Fred Hutchinson Cancer Research Center

Study of Facility Management and Operations Best Practices

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

National Science Foundation
Advanced Technological Education Program
Award #0802595

This material is based upon work supported by the National Science Foundation under Grant No. 0802595. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Rev D 2012-04-26

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Introduction

This case study is one of several studies conducted on facilities that demonstrate excellence in building operations, maintenance, and management. The study was commissioned by Laney College's Environmental Control Technician Program, 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. Best practices 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.

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 research 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.

Best practices featured in this case study include:

1. Design for the life cycle
2. Understand the building's mission
3. Apply an energy philosophy
4. Retain and increase tribal knowledge
5. Always have a contingency plan for system and equipment failure

Facility Overview

The Fred Hutchinson Cancer Research Center (FHCRC) is located in Seattle, Washington. Since the facility opened in 1975, the mission of FHCRC has been to eliminate cancer and related diseases as causes of human suffering and death. Some of the medical advances that were shaped by the work of the Fred Hutchinson Cancer Research Center include the development of a bone marrow transplant as a cure for leukemia, development of a method for early cancer detection and new methods to identify the locations of brain tumors. FHCRC is funded through private donations and research grants.

Background

Buildings and Systems

The urban campus has 13 buildings across a 14 acre site. The 1.4 million square feet encompasses primarily high tech research and patient treatment space, as well as a 225,000 square foot Seattle Cancer Care Alliance facility. Although the temperate climate of Seattle may not require as much heating, cooling, humidification or dehumidification as other parts of the United States, the facility has a large population of HVAC and refrigeration systems across the campus, many of which operate 24 hours a day, seven days per week. These systems include:

- More than 57 air handling units, many of which are double stacked to reduce the amount of required floor space
- Chiller and boiler plants in many buildings
- Nine cooling towers

Substantial backup power resources include:

- 6.8 megawatts of emergency power
- 175 uninterruptible power supplies

In addition to the typical mechanical and electrical systems found in most buildings, many specialized systems at FHCRC support laboratories and patient care, such as:

- 900 freezers that store research specimens
- 42 ice machines
- 32 different water systems, such as the deionized water system (Figure 3)
- Multiple clean rooms

Laboratory facilities differ from most other buildings in some important ways. With a significant portion of the campus' floor space composed of laboratories, unique considerations can be contrasted with office buildings.

- Difference in priorities. Within a lab, the priorities, in order of most to least important are:
  1. Room pressurization
  2. Sufficient air change rates
  3. Temperature control
  4. Occupant comfort

  In contrast to lab space, in an office environment comfort is generally the top priority and temperature is adjusted as needed. Pressurization and air change rates are given much less consideration. Within buildings where occupants and facility management teams are concerned with indoor air quality, air change rates are considered through the volume of fresh air brought into a space. Building pressurization is of least concern, and generally only addressed when significant problems occur, such as when the doors of a building are difficult to open or close as a result of pressurization problems.
- Higher air change rates. Relative to office buildings, higher volumes of air pass through the filters. Coupled with 24 hour a day, seven day a week operation, the greater air flow volume requires that filters be changed more often.
- More stringent oversight. The Joint Commission on Accreditation of Healthcare Organizations (JACO) has stringent requirements for the operation of healthcare facilities, such as when it is necessary to perform maintenance within a suspended ceiling.
- Precise monitoring and control of space conditions. Space temperature, relative humidity and pressurization must be closely monitored.
- Redundancy. Since FHCRC houses many laboratory experiments and laboratory animals, system redundancy is very important. Unlike an office area, where people can go home if the conditions in the building become intolerable,

lab animals do not have another place to go. Also for to support redundancy, emergency power is critical for laboratory equipment. For example, when the power goes down, equipment restarts. This can adversely impact experiments. In an office building, a short disruption in power will have less of an impact.

These differences offer a variety of challenges to the facility managers, operators and technicians responsible for keeping FHCRC's facilities in top working order.

Facility Staff

Forty-five personnel working eight-hour shifts provide facility management, operations and maintenance services for the campus.

Figure 1: FHCRC Facilities Engineering team

To operate and maintain the equipment, in addition to HVAC, electrical and plumbing technicians, FHCRC also has specialized refrigeration technicians to maintain the freezers, ice machines and other refrigeration systems.

An analysis performed by Tradeline finds that staffing levels at FHCRC are lower than other similar facilities. FHCRC has 32 fewer full-time employees than facilities of similar size and mission complexity (Cowan 2011).

Best Practices

Best Practice #1: Design for the Life Cycle

A building is often built to last 50 to 100 years. Therefore, it is important that the operations and maintenance of the building be considered during design. However, such thinking is not generally part of current standard practice.

To make sure that the buildings built on the FHCRC campus are designed and engineered for the life cycle, several strategies have been put in place:

1. Active involvement of the facilities team in the design and construction process.
2. Application of a design standard.
3. Participation in design reviews.
4. Involvement in value engineering.
5. Use of a commissioning process.

Each of these strategies is addressed in further detail in the sections that follow.

Active Involvement in Design and Construction

Design and construction decisions can have a large impact on how a building is used, operated and maintained. Facilities team involvement encourages and supports careful and thoughtful consideration of how design and construction decisions will impact operations and maintenance. Such involvement also allows lessons learned from past and current systems and their operation to be passed forward to the design team. Getting involved as early as possible, during schematic design or even as the basis of design is first written, provides the greatest opportunity for the facilities team to influence the design. Involving both facility managers and technicians can help to get the design and construction teams thinking about long term needs of the facilities team before major aspects of the design are determined. This is important because as projects progress; it becomes increasingly more difficult and costly to make changes. Therefore, by making needs known early, it is possible to advocate for the resources needed. Although some designers will resist involving the facilities management team during design, due to the false perception that it will make the designer's job more difficult, facilities teams should advocate for and seek such involvement.

What exactly does it mean to be actively involved in the design and construction process? In general, it consists of partnership and collaboration with the design team, where specific activities may include sharing requirements, participating in design reviews, and collaborating on solutions, options and alternatives. In other words, the general strategy of involvement is central to the best practice of life cycle design, and it is carried forward in specific ways by the remaining four strategies.

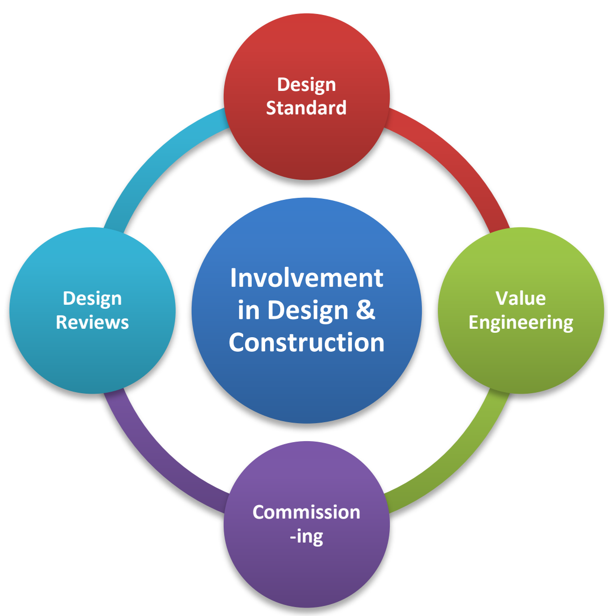

Figure 2: Involvement strategies

Application of a Design Standard

Explicitly stating and documenting operations and maintenance requirements provides the design team with a basis for specifications, and a set of criteria against which to judge design options and alternatives. To help convey design requirements, the FHCRC facilities team maintains and provides a design manual for mechanical and electrical systems. The intent of the design manual is to provide project guidance, starting with the basis of design. Having a design manual provides a standard set of criteria for the type and quality of systems required. This can be very helpful when trying to justify value during a value engineering exercise. The design manual includes a list of 200 items that are to be incorporated in design. In other words, this is FHCRC's vehicle for documenting and sharing requirements.

As a design project starts, if the design team is not familiar with the design manual, the facilities team works with the design team to help them understand the value of the manual. At FHCRC, the facilities team typically works with a small set of engineering design firms, which helps because many of the team members are familiar with the manual from previous projects. In any case, as the facilities team owns the design manual, part of the role of the facilities team is to hold the design team accountable to the requirements and guidance provided by the manual.

"Providing details to the design team comes with a lot of responsibility. To provide details requires an understanding of what systems are needed and why." Mark Hungerford, Lead Electrician

Requesting specific vendor products is one strategy that is often helpful for communicating between design engineers and facility management team members.

Examples of design requirements proactively provided by FHCRC's facilities team include:

- Application of variable volume, variable pressure systems.
- Use of interstitial space.

The use of variable volume, variable pressure systems allow the static pressure to be reduced after the building is in operation. Sometimes, during design, the fans may be sized or designed to be controlled at a higher power than what is required to overcome the calculated static pressure in the ducts. However, after the building is in operation, it is possible to know the actual static pressure characteristics of the systems and operating conditions can be changed to reduce static pressure, reducing energy consumption.

400,000 square feet of interstitial space is hidden amongst the laboratories at FHCRC. Interstitial space is fully accessible walk-through space above a ceiling or beneath a floor that is used only for mechanical and electrical equipment. There are many benefits to interstitial space applied in this manner.

First, interstitial space allows equipment to be located with sufficient clearance for maintenance. Second, interstitial space makes it possible for most maintenance to be performed outside of lab space. This reduces the time required to perform maintenance because it is not necessary to cover or remove lab equipment from the space, and it minimizes disturbances to the researchers. Additionally, technicians can work at ground level instead of on ladders, making the task safer to perform.

Third, interstitial space reduces operations costs. Long straight runs of duct and pipe are possible because dedicated space is provided for HVAC systems. This helps to reduce operations costs as fewer bends in duct work lower the system pressure drop. A lower pressure drop allows smaller fans and pumps to be used, reducing energy consumption.

Finally, as the function of labs can change overtime, wood inserts installed in sections of the floor of the interstitial space increase accessibility. The insert can easily be moved to make a change to a system, compared to drilling a hole in the concrete.

Figure 3: Straight duct and pipe runs within interstitial space

Figure 4: Wood insert within floor of interstitial space

While the benefits of interstitial space can be measured in reduced maintenance time and cost, and minimized disturbance to labs and researchers, the cost of locating interstitial space in a lab building does not necessarily increase the capital cost. Some of the reasons why include:

- Mechanical, electrical and plumbing systems are installed simultaneously while other contractors install drywall, flooring and complete other architectural aspects of construction.
- Installing long straight runs of duct and pipe takes less time than duct and pipe that requires many bends.

- HVAC and electrical systems can be placed in the interstitial space, instead of on occupied levels, preventing mechanical systems from occupying space that can be used for labs and offices.

Participation in Design Reviews

The next strategy in the pursuit of involvement consists of reviewing design drawings and documentation, and providing feedback to the design team. Examples of items to check for when reviewing drawings from a life cycle perspective include the following:

- Is space provided to store necessary supplies, such as filters?
- How is the building zoned? When lights or HVAC are turned on or off, can just one zone be turned on or off? Or, is an entire floor one zone?
- Has proper clearance been provided around equipment to allow access during maintenance and replacement?
- What is the work flow during maintenance? For example, if a motor control center is located on a floor, are the motors it controls on the same floor?
- Do control drawings include points lists and sequences of operation? And, do the sequences make sense? Are points and sequences properly coordinated with equipment?

During the design review process, it is important to know that the timelines for review do not always fit the schedules of the facility management team well, and that the review periods are generally short. Therefore, it is important for those reviewing the design to be able to prioritize how to meet other demands while providing the level of design review that is required.

When the question, "How many building engineers does it take to change a light bulb?" came up during design of a new facility at FHCRC, the answer was, "It depends where the light bulb is located." During one of the design reviews, the facilities team determined that some lights in a prominent public space were to be located where it would be nearly impossible to bring in a ladder to change the light bulbs. Working with the architects, the facilities team was able to relocate the lights to a very accessible, yet still visually acceptable, location at each landing on the staircase (Figure x-4).

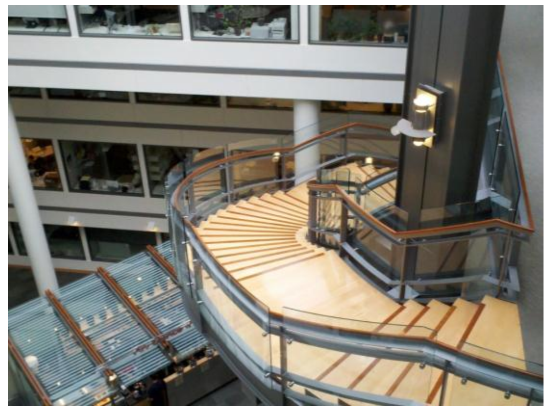

Figure 5: Lights located at easily accessible locations

> **"If you don't design it right, then you're in trouble. If it's not installed correctly, it can be done over. Start up and commissioning can be done over until it is perfect. Operating and maintaining the gear can be done wrong, and that can be corrected before it is too late. Of all of them, designing is most important, because that's the hardest to go back and rectify and it affects everything that comes after it." Mark Hungerford, Lead Electrician**

Value Engineering

As the design team looks at options and potential solutions to design challenges, an involved operations and maintenance team can weigh in with trade-offs and feedback from their perspective, and provide input on key design decisions.

Don't allow key features to be value engineered out of the design.

This becomes very important in value engineering, a process of evaluating all of the elements of a construction project to reduce the overall cost. The value engineering process is most often lead by the building owner's planner. The planner typically has a general knowledge of buildings, but not specific knowledge of building systems. So he or she may not understand the value of various design aspects of mechanical and electrical systems.   The goal of the planner is to reduce the cost of the project to meet the project budget.

Thus, it is possible in some cases that the resolution to a problem addressed through value engineering results in a different problem for operations and maintenance down the road. While it is possible to perform life cycle cost analysis to justify the need for more efficient systems and/or redundancy, it can take a lot of time. This is where experienced building operators and facility management professionals can help as they often can weigh in on which value engineering strategies are more or less likely to be successful.

"Once you have a great design, fight to keep it" – Jim Walker, Facilities Engineer

"I know what the after-install problems can be. And I know what it's like to advocate for a certain thing and be told it's too expensive, or to work to educate designers on why we really need a piece of equipment or a method of installation." Mark Hungerford, Lead Electrician

Commissioning

Commissioning is essentially a quality assurance process. Ideally, it begins during design and continues through construction, occupancy, and operations. However, for many buildings, commissioning it is more typically employed in the final stages of construction as the building transitions to operation. In any case, commissioning is intended to ensure that the new building operates initially as the owner intended, and that building staff are prepared to operate and maintain its systems and equipment.

Commissioning may be performed by a commissioning agent or by a contractor. Ideally, the party responsible for commissioning is not also responsible for construction or implementation; thus providing some check and balance without potential for conflict of interest. Depending on the arrangement, it can be challenging for the goals of the commissioning agent and the facilities team to be aligned.

From the facilities team's perspective, commissioning should not be completed during construction – it should be completed after construction is complete. When commissioning is scheduled during construction, it is not possible to fully test systems because they may not be completely installed or operational. At the same time, commissioning should not be completed during occupancy because systems cannot be fully tested when building occupants are in the building. Therefore, the facilities team must work very carefully to try to balance conflicting timelines, while also acknowledging that construction projects generally run behind schedule.

Commissioning also affords the opportunity to be sure that all building systems are tested during the warranty period. If equipment is not tested and problems occur soon after the warranty period has expired, the facilities team becomes responsible for the repairs. Catching problems during the warranty period can save money. Neither design nor operations budgets are unlimited. However, design and construction challenges that are not resolved before the building is open become problems that need to be resolved using operations resources. In other words, the problem does not just go away, but it is shifted to be resolved with different funds, sometimes adversely affecting energy efficiency or occupant comfort.

Skills and Knowledge for Designing for the Life Cycle

Based on the site visits and interviews conducted, building technicians and other members of the facilities team at FHCRC utilize the following knowledge, skills, and abilities as part of designing for the life cycle:

- General knowledge of and experience with the design and construction process is essential.
- Be diligent and detail oriented. It is important to keep track of requests made to the design team and make sure they are included as part of the design or agreement about why the request cannot be made has been reached.
- Be able to prioritize. It is important to determine what needs are most important and what needs may not be as critical.
- Teamwork. Work as a team to make decisions and compromise when necessary.
- Working with design and construction documentation: Knowing how to read drawings, what should be included in a drawing set, and understanding specification language are key skills.
- Systems knowledge. Have extensive knowledge of mechanical, especially HVAC, and electrical systems.

Successfully designing for the life cycle requires the involvement of the facilities team. Involving the facilities team early in the project can:

- Reduce operations and maintenance costs by increasing accessibility and catching problems before they are part of the building.
- Increase safety of technicians servicing systems and equipment.
- Help to minimize energy consumption and cost.

Best Practice #2: Understand the Building's Mission and Use

Understanding a building's primary purpose and how it is used is an essential part of its management, operation and maintenance. But, when a building is designed, it is not possible to know exactly how it will be used, and its usage may change over its life. At FHCRC, this plays out in a variety of ways, three of which are discussed here:

- Support the core mission
- Sizing and resizing of equipment
- Occupant education and user guides

Support the Core Mission

Building systems can support or detract from a facility's core mission. In design, it is not always possible to foresee how well the systems will support the mission, or if they will present challenges or obstacles. An example from FHCRC of how a system stood on the way of the building's purpose involved lighting controls. In this case, it was discovered that the frequency of the motion sensors used to turn the lights on and off was preventing trans-genic (multi-generational) mice from breeding. After an analysis was performed by an ultrasound expert, it was determined that the ultrasonic signal transmitted by the motion sensors was preventing the mice from breeding. While humans hear noise up to frequencies of about 20 kHz, the mice hear up to frequencies of 90 kHz. After removing the motion sensors within that area of the building, the mice started to breed. Although the motion sensors had to be removed, the space could now be used for its intended function. But, it took some understanding of the space's purpose combined with a particular control technology to resolve the issue.

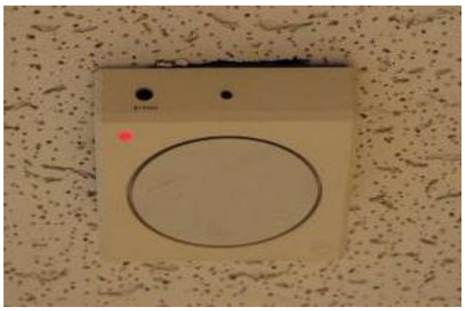

Figure 6: Motion sensor to turn lights on/off

Sizing and Resizing of Equipment

In building design, systems are generally oversized because a safety factor is used to account for unknown conditions during building operation. After a building has been in operation for a period of time, set points, building schedules, fan speeds and other operational parameters can be adjusted to optimize energy efficiency. Additionally, at equipment end of life, performance data can be used to determine if a given piece of equipment should be replaced with one of the same size, or if its size can be adjusted, and in many cases, downsized. For example, at FHCRC, using water meter data it was possible to determine that an 80 gallon per minute water heater was oversized, and that its replacement needed only to be a 16 gallon per minute unit.

For large systems, replacing oversized equipment may be economical even before equipment has reached its end life. Again, using water meter data at FHCRC, it was possible to determine that a 300 gallon water heater could be replaced with two 100 gallon water heaters. Using two smaller tanks reduced the amount of stored water that needed to be kept at the required temperature when the hot water demand was low. An economic analysis was used to determine if equipment could be economically replaced before its end of life.

> **"Once you know the building you do not need a safety factor" – Bob Cowan, Director of Facilities Engineering**

Occupant Education and User Guides

Along with understanding the building's usage, it is important to understand the building's users. Educating and working with occupants can positively impact the building's operation.

For instance, during occupancy it is important to determine if occupancy sensors are being used correctly and not being overridden. One proactive strategy FHCRC uses to help occupants understand the workings of the buildings they use is by providing training about how the building works when a new building opens. During the training, occupants receive a building user guide. The user guide provides key information about the heating and cooling systems and lighting controls. Specific instructions are provided about how to override the heating and cooling system during unoccupied hours. Occupants must understand that when they override the system, the system turns on the occupied zone for a specified period of time. After the time period elapses, the system shuts off unless the occupant overrides the system again.

Skills and Knowledge for Understanding the Building's Mission and Use

Based on the site visits and interviews conducted, technicians and other key facilities personnel at FHCRC utilize the following knowledge, skills, and abilities to support the buildings intended function:

- Root cause analysis. Be able to understand a problem and dig for potential root causes.
- Recognize when specialized skills or knowledge is needed. As in the case of the ultrasonic sensors, a specialist was brought in to confirm the problem's root cause.
- Communicate effectively with occupants. This includes the writing of user guides, providing training, and soliciting constructive feedback.

Adapting the building over its life to support the mission while meeting operating and energy efficiency goals requires additional skills and knowledge:

- Read drawings and equipment schedules.
- Collect and analyze data from meters and sensors to determine actual operating conditions.
- Compare operating conditions against design.

Best Practice #3: Apply an Energy Philosophy

At FHCRC, the facilities team abides by an energy philosophy: *Deliver the right amount of energy, deliver the energy just in time and deliver the energy as efficiently as possible.* Providing the right amount of energy includes:

- Maintaining accurate space temperature control to meet the occupant needs.
- Providing the correct number of air changes.
- Maintaining proper space pressurization.
- Providing appropriate ventilation (or outside air).

Delivering the energy just in time means delivering when the energy is needed: during occupancy. Building schedules within the building automation system are set to adjust temperature set points, space pressurization and outdoor air volumes accordingly. Occupancy sensors are used to control lighting. Finally, delivering the energy as efficiently as possible means that adjustments are made to fan speeds and damper positions to reduce duct static pressure and air change rates are set to meet but not exceed space requirements. One hundred percent outdoor air may be needed during occupancy, but when spaces are unoccupied, in many cases, less outdoor air can be provided, reducing energy consumption.

FHCRC energy philosophy:

- **Deliver the right amount of energy**
- **Deliver the energy just in time**
- **Deliver the energy as efficiently as possible**

Examining the impact of such a philosophy over the long term, between 1999 and 2009, FHCRC implemented 114 energy conservation projects to reduce electricity consumption. The total cost of these projects was $4.4 million dollars, resulting in about a four year simple payback with rebates and incentives. Some of the energy conservation measures implemented included temperature setbacks during unoccupied periods, replacement of existing motors with high efficiency motors, installation of variable speed drives on motors, replacement of existing chillers with high efficiency chillers and utilization of occupancy sensors and high efficiency lighting. Over the same time period, 17 projects to reduce natural gas consumption were completed. The cost of these projects was $230,791, resulting in an eight month simple payback with incentives and rebates, and yielding an annual savings of $383,000. Furthermore, the natural gas conservation projects reduced the number of operating hours for some equipment, thus reducing the maintenance required for natural gas consuming equipment.

FHCRC extends the energy philosophy to a continuous improvement cycle to identify energy conservation opportunities. An energy manager, engineer, or senior technician leads the process which consists of the following steps:

1. Collect ideas
    a. From all members of the facilities team.
    b. From other facilities by touring other buildings and gathering ideas from industry conferences and meetings.
2. Review ideas collected to determine what is feasible.
3. Develop a plan to implement feasible ideas.
4. Implement the plan.
5. Measure the savings to determine if the goals have been met.

Utilization of this process makes the energy philosophy a reality, and supports development of a culture of energy efficiency. Therefore, energy conservation efforts are continuously being considered and performed. Graphs of energy consumption are examined weekly to find building scheduling problems, equipment cycling or simultaneous heating and cooling problems. Seattle Meter Watch, a real-time utility metering software tool, is used. Technicians play a critical role in this process as they help to correlate energy data with what is really going on in the building operationally. In one case, by looking at the weekly graphs for one building, it was possible to determine that a new security guard was using the wrong override command when the janitors needed access to a space. Since the janitors were only in the space for a short time, it was only necessary to turn on the lights. However, unknowingly, the security guard was using the override that turned on the lights and the HVAC. By explaining the different functions of the override commands, the reason for the increase in energy consumption was eliminated.

Another case involves scheduling. During design, the schedule for a building is determined based on design assumptions and estimates provided from the building owner's team. However, after the building is in operation, it is possible to know what the actual schedule is and to make adjustments. For instance, an elevator survey was completed in-house to determine if the building schedules aligned with actual occupancy. The number of elevator calls and time of the trips was recorded and analyzed, as shown in Figure 8. The frequency of calls was the most important data for the analysis. Figure 9 shows the largest variation in energy use for the building is before the schedule changes (green line) and after the schedule changes (blue line) was during periods of low occupancy, before 6AM and after 6PM.

UP/DN CALL SUMMARY — 15 MINUTE INTERVALS
Start Time 10/30/2008 3:48:30PM
Stop Time 10/30/2008 9:03:30PM

	Time In Seconds								
Time Slot	< 15	< 30	< 45	< 60	< 120	120 +	Longest	Avg Wait	Total Calls
Dn 10/30/2008 3:48:30PM	4	0	0	0	0	0	10	6.8	4
Up 10/30/2008 3:48:30PM	1	1	0	0	0	0	21	10.5	2
Dn 10/30/2008 4:03:30PM	1	1	0	0	0	0	18	12.0	2
Up 10/30/2008 4:03:30PM	1	0	0	0	0	0	0	0.0	1
Dn 10/30/2008 4:18:30PM	2	2	0	0	0	0	24	11.5	4
Up 10/30/2008 4:18:30PM	3	0	0	0	0	0	5	1.7	3
Dn 10/30/2008 4:33:30PM	3	1	1	0	0	0	34	15.6	5
Up 10/30/2008 4:33:30PM	2	0	0	0	0	0	12	8.5	2
Dn 10/30/2008 4:48:30PM	4	5	0	1	2	0	69	25.6	12
Up 10/30/2008 4:48:30PM	2	1	0	0	2	0	105	43.6	5
Dn 10/30/2008 5:03:30PM	5	3	1	0	0	0	33	15.4	9
Up 10/30/2008 5:03:30PM	1	0	0	1	0	0	47	23.5	2
Dn 10/30/2008 5:18:30PM	3	2	0	0	0	0	21	9.4	5
Up 10/30/2008 5:18:30PM	1	0	0	0	0	0	0	0.0	1
Dn 10/30/2008 5:33:30PM	3	4	0	0	1	0	60	19.4	8
Up 10/30/2008 5:33:30PM	3	0	0	0	0	0	13	6.7	3
Dn 10/30/2008 5:48:30PM	0	2	0	0	0	0	16	16.0	2
Up 10/30/2008 5:48:30PM	0	0	0	0	0	0	0	0.0	0
Dn 10/30/2008 6:03:30PM	2	1	1	0	0	0	39	18.0	4
Up 10/30/2008 6:03:30PM	1	0	1	0	0	0	32	19.0	2
Dn 10/30/2008 6:18:30PM	0	1	0	0	0	0	15	15.0	1
Up 10/30/2008 6:18:30PM	0	0	0	0	0	0	0	0.0	0
Dn 10/30/2008 6:33:30PM	1	1	0	0	0	0	15	7.5	2
Up 10/30/2008 6:33:30PM	2	0	0	0	0	0	8	7.5	2
Dn 10/30/2008 6:48:30PM	1	0	0	0	0	0	10	10.0	1
Up 10/30/2008 6:48:30PM	0	0	0	0	0	0	0	0.0	0
Dn 10/30/2008 7:03:30PM	3	1	0	0	0	0	21	10.0	4
Up 10/30/2008 7:03:30PM	0	0	0	0	0	0	0	0.0	0
Dn 10/30/2008 7:18:30PM	0	1	0	0	0	0	16	16.0	1
Up 10/30/2008 7:18:30PM	1	0	0	0	0	0	6	6.0	1
Dn 10/30/2008 7:33:30PM	2	1	0	0	0	0	16	10.7	3
Up 10/30/2008 7:33:30PM	0	0	0	0	0	0	0	0.0	0
Dn 10/30/2008 7:48:30PM	0	0	0	0	0	0	0	0.0	0
Up 10/30/2008 7:48:30PM	0	0	0	0	0	0	0	0.0	0
Dn 10/30/2008 8:03:30PM	0	1	0	0	0	0	16	16.0	1
Up 10/30/2008 8:03:30PM	0	0	0	1	0	0	54	54.0	1
Dn 10/30/2008 8:18:30PM	3	0	0	0	0	0	11	5.7	3
Up 10/30/2008 8:18:30PM	1	0	0	0	0	0	6	6.0	1
Dn 10/30/2008 8:33:30PM	1	0	0	0	0	0	1	1.0	1
Up 10/30/2008 8:33:30PM	0	0	0	0	0	0	0	0.0	0
Up 10/30/2008 8:48:30PM	2	0	0	0	0	0	6	5.5	2
Dn 10/30/2008 8:48:30PM	3	1	0	0	0	0	21	9.3	4

Figure 7: Portion of elevator survey from October 2008

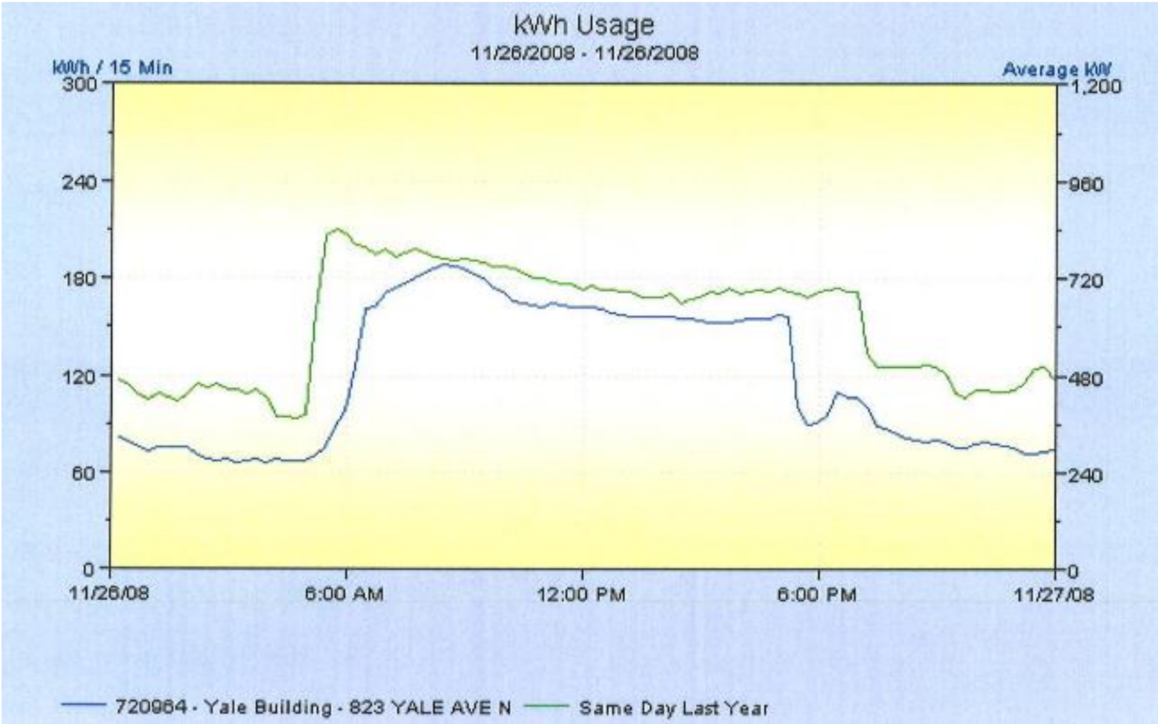

Figure 8: Energy consumption for Yale Building between 2007 and 2008

> **"If you cannot turn it off, turn it down." Bob Cowan, Director of Facilities Engineering**

One more consideration with regard to energy is its impact on safety. In lab environments, it is especially important to understand that life safety must take priority over energy efficiency. At the same time, the need to account for life safety does not mean that energy efficiency can be ignored. For example, it may not be possible to turn off the air handlers during unoccupied mode, but the number of air changes can be reduced.

Beyond energy, the philosophy can extend to other resources as well with the potential to reduce operational costs. One example identified was to reuse water when possible. It was determined by installing water storage tanks that water used to pre-wash laboratory animal cages could be reused. The capital cost of the project was $62,000 after a utility incentive of $26,000, resulting in a 2.2 year simple payback.

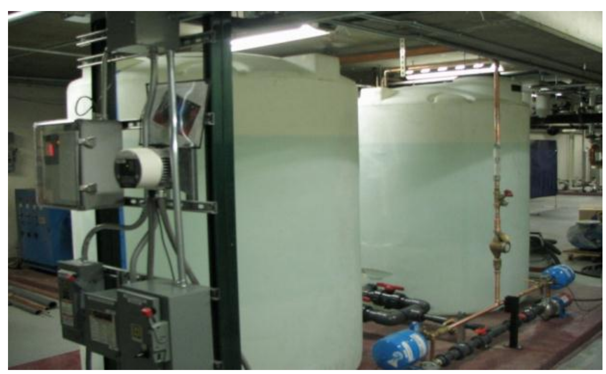

Figure 9: Cage pre-wash water storage tanks

Skills and Knowledge for Applying an Energy Philosophy

Based on the site visits and interviews conducted, building technicians and other key facilities personnel at FHCRC utilize the following knowledge, skills, and abilities to implement an energy philosophy in the management, operation and maintenance of facilities, both on a daily basis and in the pursuit of long-term continuous improvement of energy efficiency:

- Understanding of HVAC and electrical systems.
- Ability to analyze operational data and identify energy conservation opportunities.
- Ability to prioritize energy efficiency efforts.
- Ability to develop a plan and work with a team to successfully implement the plan.

Best Practice #4: Retain and Increase Tribal Knowledge

Organizations sometimes refer to collective institutional knowledge as "tribal" knowledge: For a facilities team, this consists of the vast store of knowledge in the heads of the building operators, technicians, engineers 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. At FHCRC, this is accomplished through training, communication, documentation and practice.

At FHCRC, training is important. Weekly training is provided internally by different team members. One effective way training is provided internally is by using photos of systems and equipment at the facility and having a discussion. Different team members select different types of equipment so the breadth of knowledge across increases across the team.

Communication across the facilities team also provides opportunities to retain and increase tribal knowledge through daily interactions. Forms of regular communication used include:

- Weekly staff meetings with supervisors and front office staff
- Weekly coordination meetings with supervisors and lead technicians
- Monthly crew meetings
- Labor management meetings
- Informal team communication

The department information center (Figure 11) provides another effective communication tool. It is located centrally near the entry of the facilities engineering building. It includes a three month staffing schedule, department calendar and electronic log. The calendar includes when critical equipment, such as generators, need to be tested and when training is scheduled.

Figure 10: Department information center

The electronic log (Figure 11) provides the status of current issues, what is being done to resolve the issues and information that needs to be passed along to the next shift to resolve any open issues. All high priority, unresolved items are listed in the electronic log. The log is reviewed by the

Figure 11: Electronic log, part of the department information system

chief engineer and watch stander to ensure that unresolved items are addressed in a timely manner.

A knowledge repository is kept so that information about systems and equipment is available when it is necessary to resolve operational challenges and questions. Some of the information stored in the knowledge repository includes:

- Drawings, operations and maintenance manuals and specifications, organized by discipline (architectural, controls, electrical, mechanical and specialty equipment)
- Videos of vendor training when new equipment is installed
- Photos of repairs
- Emergency procedures. FHCRC has documented 36 emergency procedures.

Practice includes completing daily on the job functions, as well as interactions with other members of the facilities team to better understand how different equipment operates and why operational changes have been made. Lessons learned are shared through the preventive maintenance program by passing knowledge of experienced technicians on to younger technicians.

The benefit of having the correct information available so that knowledgeable employees can solve operational challenges is difficult to quantify. However, it is clear that the use of information to solve problems can help to determine the root cause of the problem to prevent it from reoccurring. Solving the problem correctly the first time can prevent unnecessary equipment wear, increased energy consumption and increased occupant complaints.

Skills and Knowledge for Retaining and Increasing Tribal Knowledge

While much of the knowledge sought to be retained may be technical, retaining and growing tribal knowledge requires primarily organizational and communication skills. Based on the site visits and interviews conducted, technicians and other key facilities personnel at FHCRC utilize the following knowledge, skills, and abilities to grow tribal knowledge:

- Organize, and lead, and participate in meetings.
- Facilitate training, collaboration and sharing.
- Manage and support a knowledge repository (essentially a database).

Participants need only bring their existing skills and knowledge to the table along with a willingness and desire to learn and collaborate.

Best Practice #5: Always Have a Contingency Plan for System and Equipment Failure

No matter how proactive a facilities team tries to operate their facilities, eventually something will go wrong. To minimize the impact of an unforeseen problem, it is important to have a contingency plan. The type of systems or equipment that require a plan and the level of detailed required in the plan will vary based on equipment criticality, often driven by core mission of the facility.

FHCRC has contingency plans for critical equipment, such as the air conditioners that serve the freezer farm containing more than 100 freezers at –112°F. In July 2006, it was necessary to use this contingency plan because one of the three cooling systems for the freezer farm failed. The contingency plan clearly stated that if a failure occurred, a temporary air handler would need to be brought in and located on the engineering department loading dock. Knowing ahead of time that the unit would need to be set on the loading dock, it was understood that a sound-attenuated generator would also be needed. As a result of having the plan, within four hours after the call was made to the temporary equipment provider the units were up and running and nothing within the freezers was lost. After one week of using the temporary unit, the air handler was repaired.

Thus, it is the responsibility of the facilities team to react to unexpected operating conditions. However, if the team fails to react to a problem or the size of the problem increases, the facilities team may be assigned fault. Having a plan so that problems are resolved quickly can prevent further, undesirable challenges.

For short term operations, daily and weekly plans are in place to inspect equipment and perform maintenance. For example, emergency generators are inspected daily, weekly and annually. For each inspection interval, different preventive maintenance tasks are performed. A few examples include, the batteries are inspected weekly, the transfer switches are tested monthly and the load bank is inspected annually.

On the long-term front, the FHCRC facilities team aims to replace equipment a year earlier than the anticipated end of life. To do this successfully, a 20 year maintenance plan was created for critical equipment, while a 50 year maintenance plan was created for extremely critical equipment.

Short-term or long-term, the qualitative benefits of having a plan include having a process to inform one's thinking in the event of an emergency. This allows the team to react faster and prevent further unnecessary loss, damage and/or expense. Quantitatively, the value of having a plan depends on the potential damage the plan is seeking to minimize or prevent.

Having a plan also helps when faced with finding solutions to fix problems with limited operations budgets. To illustrate this best practice, consider this instance of equipment replacement at FHCRC. A large critical air handling unit with two 150 horse power fans and a capacity of 68,000 cubic feet per minute (CFM) continued to have operating challenges. The fan motors burnt out twice, the capacitor bank failed once and there were multiple problems with the actuators. Additionally, the final filter bank was always wet because the filters were three feet downstream of the humidifier, and the humidifier was one foot in front of the cooling coil. One day, the econo-cone, a portion of the air handler used to vary the airflow, was sucked into the fan, damaging the fan. With a plan in place, when the fan was replaced other problems were also fixed:

- Filter bank was moved to a new location
- New humidifier installed
- Drain pan installed under humidifier
- Variable speed motors installed on fan for easier start and more efficient operation
- Replaced temperature, pressure and humidity controls

Figure 12: Econo-cone within the 68,000 CFM air handler

Figure 13: Replacing the fan within the 68,000 CFM air handler

Skills and Knowledge for Always Having a Contingency Plan

Having a plan requires that the plan be made in the first place. Plans may include multiple potential courses of action, and plans always change. Furthermore, plans must be disseminated to those that may have to carry them out. Based on the site visits and interviews conducted, building technicians and other key facilities personnel at FHCRC utilize the following knowledge, skills, and abilities in the contingency planning and implementation process:

- Analyzing and interpreting data and situations
- Diagnosing problems and identifying relevant causal factors
- Predicting and forecasting
- Goal setting and identifying possible courses of action
- Evaluating and comparing possible courses of action
- Communicating courses of action and contingency plans
- Implementing actions and monitoring results.
- Being flexible and able to adapt or improvise to adjust to changing conditions or situations.

Conclusion

The Fred Hutchinson Cancer Research Center is a complex facility that operates and maintains 1.4 million square feet of high technology research and patient treatment space, including the management of the 225,000 square foot Seattle Cancer Care Alliance. With an efficient, well managed team, the building systems and equipment are operated and maintained to support the mission of the cancer research center to eliminate cancer and related diseases as causes of human suffering and death.

In their work, the facilities management and operations team at FHCRC demonstrates several best practices. As the eyes, ears, and hands of the team, technicians play a critical role in the application of and ongoing improvement of such best practices. The practices featured in this case study are summarized by the table below that concludes this document, 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 FHCRC's experience, that educational institutions will incorporate the seeds of these skills and knowledge attributes in their programs, and that the technicians themselves will strive to develop the skills and knowledge as they work towards a future of sustainable and high performance buildings.

Acknowledgements

Thanks to the Fred Hutchinson Cancer Research Center facilities management team members who helped make this case study possible:

- Bob Cowan, Director of Facilities Engineering
- Jim Walker PE, Facilities Engineer
- Mark Hungerford, Lead Electrician
- Seth Thornton FMP, Facilities Management Intern

Fred Hutchinson Cancer Research Center: Summary of Best Practices

Best Practice		Skills and Knowledge Attributes Identified in this Study that Apply to Technicians and other Key Facilities Personnel
1	**Design for the life cycle**	General knowledge of and experience with the design and construction process is essential.
		Be diligent and detail oriented. It is important to keep track of requests made to the design team and make sure they are included as part of the design or agreement about why the request cannot be made has been reached.
		Be able to prioritize. It is important to determine what needs are most important and what needs may not be as critical.
		Teamwork. Work as a team to make decisions and compromise when necessary.
		Working with design and construction documentation: Knowing how to read drawings, what should be included in a drawing set, and understanding specification language are key skills.
		Systems knowledge. Have extensive knowledge of mechanical, especially HVAC, and electrical systems.
2	**Understand the building's mission**	Root cause analysis. Be able to understand a problem and dig for potential root causes.
		Recognize when specialized skills or knowledge is needed. As in the case of the ultrasonic sensors, a specialist was brought in to confirm the problem's root cause.
		Communicate effectively with occupants. This includes the writing of user guides, providing training, and soliciting constructive feedback.
		Read drawings and equipment schedules.
		Collect and analyze data from meters and sensors to determine actual operating conditions.
		Compare operating conditions against design.
3	**Apply an energy philosophy**	Understanding of HVAC and electrical systems.
		Ability to analyze operational data and identify energy conservation opportunities.
		Ability to prioritize energy efficiency efforts.
		Ability to develop a plan and work with a team to implement the plan.
4	**Retain and increase tribal knowledge**	Organize, and lead, and participate in meetings.
		Facilitate training, collaboration and sharing.
		Manage and support a knowledge repository (essentially a database).
5	**Always have a contingency plan for system and equipment failure**	Analyzing and interpreting data and situations.
		Diagnosing problems and identifying relevant causal factors.
		Predicting and forecasting.
		Goal setting and identifying possible courses of action.
		Evaluating and comparing possible courses of action.
		Communicating courses of action and contingency plans.
		Implementing actions and monitoring results.
		Being flexible and able to adapt or improvise to adjust to changing conditions or situations.