Data Center
Salt Lake City, Utah

Study of Facility Management and Operations Best Practices

Research Supporting
National Science Foundation Project:
Educating Technicians for Building Automation and Sustainability

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eBay Data Center
Study of Facility Management and Operations Best Practices

Introduction

This case study is one of several conducted on facilities that demonstrate excellence in building operations, maintenance, and management. Laney College's Environmental Control Technician Program commissioned the study, as part of its National Science Foundation project *Educating Technicians for Building Automation and Sustainability*.

Best practices, in this context are defined as replicable, proactive strategies and activities that demonstrate excellence in the operations, maintenance, and management of a commercial or institutional facility. They typically meet end-use requirements, improve occupant comfort, reduce energy consumption and meet sustainability goals, improve cost effective operations, and stimulate occupant engagement in energy conscious behavior. Best practices span excellence in technology and design strategies, troubleshooting and problem-solving, proactive organizational management and strategic planning, education and training efforts, and shared leadership. Building technicians play a critical role in each of the best practices highlighted in this study, whether the practices are more technical or more strategic in nature.

From a different perspective, best practices are part of the knowledge distillation process and are built upon experiences and lessons learned. Over time, the ones that are most commonly used across an industry form the basis for standards.

The best practices highlighted are not intended as a comprehensive analysis of the operation of each facility. They provide snap-shots of selected areas of excellence that crystallized as particularly significant to the successful operations of each facility. The practices were identified during site visits by a team from Building Intelligence Group who conducted this research for Laney College.

These case studies demonstrate the critical role building technicians play in all aspects of sustainable building performance. It is our hope that they will inspire educators and practitioners alike in valuing building technicians as key agents of change in facilities and creating education and training opportunities to support technicians in their full professional capacities.

Facility operations and management (non-IT) best practices featured in this case study include:

1. Standardized facilities operations and maintenance procedures;
2. Communication and documentation procedures for quality control;
3. Energy monitoring and sustainability;
4. Training and continuous improvement program.

Company Overview

eBay is the world's leading e-commerce company and the world's largest online marketplace with more than 100 million active users globally (as of Q4 2011). Founded in 1995, eBay connects a diverse and passionate community of individual buyers and sellers as well as small business. In 2011, the total value of goods sold was $68.6 billion – more than $2,100 every second.

Data Centers

Data Centers are the "factories" of the digital age, storing and processing the information needed for commerce, communications and entertainment. But these large facilities are very energy intensive, with massive banks of computer servers, disk drives, and required support equipment for power conditioning and cooling. The proper management of data centers can provide significantly improved energy efficiency. This case study is focused on a facility that is truly "state of the art" in providing both improved efficiency while still maintaining critical operations and uptime.

Facility Overview

eBay Incorporated's Tier 4, 2-story, 250,000 SF data center opened in suburban Salt Lake City, Utah. The facility opened in 2010.

Background

Building and Systems

The facility was certified as LEED GOLD for New Construction in 2010 by the United States Green Building Council (USGBC) / Leadership in Energy and Environmental Design (LEED). It is the first building in Utah to achieve that designation.

Figure 1: LEED GOLD certificate

The facility includes offices, conference rooms, data / server rooms, battery, transformer, electrical, UPS and mechanical rooms. To support cabling and air distribution needs, the 50,000 SF data halls have a 3' raised floor.

Figure 2: Raised floor

Data center reliability (or "uptime") is split into four "Tiers" as defined by the Uptime Institute and approved in ANSI /TIA standard 942. The Salt Lake City center is Tier 4, the most stringent, with expected availability of 99.995%.

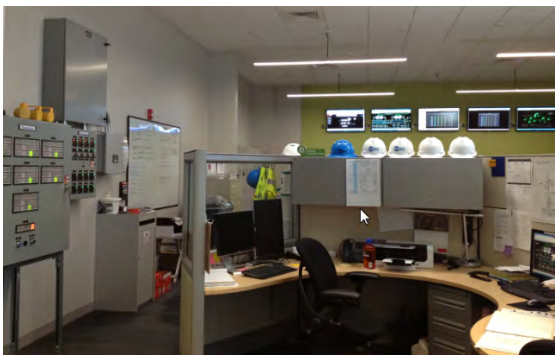


Figure 3: Facility management team office

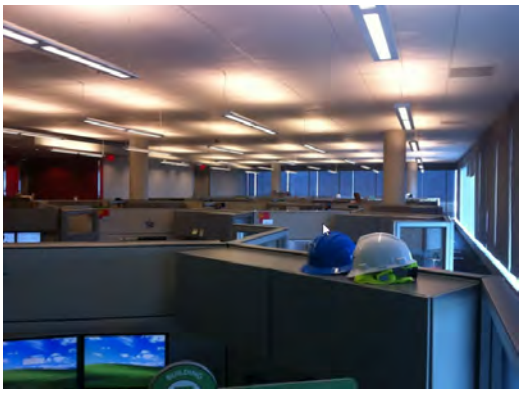


Figure 4: Administration office space

The heating, ventilating and air conditioning (HVAC) system includes four modular 1,300-ton chiller packages each of which has a water-cooled chiller, plate and frame heat exchanger and a set of cooling towers. These chiller plants are located outside of the main building. From November to March, the chillers are not typically used, since the heat exchangers can provide "free cooling" using the cooling tower water.

A conventional variable-air-volume (VAV) air handling system serves all areas except the 50,000 SF of raised floor data / server areas. The data center is conditioned with redundant computer room air handling units (CRAH). Both the support and raised floor HVAC system air handling units (AHU) have variable frequency drives for added efficiency. A separate AHU provides conditioned outside air and humidification. A boiler provides perimeter baseboard heat in the office areas.

Figure 5: Typical chiller plant

The data center provides improved HVAC efficiency by isolating the hot and cold aisles, and forcing air through the servers. Conventional data centers leave an open area around these aisles allowing for cold aisle air to easily bypass to the hot aisle, which requires lower air temperatures to provide effective cooling for the servers.

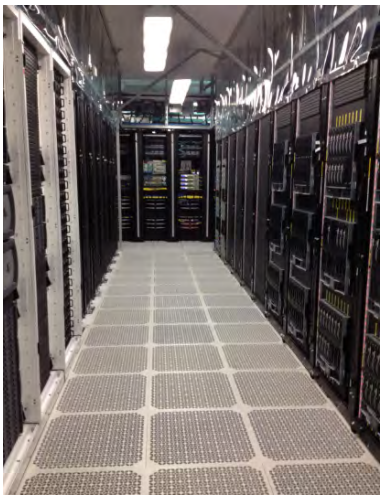


Figure 6: Typical server rack cold aisle

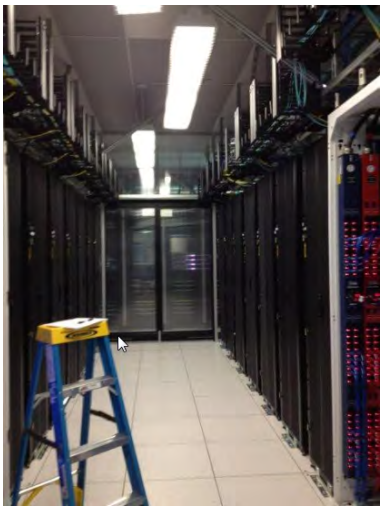


Figure 7: Typical server rack "contained" warm aisle

There are three building management systems (BMS) used in this data center: one for HVAC, the second being an overlay system to monitor energy efficiency while simultaneously reducing carbon footprint, and the third is a system for monitoring and managing real-time power consumption data and events.

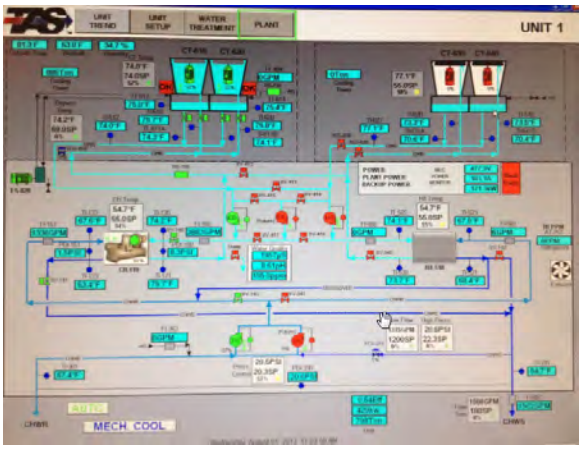


Figure 8: BMS schematic for HVAC system

The 20-acre site is fed by its own electrical sub-station. Electrical redundancy systems include seven diesel generators, an uninterruptible power supply (UPS) system, inverter and battery systems for the medium and low voltage services.

An 800 kW solar PV system is installed on the roof and the power is sold back to the grid.

Figure 9: Generators

Figure 10: Battery room

Figure 11: UPS room

Energy and Environmental Goals

"eBay is committed to continually improving the efficiency and environmental sustainability of our business. Data centers are the core engine of so much of what we do, and it's essential that we continue to innovate to get the maximum amount of work out of them while consuming the minimum amount of resources."

eBay
Public Relations Department

Energy efficiency, sustainability, and greenhouse gas / carbon footprint reductions are part of eBay's corporate management goals.

Given the LEED recognition received at this data center, sustainability and energy efficiency are also focus areas of the facility management and building operations team. The team works diligently to maintain the LEED GOLD rating.

The efficiency of the facility has been progressively improving. The current power utilization effectiveness (PUE, the total facility energy divided by the IT equipment energy) is 1.5 with a goal of 1.2. Traditional data centers' PUE is in the range of 2.0 - 2.2.

The facility's current EPA ENERGY STAR rating is 71. It is anticipated that the facility will earn a score of 75, which is the threshold for the facility achieving the ENERGY STAR rating.

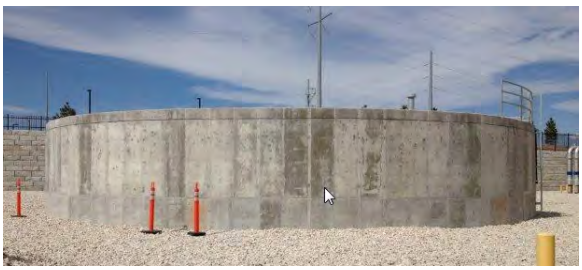


Figure 12: 310,000-gallon cistern

A 310, 000-gallon cistern supports eBay's LEED and water utilization effectiveness (WUE) goals; the system will capture rainwater for cooling tower make-up, irrigation and toilet flushing in the future.

"PUE is the de facto standard driving efficiency in our data centers, and the emergence of additional metrics, including WUE and CUE, will help us drive further cost reductions while minimizing our environmental impact."

DEAN NELSON
Senior Director
eBay Global Foundation Services

Facility Staff

For a Tier 4 data center, the primary focus of the facilities and maintenance team is high uptime. To achieve this, eBay has outsourced all facility operations and management functions to McKinstry. This allows eBay to focus on their core e-commerce businesses.

McKinstry is a specialized data center facility operations services provider. Their key performance indicators (KPI) for "DC readiness" include procedures, energy efficiency, sustainability, communication and quality control.

While McKinstry is the "first responder" to maintenance issues, other specialty equipment vendors (UPS, transformers, chillers, etc.) provide maintenance for their specific equipment.

"In a data center, there is nothing that does not change! You're always changing and adapting, and challenged every day!"

DAVID HILL, CFE-3 LEAD
Critical Facility Engineer Lead
McKinstry

Under McKinstry's "hybrid model" of doing more work in-house than a typical operations and maintenance (O & M) service provider, they have developed a team of Critical Facility Engineers (CFE) to perform the specialized (non-IT)

procedures for the 24/7 operation and maintenance of the data center. Currently, most of the CFEs have electrical, electronics or mechanical backgrounds from the construction industry or military.

Four O & M procedure types were identified:

- Administrative Operations Procedures (AOP) including safety items;
- Emergency Operating Procedures (EOP) to identify an issue;
- Method of Procedures (MOP) including checking, fixing items. Levels 1, 2, 3;
- Standard Operating procedures (SOP) which are diagnostic in nature.

The McKinstry CFE structure identifies four competency levels for their data center operators:

- CFE 1 where basic team contributions are expected and have received the following training: OSHA 10, first aid, CPR, lock-out / tag-out (LOTO) electrical safety procedures, confined spaces, man lifts. The CFE 1 contributes through basic preventive maintenance work and has been trained on all administrative procedures;
- CFE 2 where the technician possesses additional technical skills, is operator trained on all procedures, and writes MOPs, EOPs, AOPs and SOPs;
- CFE 3 is considered a subject matter expert, trains level 1 and 2 CFEs, and has additional technical training and experience with MOPs, EOPs AOPs and SOPs;
- CFE Lead has management skills and responsibilities. The Lead's main responsibility is training staff and the prioritization / delegation of work to the CFEs.

Best Practices

eBay Best Practice #1: Standardized Facilities Operations and Maintenance Procedures

Preventative maintenance (PM) is proactive, planned work to reduce the number of reactive and emergency repairs. In order to maintain the required equipment uptime, the PM program utilizes "reliability-centered maintenance" a best practice supported by other leading facility management teams. The expectation in doing maintenance work is "to know the outcome before taking action" since the data center is "live" 24/7 and that it is a "system" with action / reaction consequences.

In-house CFEs or the specific equipment vendor may do PMs. McKinstry does not currently identify a time budget for routine activities for scheduling or budgeting purposes.

Figure 13: "Sticky" floor mats to server areas are changed twice daily

Being a data center, a clean environment is critical. Food and drinks are not allowed outside of office areas, reinforcing that mind-set of all CFEs. Sticky floor pads, located at doors into critical areas, are changed twice daily.

Monthly Preventative Maintenance

McKinstry's computerized maintenance management system program (CMMS) plans the 300 – 500 monthly preventative maintenance activities. The PMs are then prioritized and scheduled by the lead technicians.

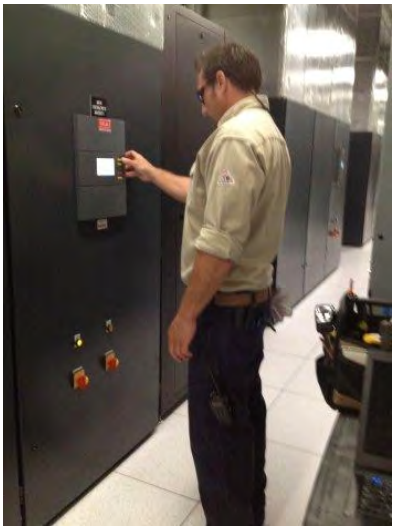


Figure 14: CFE-2 doing a PM on a CRAH

Routine monthly preventative maintenance tasks include:

- Verify HVAC unit fan operation;
- Inspect HVAC unit filter condition to determine timing for replacement;
- Inspect chillers, cooling towers, pumps;
- Inspect pumps for vibration and temperature;
- Listen for familiar / unusual noise;
- Look at all aspects of the equipment;
- Check operating ranges (water and air temperatures, kW, fan CFM, VFD percentage);
- Check generator fuel level;
- Check server indicator lights (red, green) for operating status;
- Battery and generator testing.

Figure 15: ACFM monitoring electrical gear

> "Procedures force us to think twice, think through what our actions are going to do to the system - it forces us to pre-plan."
>
> ADAM ENGLEBRIGHT, CFM
> Critical Facility Manager
> McKinstry

Alarm-Generated Maintenance

McKinstry is the "first responder" to alarms that are generated by the BMS. In the event of an alarm during the day, the Lead and other management personnel receive a phone call, or the ringer sounds in the engineering office. If at night, the security department receives the alarm and the night shift CFE responds. Depending on the magnitude of the alarm, the CFE is expected to make the judgment call of whether and how to take action, or if the equipment vendor or day crew will take responsibility.

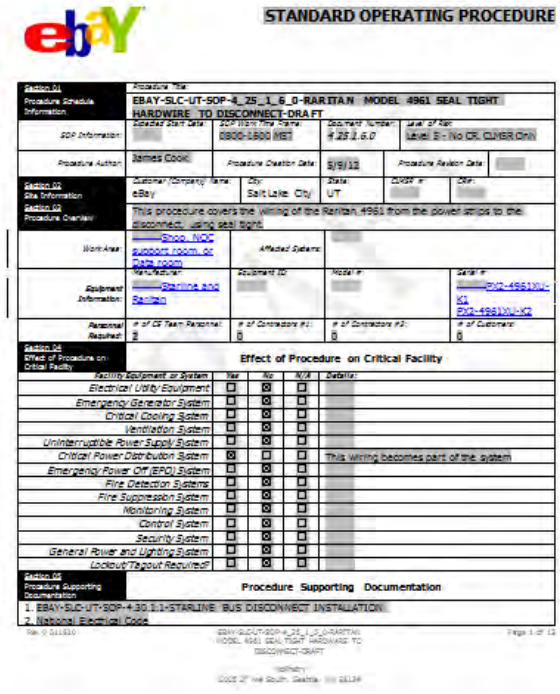
Major Equipment Preventative Maintenance

McKinstry plans and schedules all in-house and vendor maintenance activities that are done at greater than monthly intervals on major pieces of equipment, such as cooling tower and chiller tube cleaning.

Un-scheduled Maintenance

McKinstry conducts un-planned maintenance activities similar to a "fire drill" to simulate emergency operations and response procedure readiness.

They are also in the mode of continuously tweaking building systems attempting to identify any potential system deficiencies that surfaced during design and construction.


STANDARD OPERATING PROCEDURE

EBAY-SLC-UT-SOP-4_25_1_6_0-RARITAN MODEL 4961 SEAL TIGHT HARDWIRE TO DISCONNECT-DRAFT

Effect of Procedure on Critical Facility

Facility Equipment or System	Yes	No	N/A	Details:
Electrical Utility Equipment	☐	☒	☐	
Emergency Generator System	☐	☒	☐	
Critical Cooling System	☐	☒	☐	
Ventilation System	☐	☒	☐	
Uninterruptible Power Supply System	☐	☒	☐	
Critical Power Distribution System	☒	☐	☐	This wiring becomes part of the system
Emergency Power Off (EPO) System	☐	☒	☐	
Fire Detection Systems	☐	☒	☐	
Fire Suppression System	☐	☒	☐	
Monitoring System	☐	☒	☐	
Control System	☐	☒	☐	
Security System	☐	☒	☐	
General Power and Lighting System	☐	☒	☐	
Lockout/Tagout Required?	☐	☒	☐	

Procedure Supporting Documentation

1. EBAY-SLC-UT-SOP-4.30.1.1-STARLINE BUS DISCONNECT INSTALLATION
2. National Electrical Code

Figure 16: Excerpt from SOP for an electrical connection procedure developed in-house, eliminating the possibility of connection failure to a server, and saves time / money

Operations Procedures in Support of Maintenance Activities

McKinstry has the following established maintenance support procedures:

- Documenting, editing, generating, and tracking AOPs, MOPs, EOPs, and SOPs;
- Web-based procedure numbering system for ease of access, identification and retrieval;
- Including photos and links within a MOP, EOP, SOP, and AOP to ensure the successful completion of the procedure.

Skills and Knowledge for Standardized Facilities Operations and Maintenance Procedures

Based on the site visits and interviews conducted, building technicians and other members of the facility O & M team at the eBay data center utilize the following knowledge, skills, and training in order to be successful in their roles:

- Comprehension of the expectation of 100% up-time and being an advocate for the building as a whole;
- Safety-mindedness in all activities;
- A desire to troubleshoot and fix things;
- Attention to detail to look for changes in operating conditions for different types of HVAC and electrical equipment;
- Communication with many different professionals, including security, IT, building occupants and contractors;
- Be self-directed, able to pre-plan and have the ability to make decisions, such as performing or requesting the scheduling of a maintenance procedure based on observations;
- Ability to read as-built drawings to ascertain design intent;
- Hands-on electrical / electronic experience;
- Hands-on mechanical / HVAC service experience;
- Mastery of intermediate computer skills, including the ability to navigate the BMS computer screens, completion and generation of maintenance performance forms;
- Be analytically-minded, questioning operational parameters and why changes have occurred, to look for patterns in data collected during maintenance procedures;
- Be a careful listener and observer, especially with regard to learning from more experienced technicians.

> "Attitude and personality are the biggest win-wins. It takes a very thorough individual who likes to be challenged on an hourly basis, sometimes by the minute…..and a good educational foundation."
>
> ADAM ENGLEBRIGHT, CFM
> Critical Facility Manager
> McKinstry

Although performing daily physical and virtual rounds is a task completed regularly within many operations and maintenance teams, the benefits of these tasks are significant. If they were not performed, abnormal equipment operating conditions may occur and go un-noticed. Over time, such conditions can lead to poor reliability of critical equipment, catastrophic failures or uncomfortable space conditions for building occupants.

eBay Best Practice #2: Communication and Documentation Procedures for Quality Control

The McKinstry facility team at the eBay Salt Lake City data center work three shifts per day with two shifts per week: Sunday – Wednesday is referred to as the "front half"; Wednesday – Saturday is referred to as the "back half". The "day" shift is 7 A.M. – 5:30 P.M. The "swing" shift is 11 A.M. – 9:30 P.M. The "graveyard" shift is 9 P.M. – 7:30 A.M.

Figure 17: Typical "Pass Down" meeting

Every Wednesday morning at 7 A.M., a "Pass Down" meeting is held where all CFEs are briefed on what has transpired during the "front half" shift for seamless transition to the "back half" shift.

Communication and documentation across the facilities team also provides opportunities to retain and increase tribal knowledge, resulting in higher quality performance. Quality assurance (QA) for the O & M functions is achieved on many levels through many activities, including:

- Standardized procedures and reporting, referenced in best practice #1 above, that go "up and down" the chain of command, between departments and company organizational structures for review and approval, including the abnormal incident report (AIR) which documents what happened and when, how the issue was found and resolved, the root cause and the subsequent issuance of a new or revised MOP, SOP, EOP or AOP;
- Monthly CFE procedure development, writing and review quota requirement;
- "Event" root cause analysis with team collaboration, "what if" reporting forms (AIR) and vendor analysis;
- Regular team meetings;
- McKinstry interface with IT personnel;
- CFE design review and comment process of the construction documents for the next phase of the data center build-out;
- QA inspections with an initialed and dated sticker applied by a licensed team member at the site of the work project;
- Color-coding wiring (red and blue) to identify the power source (A or B) to ensure the correct power source is accessed;
- Labeling at both ends of cables and of all equipment.

Figure 18: QA procedure verification and sign-off by team member

Skills and Knowledge for Communication and Documentation Procedures for Quality Control

Based on the site visits and interviews conducted, building technicians and other members of the facility O & M team at the eBay data center utilize the following knowledge, skills, and abilities in addition to those identified in best practice #1 above:

- Ability to organize and lead a meeting;
- Veteran CFE leading the shadowing of a new-hire;

eBay Best Practice #3: Energy Monitoring and Sustainability

McKinstry is developing a three-year energy efficiency plan for eBay. The focus is on water, carbon, electricity, natural gas and solar with a goal of carbon emissions reductions.

Toward reaching these goals, McKinstry monitors the energy consumption data provided, tracks the PUE, WUE, and CUE metrics, and logs consumption data toward ENERGY STAR certification.

Figure 19: Server rack aisle power monitoring

On-going, proposed modifications to systems to increase energy efficiency include:

- Adding / modifying pump and fan VFDs;
- Adjusting space temperatures;
- Adjusting chilled water temperatures;
- Calculating the CFM needed in the server cold aisles for relocating the perforated raised floor sections to efficiently handle the cooling load;
- Adding a separate HVAC unit for the office areas so that one of the 1300 ton chiller systems does not need to operate for it.

Utility company incentives have been used extensively for previous energy-saving modifications.

The efficiency of the Salt Lake City facility has been progressively improving. The current PUE is 1.5 with a goal of 1.2.

Figure 20: PUE tracking

Skills and Knowledge for Energy Monitoring

Based on the site visits and interviews conducted, building technicians and other members of the facility O & M team at the eBay data center utilize the following knowledge, skills, and abilities in order to be successful in their role in energy monitoring for the sustainability program:

- Have a mind-set for efficiency and sustainability, and embrace these concepts;
- Understand measurement metrics;
- Push the envelope to propose concepts to optimize HVAC, electrical and IT systems;
- Ability to develop concepts and solutions to address the requirements and goals of programs such as LEED and ENERGY STAR;
- Quantitative skills, such as the ability to use software programs for energy consumption monitoring, use spreadsheets to analyze data and the ability to develop and compare solutions;
- Understanding of HVAC and electrical systems and all associated BMS;
- Understand data center capabilities and density –vs. – power as they relate to HVAC consumption and efficiencies (e.g., kW – vs. - CFM).

Energy and building operations related certification programs applicable for a data center CFE include Certified Energy Manager (CEM) through the Association of Energy Engineers (online courses), and Building Operators Certification (BOC) levels 1 and 2 (offered through many community colleges).

Best Practice #4: Training and Continuous Improvement Program

The local Salt Lake City area talent pool has been a driving force in shaping the robust training program McKinstry has in place at this data center.

The first stage of new employee training is through McKinstry's online technical program and vendor-provided videos. Vendors have the responsibility for training on the equipment that they do not maintain themselves. A competency test is administered at completion.

"During commissioning, vendors videotaped all their training. The first week as a CFE will be spent watching these videos."

DAVID HILL, CFE-3 LEAD
Critical Facility Engineer Lead
McKinstry

These skills are then built upon with "on the job training" (OJT) for the specialized equipment in the data center. New hires "shadow" a veteran for 2 – 3 months, depending on competency and performance.

McKinstry cross-trains their CFEs so they are not siloed in their functions; they "pair" mechanical and electrical technicians. The expectation is that "everyone has to be able to do it all." The exception to this is with electrical work, which is done by CFEs who are licensed electricians. This in-house work performance is estimated to have saved eBay $300,000.

"We don't want to silo people. We build out peoples' strengths. We want people to see the big picture, to understand the full site impact of events; provide high level training then drill down from there."

CHRIS DAWES, ACFM
Assistant Critical Facility Manager
McKinstry

The need to retain and increase team "tribal knowledge" was noted as being important; this is supported through the PM / MOP reporting system and increased employee retention. "Tribal knowledge" is the collective institutional knowledge; for a facilities team, this consists of the vast store of knowledge in the minds of the CFEs and facility managers that enables them to effectively operate their buildings. Retaining and increasing this knowledge is a strategy for supporting employee retention and growth by providing opportunities for them to continue learning, and the resources to properly carry out the duties of their jobs.

The expertise of a Professional Engineer (PE) is not an on-site data center requirement since McKinstry has access to that off-site as needed.

Data center specific certification programs offered through community colleges, and specialized continuing education were discussed and viewed as valuable for the data center facility operations and maintenance profession.

Skills and Knowledge in the Training Program

Based on the site visits and interviews conducted, in addition to those identified previously, some of the important skill sets sought in new-hires include:

- Hands-on HVAC service experience including CFC certification;
- Community college 2-year technical degree;
- Union training;
- Appetite for learning;
- Intuitive trouble-shooting ability;
- Willingness to take on new challenges;
- Having a team player attitude;
- BMS system expertise;
- Electrical journeyman or master electrician;
- Previous project experience. Some of the top technicians moved from the building construction team to operations..

"MOPS force us to think twice, think through what our actions are going to do to the system - it forces us to pre-plan."

ADAM ENGLEBRIGHT, CFM
Critical Facility Manager
McKinstry

A look to the future

Phase 2: New Tier 2 Data Center in 2013

eBay has phase 2 plans for a new Tier 2 modular, "container" data center build-out on this same site that will draw its primary power source from alternative energy fuel cells.

These natural gas fuel cells are a substantially cleaner and more efficient source of energy than coal, enhancing eBay's CUE metric.

Figure 21: Future fuel cells

The fuel cell manufacturer will be responsible for the maintenance of the fuel cells, but McKinstry will be the first responder to any emergencies. For this, training on this technology and system will be developed. Energy and carbon savings tracking from the fuel cells will be an additional task within the energy monitoring and sustainability data capture function.

Future Efficiency and Improvements

McKinstry has plans to go "paper-less" through the CFE's use of iPads. Each piece of HVAC equipment has a bar code which is intended to be scanned and electronically "pull up" PM and MOPs history and procedure information.

The use of iPads will require proficiency with that device.

Figure 22: HVAC unit bar code

The desire to have the MOPS system tie into the company supply chain division was expressed as being valuable and a future consideration. For this, the CFEs will need supply chain process understanding and department interface.

A strong recommendation is for McKinstry to obtain complete as-built documentation for the entire data center, including the evolution of changes that have been made over the past 2.5 years.

Conclusion

As McKinstry and eBay as a team strive to be leaders in data center management, energy efficiency and sustainability, the best practices described above, combined with good communication, are a key part of achieving this goal.

As the eyes, ears, and hands of the facilities and operations team, CFEs play a critical role in the application and ongoing improvement of such best practices. The practices featured in this case study are summarized in the table that follows, where the skills and knowledge attributes associated with each best practice are listed. It is the intent and hope of this work that other facilities management and operations teams will benefit from the combined experience of eBay and McKinstry, that educational institutions will incorporate the needs of these skills and knowledge attributes in their programs, and that the technicians themselves will strive to develop the

necessary skills and knowledge as they work toward a future of sustainable and high performance buildings.

Acknowledgements

Thanks to Greg Fennewald, Sr. Manager, Global Data Center Services, eBay, and the McKinstry team at the eBay Salt Lake City data center, including Adam Englebright, CFM, Critical Facilities Manager; Scott Harris, Operations / Energy Manager, National Critical Environments Team; Chris Dawes, ACFM; David Hill, CFE Lead; David Castro, CFE-2.

Resources

USGBC LEED EB

http://www.usgbc.org/DisplayPage.aspx?CMSPageID=221

ENERGY STAR

http://www.energystar.gov/index.cfm?c=business.bus_index

Uptime Institute

http://uptimeinstitute.com/

McKinstry

www.mckinstry.com/

EBAY

www.ebayinc.com

Association of Energy Engineers

http://www.aeecenter.org

Building Operator Certification

http://www.theboc.info

Table 1: Summary of best practices

Best Practice		Skills and Knowledge Attributes Identified in this Study that Apply to Technicians and other Key Facilities Personnel
1	**Standardized Facilities Operations and Maintenance Procedures**	Comprehension of the expectation of 100% up-time and being an advocate for the building as a whole
		Safety-mindedness in all activities
		A desire to troubleshoot and fix things
		Attention to detail to look for changes in operating conditions for different types of HVAC and electrical equipment
		Communication with many different professionals, knowing the respective jargon, including security, building occupants and contractors
		Be self-directed yet pre-plan and have the ability to make decisions, such as performing or requesting the scheduling of a maintenance procedure based on observations
		Ability to read as-built drawings to ascertain design intent
		Hands-on electrical / electronic experience
		Hands-on mechanical / HVAC service experience
		Mastery of intermediate computer skills, including the ability to navigate BMS computer screens, completion and generation of maintenance performance forms
		Be analytically-minded, questioning operational parameters and why changes have occurred, to look for patterns in data collected during maintenance procedures
		Careful listening and observation, especially with regard to learning from more experienced technicians
2	**Communication and Documentation Procedures for Quality Control**	Comprehension of the expectation of 100% up-time
		Safety-mindedness in all activities
		A desire to troubleshoot and fix things
		Attention to detail to look for changes in operating conditions for different types of HVAC and electrical equipment
		Ability to organize and lead a meeting
		Communication with many different professionals, knowing the respective jargon, including security, building occupants and contractors
		Be self-directed and pre-plan activities
		Ability to read as-built drawings to ascertain design intent
		Mastery of intermediate computer skills, including completion and generation of maintenance performance forms
		Be analytically-minded, questioning operational parameters and why changes have occurred, to look for patterns in data collected during maintenance procedures
		New-hire shadowing a veteran CFE
		Be a licensed electrician

Best Practice		Skills and Knowledge Attributes Identified in this Study that Apply to Technicians and other Key Facilities Personnel
3	**Energy Monitoring and Sustainability**	Have a mind-set for efficiency and sustainability, and embrace these concepts
		Understand measurement metrics
		Push the envelope to propose concepts to optimize HVAC, electrical and IT systems
		Ability to develop concepts and solutions to address the requirements and goals of programs such as LEED and ENERGY STAR
		Quantitative skills, such as the ability to use software programs for energy consumption monitoring, use spreadsheets to analyze data and the ability to develop and compare solutions
		Understanding of HVAC and electrical systems and all associated BMS
		Understand data center capabilities and density –vs. – power as they relate to HVAC consumption and efficiencies (e.g., kW – vs. - CFM)
4	**Training and Continuous Improvement Program**	Hands-on electrical / electronic experience
		Hands-on HVAC service experience
		Community college 2-year technical degree
		Union training
		Electrical journeyman or licensed master electrician. Some were on-site during the original construction of the building. This combination has been found to be extremely desirable
		Appetite for learning
		Intuitive trouble-shooting ability
		Willingness to take on new challenges
		Having a team player attitude
		Building management systems expertise

Abbreviations

ACFM	Assistant critical facilities manager
AIR	Abnormal incident report
AOP	Administrative operations procedure
BMS	Building management system
CFE	Critical facilities engineer
CFE-1, 2, 3	Critical facilities engineer, level 1, level 2, level 3
CFM	Critical facilities manager
CMMS	Computerized maintenance management system program
CRAH	Computer room air handling unit
CUE	Carbon utilization effectiveness
DOE	U.S. Department of Energy
EOP	Emergency operations procedure
EPA	Environmental Protection Agency
HVAC	Heating, ventilation, and air conditioning
IT	Information technology
KPI	Key performance indicator
Lead	CFE-3 with management responsibilities
LEED	Leadership in Energy and Environmental Design
LOTO	Lock-out / tag-out
MOP	Method of operation procedure
O & M	Operations & maintenance
OJT	On the job training
PDU	Power distribution unit
PLC	Programmable logic controller
PM	Preventative maintenance
POP	Point of presence (connection point to the internet)
PUE	Power utilization effectiveness
PV	Photovoltaic
SF	Square feet
TCO	Total cost of ownership
UPS	Uninterruptible power supply
VAV	Variable air volume
WUE	Water utilization effectiveness