significant hedge on the cooling load, and will avoid bringing on the chillers until later in the day.

3. **ISSUE:** While the operations staff are now logging and graphing kWh usage on a daily basis, additional timely electrical usage information would be useful for energy management purposes. **RECOMMENDATION:** Recording interval for kWh be increased from once every 24 hours to once every four hours, or even more frequently. This additional usage information would help to identify specific usage patterns, and would also allow the building operations staff a better opportunity for discovering unnecessary usage during unoccupied periods. In addition, it would be helpful to record the individual tenant kWh meters on a daily basis in order to establish baseline daily usage profiles for each zone and to provide more timely feedback (graphical usage plots) to the tenants regarding electrical usage levels so that they might be more inclined to implement energy conservation measures themselves. One more idea might be to initiate some type of contest between tenants that would award a prize for the greatest reduction in kWh per square foot from one month to another.
4. **ISSUE:** Noted AHU heating/cooling coils fouled with dust and dirt. **RECOMMENDATION:** Consider the addition of filter media or new filter type to allow for better filtration of inlet air. Additional filtration will allow for better coil protection from dirt and dust reducing the need for coil cleaning.
5. **ISSUE:** Noted several areas where OSA inlet wall louver bird screening is partially blocked with dust and dirt. **RECOMMENDATION:** Check all OSA inlets and clean as required.
6. **ISSUE:** Noted AHU inlet balancing dampers closed. Units with these dampers closed are not providing the proper amount of supply air to the spaces they serve. Units are not provided with a means of locking these dampers in place. **RECOMMENDATION:** Install damper locking devices to allow for dampers to be locked in the open position.
7. **ISSUE:** Noted many AHUs with OSA dampers disconnected from motorized dampers. Other OSA dampers have no motorized dampers. Found several OSA dampers closed. Units with the OSA dampers closed are not providing the proper amount of supply air to the spaces they serve. Units are not provided with a means of locking the OSA dampers in place. **RECOMMENDATION:** Install damper locking devices to allow for dampers to be locked in the open position.
8. **ISSUE:** Noted SEF (smoke evacuation fan 37kW) fans (3) that serve the garage are currently operated daily on a time schedule. These fans are equipped with inverters that allow for two speed operation. One speed for garage ventilation and one speed for fire alarm operation. **RECOMMENDATION:** Install garage carbon monoxide monitoring sensors and turn these fans on/off as required to maintain safe garage carbon monoxide levels.
9. **ISSUE:** While the lighting fixtures we observed were generally high efficiency design, there appears to be limited use of occupancy sensors to control lighting in seldom occupied areas. Also, even though lighting levels seemed to be generally appropriate in

most areas, there may be some potential for lowering illumination levels in areas where higher than normal task lighting levels are not necessary. Lighting levels of 400 lux at desktops should be sufficient for most office related tasks. **RECOMMENDATION:** Complete a thorough survey of all lighting fixtures and space lighting levels to determine where there may be opportunity to reduce lighting levels by removing fixtures or reducing the output of fixtures, and where low-cost lighting control occupancy sensors may be appropriate. In addition, tenants should be reminded that it may be appropriate to shut off lights when light from ambient (outside) lighting sources can provide sufficient office task illumination. It may also be prudent to test fixtures that can automatically reduce fixture lighting levels as ambient light sources increase (day-lighting controls).

10. **ISSUE:** While it seems apparent that most tenants are getting all lighting and HVAC related loads turned off in their individual spaces at the end of the work day, there may be some potential for savings by insuring all possible loads have been shut down. **RECOMMENDATION:** It may be prudent to assign one person to review all tenant spaces at the end of each day to verify (through the use of a checklist) that all unnecessary lighting and HVAC loads have been shut down. This same person could be responsible for recording the kWh usage data for each tenant space.
11. **ISSUE:** Because of the current HVAC control system design, there are no points provided for measuring and logging temperatures within individual tenant spaces. This information could be useful in determining actual current heating and cooling loads for specific zones within the building, and would also be useful for identifying potential problem areas. **RECOMMENDATION:** The addition of space temperature sensors to be located within each tenant space, and each retail/restaurant area on each floor, with the data displayed on one separate screen of the DDC system graphical user interface computer.
12. **ISSUE:** While the ventilation rates currently appear to be providing a good general level of fresh air to the building, it would be helpful to monitor CO₂ levels in some representative areas in order to determine if the building is over or under ventilated at any given time. This information could also be used to better control the AHU outside air intake rates. **RECOMMENDATION:** The addition of several strategically located CO₂ sensors onto the DDC control system in order to provide better information for control of the building HVAC systems.
13. **ISSUE:** In some of the spaces we noted that several fan coil thermostats were placed in the same location on the wall. Individual thermostats should be located within the specific zone served by the associated fan coil unit to avoid overheating or overcooling any zone. **RECOMMENDATION:** Wherever possible, individual fan coil thermostats should be moved to wall locations within the space served by the associated fan coils. This should also be the procedure followed whenever tenant spaces are remodeled.
14. **ISSUE:** In general, many of the original control system operational sequences are not being used, and many of the HVAC system components are being run in a substantially

manual mode. Also, many of the design system components are outdated and the entire HVAC system would benefit from a general control upgrade. **RECOMMENDATION:** A thorough review of the original HVAC control system operational sequences to determine if they are appropriate for the current operational needs of the building. We would recommend reinstatement of all automatic control, and the completion of any changes to the original operational sequences that are now desired. We would suggest consideration of a control system upgrade to a more recent software version and also upgraded hardware where appropriate. Once these changes are made, we would suggest consideration of a comprehensive functional testing of all HVAC related system components in all operational modes to insure the systems are operating in compliance with the current desired design intent.

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