Operations and Maintenance, a Critical Part of Resilience

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When it comes to system resilience, an important first step is to minimize the chance of unexpected system failure that will lead to the need to implement resiliency measures. This is the basis of developing and administering a proactive Operation and Maintenance (O&M) program.

The term “Operation and Maintenance” covers many facets of facility management. A common definition is the administration of programs that complete preventative maintenance and reactive repair of systems. But it also includes the lobbying of proper funding budgets both in annual funding to complete regularly scheduled maintenance as well as long-term capital improvement project planning that allows for predictive replacement of equipment and systems before they fail. It includes the development of written standards and active involvement in the design of projects to ensure systems are constructed with maintenance in mind and to minimize long-term operational costs. It includes the ongoing training of both facility maintenance staff and user groups to ensure that systems operate efficiently and effectively.

How Does Operation and Maintenance Relate to Resiliency?

Operation and Maintenance is vital to a successful resiliency plan. It is more likely that the event that generates the need to have resilience in place is caused by the failure of a piece of equipment or system rather than an outside force such as a natural disaster. A robust O&M program will minimize these system failure occurrences.

Resiliency, like redundancy, relies on back-up equipment such as generators, secondary sources of heat, and the ability to quickly get systems back online. O&M is critical in ensuring that these secondary systems will operate when needed. This includes regular testing of equipment such as standby generators, as well completing scheduled maintenance and overhauls of that equipment and its supporting systems. Standby generators need to have adequate amounts of clean fuel available. For fuel oil based systems, this would include regular inspection and testing of the stored fuel to remove water and ultimately replace old fuel with new fuel.

Even static resiliency measures, such as a robust thermal envelope, require regular maintenance to ensure that they too will be performing their best under needed circumstances. Replacing broken windows and deteriorated door seals will prolong the facility’s ability to maintain its thermal heat mass.

Training, a vital part of O&M, is needed so that operators know how to implement resiliency plans. There needs to be clearly written checklists, and potentially photos and/or diagrams, available to onsite personnel to assist them in implementing the various plans that should be in place to address multiple threats. The operators need to have familiarity for where key components are located within the facility such as diverting valves or exterior portable generator connections as well as how to manipulate those components to implement a resiliency plan.

If there is a failure and a resiliency plan needs to be initiated, the ability to quickly get the original/primary systems operational is a combination of both training and having the appropriate tools and spare parts available. Aside from static measures, most resiliency plans are based on activities that are intended to be temporary. The backup solutions are also typically sized to only maintain minimum critical infrastructure such as maintaining a building temperature just above freezing temperatures. The resiliency solution will likely not be sized to provide full indoor air quality or environmental control, leaving occupants with a less than ideal working and living condition. Most secondary systems, such as electric heat, can be very expensive to operate; therefore the need to get the original systems fixed and back to normal operation is highly important.

Why is this Unique to Cold Climates?

Proper operation and maintenance is important for all facilities. However, it is especially important in cold climates because buildings temperatures can quickly drop to critically low values in sub-zero temperatures. When a heating system goes cold, it is a race against time. Freezing of water pipes or wet sprinkler systems is inevitable without action, resulting in significant property damage and loss of mission readiness.

Transportation access to sites can be very challenging. It is not uncommon in Alaska and other arctic-regions for sites to be off of the road system and only accessible by air or snowmobile during the winter. And these means of access can be made unavailable for several days due to winter storms. In these locations, having replacement parts onsite, or even complete assemblies such as pumps, can provide corrective fixes regardless of weather conditions.

Power outages can be caused by multiple reasons in cold climates. Snow and ice, as well as high velocity wind storms, can cause trees to fall on power lines. Alaska has seen avalanches destroy high voltage power distribution systems. And there is the occasional wildlife mishap that can result in power loss. A standby generator, or the ability to plug in a portable standby generator, is common for most facilities. As noted above, performing regular maintenance on these standby generators will ensure they will operate when needed.

Remote locations typically have less dependable utilities. In addition to power outages, these locations are prone to other electrical system abnormalities such as “brown-outs” or the loss of a phase of power that can significantly damage motors and electrical components throughout a facility.

Though rare, there are some items related to operation and maintenance that can affect the life and safety of occupants. An improperly maintained fuel-fired device and flue system can result in the discharge of carbon monoxide into a facility with tragic results.

Planning for Operation and Maintenance

A critical part of O&M is funding. This includes annual funding to have staff and parts available to address immediate actions, such as a failed pump seal, and preventative maintenance activities such as replacement of air filters. This is a minimum funding level of all facility management programs but still requires planning to properly estimate these costs for each upcoming year’s annual budget.

There are several software packages available that track maintenance activities including daily work-orders for immediate action and regularly scheduled preventative maintenance activities. These will help in defending an annual budget request.

Do not defer preventative maintenance. It costs four times more to repair/replace a system than to maintain it.

An enhanced facility management plan, and more inline with a comprehensive resiliency program, incorporates proactive planning and funding of system renovations and replacement before a critical failure occurs. This is sometimes referred to as predictive maintenance.

The first step in a proactive approach to Operation and Maintenance is developing a future looking (traditionally 5-year) Capital Improvement Plan (CIP). In developing a CIP plan, all equipment and systems are evaluated based on current condition and estimated end-of-useful life. There are several sources of information available that provided how many years of expected useful life you can get out of a piece of equipment, such as a boiler, and a building envelope system such as a roof membrane. The CIP plan incorporates the replacement of these systems a couple years prior to when they are expected to fail, ensuring that downtimes are planned with minimal impacts to services and mission.

The CIP plan also includes funding for major facility upgrades, additions, and renovations. A Master Plan, important but not addressed with O&M, helps develop and identify these major construction projects. If a facility does not currently have the proper tools and replacement parts to implement appropriate resiliency plans, this too can be incorporated into the CIP as a major expenditure outside of the annual maintenance budget.

Having a CIP plan allows leadership to plan and lobby for additional funding beyond the annual facility maintenance budget needed to address immediate activities and scheduled preventative maintenance.

As previously noted, once a system breaks, the facility team will need parts and tools to fix it. There are several steps to being prepared for these inevitable events.

1. Identify what can fail. That's pretty much everything, but there are more traditional items that a facility team addresses as well as system critical components will require immediate action.
2. Have maintenance documentation available onsite for at-risk systems and materials. This is traditionally the Operation and Maintenance Manual. This includes information about the product, exploded view of parts with part numbers, troubleshooting guide, warranty information, and preferably contact information for the local supplier of parts and maintenance technicians (if applicable).
3. Identify and have on-hand spare parts and tools that will be needed for critical system repair.
4. Have an organized spare part location so that parts and tools can be readily found. Complete regularly scheduled inventory of tools and parts to ensure they are available when needed.
    a. Keeping track electronically of what spare parts are available and when they are used on a project to ensure that replacement materials are ordered so that they are ready for the next incident.
5. Provide training and/or have training videos available onsite that can show how to perform needed maintenance/repair to the system.

For large organizations, developing equipment and system standards can greatly decrease the number of unique parts, tools, and training needed to operate facilities. This can significantly lower the operational costs of an organization. The development of a standard is beyond the scope of this paper, but it typically includes the following:

1. Surveying and inventorying the existing equipment and materials that are already in use and operators are used to working with.

2. Identify the preferred equipment based on performance and local support (spare parts availability, local vendor service and knowledge, etc.). Talk with other facility operators, engineers, and vendors to see if there are better products out there to standardize around.
3. Develop a list of standardized manufacturers. This will at least limit the spare parts to a single vendor. Financing may require two manufacturers for competitive pricing.
4. Where applicable, standardize around one or two models if possible. This may be applicable for simple things like lavatory faucets. This will further reduce the spare parts inventory.

The next level of standards development is to document how the facility management team wants the systems designed and installed. This is often referred to as a Facility Design Guide. In addition to including the above noted system and equipment standards, this document includes a means and methods for what systems will be installed and how they'll be installed. The information can be based on personal experience, lessons learned from past projects, and best practices obtained from other professionals and the industry as a whole. This document is intended to be provided to designers and contractors for new facilities and renovations to ensure that they install components/equipment that the facility team is used to working with, thereby optimizing the long-term operational costs of that new installation. This document should be regularly revisited and updated so that it is current for the next project.

Contracts with both the design team and the contractors are also areas where O&M planning takes place.

Commissioning is commonly required for all facilities. Commissioning is a great way to prove that installed systems meet the intent of the design and are operating correctly. For resiliency, this includes the commissioning of the secondary/back-up systems to ensure that they will perform correctly when needed but also commissioning of the thermal building envelope and vapor barrier. Thermal envelope commissioning can be accomplished either through blower door testing or thermography. The Alaska District Corps of Engineers has an excellent specification for this. Part of the commissioning close-out documents includes a Commissioning Report which includes the checklists, final settings, and tweaks to the Sequence of Operation at the time of owner occupancy. This is important as some sequences may be changed during the commissioning process.

Provide a means of remote assistance. This can be remote access for the Building Automation System or installing a high-speed Wi-Fi network within the facility that can handle live video streaming from a smart phone or tablet so that remote operators/technicians can see and hear an issue. This can facilitate the ability to troubleshoot and fix an issue remotely or walk onsite personnel through the process of fixing the issue. It can also provide a remote service technician an initial view of the issue so that they can be sure to bring all of the appropriate repair materials/spare parts and tools to the site.

Documentation and Training

The owners should require that contractors document Record Drawings during construction and submit them at the end as part of project close-out. It is recommended that a significant amount of money be associated with this in the Schedule of Values to ensure that it is completed. Likewise, the design team needs to be contracted to incorporate the contractor's Record Drawings, as well as any changes that were made to the design during construction, into a final electronic Record Drawing set of documents. These documents, as well as the O&M Manual, need to be provided to the owner in electronic format to ensure they are easy to locate during the life of the building.

The contract specifications should also be archived electronically. Some contract documents, such as the sequence of operation, are only located in the specifications.

In addition to new design and construction, all existing project drawings and O&M manuals should also be scanned and archived.

The other important part of close-out documents is the development of a robust Operation and Maintenance Manual. These should be provided electronically but the site should also have a printed hard copy in case the electronic file is not accessible at the time of need (power outage, crashed hard drive, etc.). Having an electronic copy assists remote operators and technicians in troubleshooting and parts ordering. Electronic copies are easier to read over time and are also sometimes easier to access than the hard copies. A thorough O&M manual is important for resiliency as they will be an important reference document during an event. The recommended requirements of the O&M Manual were listed earlier.

Additional documentation that assists with resiliency programs is the posting of large format drawings with system schematics (piping diagrams, ventilation system diagrams, etc.) on the wall where the equipment is located. Posting the final sequence of operation next to these diagram provides a single point of reference of how the system is designed and how it will operate. Step-by-step procedures to start and stop equipment, as well as execute resiliency back-up plans, should also be laminated and posted in conspicuous locations in the facility. This is helpful for transient technicians and new facility management personnel. Best practice is to also have these laminated for long-term durability. Having laminated drawings noting where the main isolation valves are in the building, including the water service entry, can prove invaluable during the hectic times of a catastrophic leak.

All of the above noted documentation needs to be kept up to date as equipment is replaced and system modifications are completed. Having accurate reference documentation will save time during an emergency.

It is recommended that owners develop an Emergency Preparedness manual. This is, in essence, documenting the resiliency plan but tying it to specific activities such as power outages, earthquakes, catastrophic water leaks, loss of heat, and fuel spills.

The final part of project close-out contracts is the requirement for owner training. The following are recommendations to maximize the effectiveness of post-construction training:

1. Digitally record all training. Make sure that the audio of the training is clear and consider having the training professionally recorded if budget allows. Have the digital training indexed so that it is easy for an operator to go to the specific equipment/system of interest. Store the digital files with the electronic copy of the O&M Manual. Have a digital copy (i.e., DVR) located with the hard copies of the O&M manual as a secondary source.
2. Have training separated into a classroom and field component. The field component is to show the piece of equipment and point out exactly where all of the valves, actuators, filters, grease Zerk fittings, and other components associated with maintenance are located.
3. Have training write-ups as part of the Emergency Preparedness manual and of the associated resiliency measures, such as how to hook up a portable generator. The write-ups should include step-by-step procedures with equipment and field photos as well as screen shots of the Building

Automation System as appropriate. Keep both hard copies and electronic copies but also post the procedures near where the resiliency measures will be carried out.

4. Have some training repeated 10 months after owner occupancy. Refresher training of the Building Automation System is especially effective and provides an opportunity for the contractor to adjust/reset the system to where it was at time of owner occupancy. Operators may unknowingly make incorrect modifications to the BAS system when they first get the building, not aware of how it operates.
5. Schedule regular operator refreshers of the training videos throughout the life of the building and require new employees to watch the videos as part of their orientation.

System and Equipment Identification

Part of an effective preventative maintenance program, and efficient resiliency measures, is having properly identified systems and equipment.

All piping systems should have system identification and flow arrows to facilitate troubleshooting of systems as well as isolation in case of leaks. Ductwork too can benefit from having system and flow direction identification though it is less common to see duct systems being identified. The exception being when the airflow is hazardous or toxic such as a laboratory fume hood or dust collection exhaust system.

All pieces of equipment should have unique identification tags, prominently located on the piece of equipment. Some O&M software programs integrate in a barcode system that, when applied to equipment, facilitates the capturing of scheduled preventative maintenance activities.

Likewise, electrical and control panels as well as equipment disconnects and Variable Frequency Drives (VFDs) also need to be prominently labeled.

Ceiling tags should be used where there are components concealed above an acoustical grid ceiling or in general concealed. These would include items such as valves, dampers, fire dampers, and major system isolation valves. Best practice for acoustical grid ceilings is to use descriptive labels and attach them to the grid at the tile that is to be accessed. Ceiling tacks fall out and ceiling tiles get replaced. Place an arrow on the label so the operator knows what tile they should remove.

Designers should coordinate the naming of all panels, equipment, and system abbreviations to be consistent with existing facility naming conventions (i.e., B for boiler, EF for exhaust fan, etc.), as well as already used equipment numbers.

If the owner has multiple facilities or sites, they may consider developing a more robust equipment naming convention that defines what facility the equipment is or potentially where the equipment is in the building (i.e., VAV boxes or terminal heating units). This will help when analyzing Building Automation alarms.

Isolation valve have long been provided with unique identification tags. Recommend that each tag have a unique number, a system identifier, and their normal position. Locate a framed or laminated valve tag directory in the mechanical room with information about where each valve is located. This can be very helpful during start-up, shut-down, seasonal change overs and emergency leak conditions.

Designing with Operation and Maintenance in Mind

The facility management team should be active throughout a design project. After all, they are the ones who will be operating and maintaining the systems for the decades after the project is constructed. The design teams should be coordinating their proposed systems and receive buy-in from the facility team at the schematic level of a project. The facility team should also be able to review and provide written review comments on the design at each major submittal milestone. This helps to ensure the facility is being built with long term operational costs (energy conservation plus maintenance costs). Having the facility management team actively reviewing design drawings gives them a familiarity with the systems and where items such as isolation valves and fire dampers are located in the building for access later.

The design team needs to follow the design standards (noted above) that have been developed by the facility management team. If a standard for a piece of equipment has not been established, the design team should select equipment based on reliability, energy efficiency, and availability of local parts and services.

All cold climate and remote location projects must incorporate redundancy in their design for critical systems like heat. Redundancy can be provided in several forms including:

1. Complete redundant equipment or systems, sometimes referred to as N+1 redundancy. A common example are two main circulating pumps piped in a primary/back-up configuration.
2. Having additional equipment designed to operate in parallel, but sized with redundancy. A typical example of this is having two boilers sized at 66% of the calculated peak heating load.

It is good practice to design in secondary sources of heat if available. Though fuel fired boilers are the preferred source of heat for cold climate buildings, examples of additional heat sources include:

1. A district waste/recovered heat distribution system that feeds the building.
2. Fuel fired air system whether that is an air handler or roof top unit.
3. Fuel fired space heater(s).
4. Solid fuel space heaters such as wood or masonry stoves.

Facilities have extensive Operations and Maintenance needs, particularly in cold climates. This paper does not attempt to include all Operation and Maintenance best practices but instead just those that are related to resiliency and emergency preparedness.

Site Design

In cold climates, an important part of site management is handling snow and ice.

Snow needs to be easily removed from a site to maintain access but also stored in locations that will not hamper emergency access to the facility for first responders or to limit access to storage units that contain emergency equipment including generators. Maintain access to fuel and fire water storage tanks.

Likewise, falling snow and ice from a roof can block access to exterior doors. This may not be noticed until access is needed (such as exterior only access to the boiler or generator rooms).

Accidents when completing snow removal can generate utility interruptions. Be sure to clearly identify fire hydrants, electrical transformers, and other utility equipment that is on the ground so it is obvious to snow removal operators.

Items that will need to be accessed but will be covered during the winter, such as exterior sanitary sewer waste cleanout, water service key/curb boxes, and well heads should be flagged or have some methodology of locating them without major snow removal effort.

Building Design

Creating a robust and resilient building envelope is critical for cold region design. Not only will this help prolong the time that a building can go without heat, but it will also have the most significant impact on energy conservation. Use building materials that will not impact the overall performance of the building envelope if they are damaged such as vacuum panels or large windows that if broken, cannot be easily covered with a sheet of plywood.

Specify robust windows and window hardware. Broken or loose hardware can result in significant infiltration. “Tilt-turn” type windows are not recommended in cold climates. Smaller windows are easier to maintain, operate, and replace.

The building floor plan should be designed to make maintenance easy. This includes ample room within mechanical spaces to complete maintenance activities. Provide both interior and exterior access to mechanical room. Exterior doors may become inaccessible during the winter. Operators should be walking through the mechanical spaces daily looking for leaks and that is more likely to be completed if there are interior door access. If possible, locate all mechanical system equipment within the warm building envelope. This will make maintenance and repair during the winter easier to conduct. Having equipment in a conditioned space also increases the life of the equipment, particularly in coastal areas where the salt air can be quite corrosive.

Provide interior roof access. Exterior roof access, such as ladders, can be icy and dangerous to use during the winter.

Structural and Seismic Design

In locations that are subject to earthquakes, improperly designed and installed seismic support systems can create significant issues. Preparing a facility for an earthquake can prevent the need to instigate emergency resiliency plans.

On November 30, 2019, Southcentral Alaska experienced a 7.1 earthquake. Thankfully there were no deaths or injuries associated with the earthquake but there was significant property damage. In the site investigations and audits that were completed immediately after the earthquake, much of the damage could have been prevented with proper installation and maintenance.

Several facilities throughout the region experienced water damage from sheared domestic water piping, hydronic heating piping, and more often sprinkler piping. Sometimes it was that the piping was not properly supported but more typically it was an adjacent piece of equipment or duct that was not properly seismically supported that fell on the pipe or it was an improperly braced piece of equipment that moved, resulting in separation or breakage at the pipe connection.

Large HVAC equipment such as air handlers and fans sheared their seismic hold-down bolts. This was typically due to undersized bolts or non-seismic spring isolators.

There were several examples where seismic straps for large vertical tanks and equipment maintained their connection to a steel rack, but the rack itself was not properly anchored to the wall structure. This resulted in the entire assembly, tank and straps, coming free from the wall and moving.

Diffusers and lights fell from acoustical tile ceilings because they were not properly seismically supported. Lights and diffusers are supposed to be independently supported from the grid. Sprinkler heads should have flexible connections or oversized escutcheons so they move independently from the ceiling tiles.

Most of the above items could have been prevented. Improperly sized systems can be mitigated by having the seismic design calculations be completed and reviewed by a licensed structural engineer. Facility maintenance staff should be trained on proper seismic support; where and when it is required as well as what are acceptable means of seismic support. Then complete an onsite inspection throughout your existing facilities. Request that renovation costs be included in a CIP budget to expedite their completion.

Structural engineers should be hired to complete a Tier 1 seismic evaluation of all existing facilities. This evaluation follows evaluation and rehabilitation recommendations found in ASCE/SEI Standards 31 and 41. This is a fairly quick analysis that does not require much work. In Alaska, all schools are required to have a Tier 1 assessment completed as part of any state-funded renovation project.

Military and industrial facilities may need additional levels of preventative construction such as blast resistance, progressive collapse analysis, and even HEMP shielding.

Mechanical Systems

For thousands of years, the most critical system in a cold climate building has been heat. Having redundancy and resiliency built into a facility’s heating system is a must.

The heating system should have redundancy in all critical components and, if possible, a second source of space heat. Examples of secondary sources of heat were noted earlier.

The heat distribution primary mover, whether that is via pumps or fans, should also have redundancy if at all possible. Having redundancy plans for any single point of failure, including power, is important.

All of these secondary sources of heat need to be included in a preventative maintenance program. Fuel fired equipment should be inspected and tested annually prior to the heating season. As noted, fuel storage systems should also be annually tested and inspected.

Simple systems are typically more reliable and easier to maintain. They are also more easily understood by transient technicians.

Equipment should be located in easily accessible locations. Ideally, all mechanical equipment is located in environmentally controlled mechanical spaces with ample maintenance access. Heavy equipment such as pumps should be located on the floor or wall mounted. Wall mounted equipment should be located within 6 ft (1.8 m) of the floor or platform. Minimize equipment that is concealed above a ceiling or in piping chases. It is not only difficult to reach and maintain but it is also prone to being forgotten about and preventative maintenance not completed.

Mechanical room access should be designed to be able to easily remove and replace all equipment. This includes boilers, water heaters, and heating coils. Access needs to be maintained from the piece of equipment to the outside of the building.

It is recommended that a structural beam or picking point be located above heavy fan and pump motors, 15 horsepower and higher. Having a picking point will facilitate the ability to replace a failed motor with a single person and a chain hoist/tackle block. If that is not possible, having onsite a tripod with a picking point is acceptable but there needs to be access around the piece of equipment to set the tripod. Another item to remember for motors is to select motors that have readily available replacements, such as 1750 rpm motors, or keep extra motors onsite as spares. Motors that are 1200 rpm have historically had a long lead time for replacements.

Facilities should be provided with a substantial amount of isolation valves. This allows parts of a facility to be isolated for both preventative and reactive maintenance activities without impacting the rest of the building operations. Ball valves are preferred whenever possible.

It is important to annually test the water/glycol in hydronic systems for pH and inhibitors. If not chemically treated, a hydronic system fluid can become aggressive and generate pin hole leaks in piping and attack gaskets and seals. It is recommended that samples be occasionally sent to a lab for testing as pH strips do not identify organics, chemicals, and other things that can degrade a system.

For glycol systems, glycol concentration should also be annually tested to ensure it is providing the proper temperature of freeze protection for that region. Glycol systems should never have domestic water make-up connections, but instead either be manually filled or have an automatic glycol make-up feeder system. With an automatic make-up water connection, an unnoticed leak can slowly dilute the glycol to a percentage that results in a coil freeze. You also do not want it to be too easy for operators to use water to refill systems when draining down equipment for maintenance. In addition to dilution of the glycol percentage, using raw tap water for hydronic systems introduces air and can impact the effectiveness of the inhibitors.

A Building Automation System (BAS) with remote access not only provides exemplary energy efficiency, but it also has important O&M and resiliency benefits. Most BAS systems have the capability to send alarms electronically offsite. This can be in the form of emails, texts, and pre-recorded phone messages. This is good to notify operators during off hours that there is a critical condition such as a potential freezing condition in a room or a critical piece of infrastructure had failed. Higher level critical alarms can also be sent to a central alarm monitoring company or an organizations main facility management headquarters. Another important part of a BAS system is the ability to monitor and troubleshoot the systems remotely.

BAS systems should have easily understood graphical interfaces. Where operators are adverse to the perceived complexity of a BAS system, visual system performance interfaces such as red/green LED lights can be useful for operators. As with system design, simple sequences are easier to understand and have a higher probability of being operated in automatic mode rather than having equipment being manually overrode via programming or at the hand-off-auto switches.

Electrical Systems

For electrical systems, maintaining clean and dependable power is important.

Standby generators, either part of the facility or portable, along with their associated Automatic Transfer Switches (ATS) need regular maintenance and testing.

In critical infrastructure or where power quality is not dependable, consider installing power conditioners that can protect the facility from high/low voltage spikes as well as a loss of phase. UPS systems may be desired for point of use critical components and/or electronics such as BAS global controllers. Power monitoring can be added to the BAS system so that it can be trended and remotely monitored.

It is recommended that all electrical panels and electrical devices be annually inspected with a thermal imaging camera. A thermal imaging camera provides multiple benefits for a facility (reference envelope inspections). For electrical systems, a thermal imaging camera can identify overloaded circuits that will be prone to tripping and overheated motors and equipment that are signs of eminent failure. Archiving the photos will help identify differences between inspection periods.

Variable frequency drives provide energy efficiency opportunities but also conditions the power and protects motors from brown-outs and phase loss conditions. Bypasses should be considered for redundancy but the system needs to be analyzed for what will happen when the equipment is manually put in 100% speed condition.

Electric heat trace should be annually inspected prior to the heating season.

Emergency/Egress lighting batteries and systems should be tested annually. Central battery systems are easier to maintain and may be more reliable than distributed batteries.

Provide ample receptacles wherever mechanical equipment is located or where operation and service activities are expected to be completed. A popular feature in hospitals is to have color coded receptacles that denote that circuits that are powered by the standby generator.

Fire alarm panels should have intuitive interfaces so that operators and first responders can quickly assess and locate the issue that is generating the alarm. All devices should be addressable and provided with unique identifiers to facilitate locating and troubleshooting devices.

Conclusion

Operation and Maintenance is a critical part of a complete resiliency plan. Funding and implementing preventative maintenance and predictive replacement greatly reduces the likelihood of unforeseen catastrophic failures. Planning for resilience includes designing facilities for maintenance, preparing plans for resilience measures, and having onsite the parts and tools needed to execute the plans and the resulting fixing of the primary system.

Having static resilience measures in place, like a robust building envelope, provides much needed time when a heating system is down. Training and having thorough O&M and resiliency plan documentation in place expedites the initiation of back-up procedures and gets the primary systems quickly back online.