Lessons Learned from Hospital Projects

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PDHLibrary Course No 2021002
2 PDH HOURS

LESSONS LEARNED FROM HOSPITAL PROJECTS

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Objective

The objective of this course is to share lessons learned in hospital projects. Many of these lessons can be transferred to other types of design and construction projects. Below are some of the topics that are covered in this lesson:

- *Ductwork restriction*
- *What to watch out for if the electric utility replaces a transformer*
- *Duct and space pressurization*
- *Conflicts between different authorities having jurisdiction*
- *Limited above-ceiling space issues*
- *Asbestos*
- *Flood plain issues*
- *Sanitary pipe replacement*
- *Curb heights*
- *How to appropriately set up a filter fan unit*
- *Limitations to meet current codes*
- *Forecasting outages*
- *Like-for-like replacements*

Introduction

Although it is easier to remember the lessons you learn through your own mistakes and life lessons, it is less painful to learn from others' mistakes and challenges. Pain is often an effective teacher.

This course is an opportunity for you to learn important lessons of design and construction without the pain. The following stories come from hospital projects, but most of the lessons can be helpful when designing and constructing other types of projects.

Lesson 1 - Ductwork Restriction

<u>Scenario</u>

At the beginning of air handling unit replacement projects, I typically hired a test and balance firm to document the current conditions of the air handling unit and the ductwork system. For one particular project, my job was to replace two large air handling units that served multiple operating rooms in a large hospital.

The original air handling unit fans were running in the service factor (slightly more horsepower than the design for the motor) in order to provide the code-minimum required air changes in the operating rooms. The vertical space in the room was constrained by room height, air handling unit height and the height of the ductwork. Based on the preliminary test and balance report, the units were running at a very high total static pressure. The extremely high external static pressure (the static pressure through the ductwork only), was the reason for increased total static pressure. The system was originally designed to be a higher pressure system. The ductwork was oval, which is typical of higher pressure systems.

In order to find the source of the high duct static pressure, I asked the test and balance company to measure the static pressure leaving the air handling unit and measure the static pressure in the ductwork after it left the room. They also measured the static pressure before the ductwork turned up to the floor above. In hindsight, I wish that I had met the test and balance team at the site when they were troublehooting the source of the high static pressure. Based on the information in the report, it appeared that a duct silencer just on the other side of the wall of the mechanical room caused the problem.

I decided that it would be best to remove the silencer since it was over a warehouse space where noise would not be an issue. I also sized the fans such that there would be extra air flow available for a future build-out of a shelled operating room. Even then, I expected that the fans would still have a little bit of remaining capacity.

During demolition, the contractor noticed a strange ductwork connection to the existing air handling unit. The air handling unit had a notch cut out of the top of it and the ductwork was very wide, but very short. This was the reason for the high static pressure. With all of the additional fan power that I had available, I told the contractor to proceed and make the transition as smooth as possible. I re-ran my calculations and was not worried. The ductwork had been designed for a high static pressure and the air handling unit had been built for high static.

When it was time to start-up the unit, the unit kept tripping off due to high static pressure. It was determined that the controls contractor set up the high and low static limits for a low number. The setting was adjusted closer to the limit of the ductwork, but the unit still couldn't ramp up to the design air flow.

Air valves had been installed in the supply and return ducts to the spaces. It seemed as though the air valves were closing and causing restriction. This was the first time that the controls contractor had controlled this type of air valve. It was determined that the parameters had not been entered correctly. With help from the air valve manufacturer, the issue was resolved. The air flow to spaces improved, but the total static was higher and the air flow was lower than expected. Even though there was still motor horsepower capacity available at the fans, the pressure at the outlet of the air handling unit was nearing the pressure rating of the ductwork. The restriction at the outlet of the unit was determined to be the issue.

Everyone on the team huddled together to brainstorm ideas to resolve the problem. Some solutions would have required a substantially longer outage of an already long outage for the hospital. The physical constraints of the space limited the options for resolving the issue. Finally, the mechanical contractor had an idea that we could test. He proposed cutting a hole in the side of the discharge plenum and running a round duct from the side of the unit to the main ductwork leaving the room, in order to bypass some of the air around the restriction. They installed a temporary flex duct to see the effect of the proposed solution. The flex duct was limited by a lower pressure threshold, but through extrapolation, it looked like it would give enough pressure relief.

The parts were ordered and the new duct was installed. The air handling unit was finally able to ramp up to the current design air flow. Since duct leakage reduced the air flow to the spaces the air handling unit was required to run a little over the design air flow to provide adequate air flow to the spaces.

Lesson 1 Lessons Learned

- ***Understand the source of the constriction.***
  - ***Retest the pressure at various locations to ensure the source of the constriction.***
  - ***Do not be afraid to meet the test and balance team on site to see what is measured. The time invested up front may save future frustration.***
- ***Think outside the box to try to address impossible situations.***
- ***Don't easily dismiss the concerns of others. Not only double-check the concerns yourself, have someone else double-check your rationalization.***
- ***Check parameters for constant or variable air volume boxes. Compare air flow read by the box with test and balance readings.***
- ***Build in extra time to the schedule if dealing with unfamiliar equipment.***

Lesson 2 – Electric Utility Replaces Transformer

<u>Scenario</u>

My team designed a lot of projects for a hospital. The electrical engineer maintained a thorough electrical one-line diagram of the electrical system. He added the information for each new project to a composite one-line diagram he had been creating of the entire facility.

For each project, he obtained a utility fault letter indicating the available fault current at the utility transformer. Usually, the available fault was the same from letter to letter, but the code required a letter dated within the past 12 months, so he would request a new letter from the utility annually.

For this one project, when he requested the utility fault letter, he obtained a letter with a significantly higher available fault. The available fault current is used to select appropriately rated electrical switchgear. He contacted the utility to find out why the number changed. The utility representative informed him that the electric utility changed the entrance utility transformer within the past year. The new transformer had a higher efficiency than the old one, which would allow more fault current to pass through the transformer to the building switchgear.

At that time, there was another project that we had designed in construction. The electrical engineer re-ran the calculations in his fault study to see the impact of the new available fault current to the project under construction and to the rest of the infrastructure that had been documented in the composite one-line diagram.

One of the panels involved with the project under construction was now underrated and needed to be replaced. Other panels shown on the composite one-line diagram were also now underrated. Much of the rest of the facility had not been documented in the one-line diagram, so a study of the entire facility was now required.

Since the new transformer was more efficient, the available fault was now higher, requiring panels that have a higher amp interrupting capacity (AIC). The study of the entire facility identified ten underrated panels that needed to be replaced. This was an expensive impact! The ripple effect from a transformer failure was significant.

Lesson 2 Lessons Learned

- ***Design and install electrical panels with additional margin between the amp interrupting capacity of the panel and the available fault at that panel.***
- ***When a transformer needs to be replaced, try to replace it like-for-like, if possible.***
- ***If a transformer needs to be replaced, plan to conduct a new fault study including all downstream equipment.***
- ***Maintain a composite one-line diagram for the facility and a fault study. Facilities should require new consultants to modify the master.***

Lesson 3 – Space Pressurization

Scenario

Hospitals are more sensitive to space pressurization requirements than most other types of spaces. But like other types of buildings, the tightness of construction impacts pressurization. In general, the tightness of construction will impact how much more outside air is required (compared to exhaust air) to maintain a positively pressurized building.

The same is true for individual spaces. One of the most important spaces to maintain negative pressure in a hospital is an airborne infection isolation (AII) room. These are spaces where patients with airborne infections such as tuberculosis are placed. The gold standard for designing an isolation room is to provide an anteroom between the patient room and the corridor. This helps maintain negative pressure between the isolation room and the corridor even when the door is momentarily opened. Otherwise, the pressure will neutralize when the door is opened to allow healthcare workers to come into or leave the room. If only one door to the anteroom is open at a time, the anteroom provides an additional layer of protection from germ transmission.

The leakier the room is, the more differential between supply and exhaust is required. The exhaust airflow drives the air change rate calculation, so the exhaust fan will be sized to provide the air flow required to maintain the code-required air change rate. If the room is leaky, additional exhaust or less supply air will be required. The exhaust system will not likely have too much additional capacity available, so the easy solution is to reduce the supply air flow. The potential problem with reducing the supply air flow is that the space may become warm in the hot months. In the worst case, the supply air flow may need to be eliminated in order to maintain the pressure differential, which is not an option.

Having a hard ceiling and continuing the walls to the deck (to the floor above or to the roof) are architectural characteristics that are important in making a tight space. Lab grade (washable) ceilings may be allowable by code, but once the seal is broken for someone to gain access above the ceiling, it is almost never resealed. This will make the space leakier once the test and balance agent has left, causing pressurization problems down the road.

If all else fails, the use of door-sweeps or weather-stripping can also help tighten the construction.

Lesson 3 Lessons Learned

- ***For new construction, encourage the architect to design the spaces with pressure requirements by using hard ceilings and/or walls extended to the deck.***
- ***For renovations, check the tightness of spaces with pressure requirements during the design phase. Include measures to seal the spaces in the design, if needed.***
- ***Oversize the exhaust fan to allow for leaky construction.***
- ***Monitor construction to ensure that the walls and ceiling of sensitive spaces are well sealed.***
- ***Monitor construction of exterior construction to ensure that the envelope (building exterior) is well sealed. Stress the importance of a tight envelope with the architect so that he or she can provide additional attention to those details of construction.***

Lesson 4 – Outage Forecasting

<u>Scenario</u>

Hospitals are very sensitive to outages and construction delays. Every day that an operating room is not available causes the loss of tens of thousands of dollars of revenue. During times of high occupancy, every day that a patient room is unavailable, costs the hospital thousands of dollars in lost revenue. Additionally, the health of those who required care are put at risk. Kitchens are also a critical service of the hospital. If a kitchen ever needs to be shut down, a temporary kitchen must be set up since closing the food service department of a hospital is not an option. Renting and hooking up a temporary, modular kitchen, is expensive and aggravating for the kitchen staff. Designing and obtaining local jurisdiction approval of the temporary kitchen is time consuming, in addition to the time required for the delivery and setup of the modular kitchen.

Hospital CEOs must forecast revenue for the following year. If an unforesceen construction project significantly impacts availability of hospital spaces, the financial impact can be enormous.

During one construction project that impacted the operating rooms, the constant air volume boxes were supposed to be replaced with air valves. Due to the critical nature of the operating rooms and the congested above-ceiling space, pre-construction field investigation was nearly impossible. Once the ceilings were opened to make the replacements, it was discovered that the new air valves could not easily be installed in the existing locations. In some areas, the additional length of the air valves caused problems. In other areas, the width caused conflict. Other existing constant air volume boxes were trapped above other services that were installed under them. This doubled the outage duration.

Lesson 4 Lessons Learned

- ***Don't replace constant air volume boxes in crowded ceilings unless you can field-verify the fit ahead of time. Repairs or retrofits of the controls are a less risky option.***
- ***Always plan for something to go wrong in forecasting outage durations; build in a sensible contingency.***

Lesson 5 – Pressure Requirements for Air Valves

Scenario

It is common practice to install air valves on the supply and return and/or exhaust to and from rooms with critical pressure requirements such as operating rooms, isolation rooms and pharmacy compounding clean rooms.

During an upgrade project for some isolation rooms, the scope of the project was to replace the constant air volume boxes with air valves and add air valves to the exhaust with a new hazardous exhaust fan.

As we found during the post-test and balance, the supply ductwork was significantly leaky, which reduced the pressure in the supply ductwork. This is not a good situation for an air valve that requires more air pressure than a constant air volume box. Even a low pressure air valve will require at least 0.3" water gauge (w.g.) across the air valve. Standard air valves require a minimum of 0.6" w.g. across it. If it doesn't have enough duct static pressure, the controls will show that the air valve is satisfied and providing the design air flow even though it isn't.

In addition to the existing supply duct being leaky, the existing exhaust ductwork was leaky. Also, the room was leaky. The walls didn't extend to the deck; they stopped just above the ceiling. This created a case where the exhaust requirement at the fan was much higher than the design value. The exhaust fan needed to be resheaved in order to handle the additional air flow.

Lesson 5 Lessons Learned

- ***Train the maintenance staff to look at the pressure drop on the controls system in addition to the actual air flow to confirm that the air valve is operating at design conditions.***
- ***If you are planning to use air valves, pre-test the available duct static pressure at the location of the proposed installation. Select the air valve accordingly or select a constant air volume box that will operate at the available static pressure.***
- ***Design exhaust fans for spaces requiring negative pressure in existing buildings with additional capacity to account for leaky ductwork and leaky spaces.***
- ***Pre-test duct leakage in existing-to-remain ductwork.***
- ***Select exhaust fans and associated motors at no more than 85%-90% of rated capacity.***

Lesson 6 – Sanitary Piping Replacement

Scenario

Once a hospital becomes about 40 years old, the frequency of sanitary failures gets everyone's attention. Sanitary failures above kitchens or operating rooms are usually the last straw that encourages the management to start a sanitary piping replacement project. Mitigating liability becomes paramount.

There are issues with waiting too long to do a wholesale replacement project. In one facility, the cost and disruption associated with replacing all of the underground piping was too much. Lining the underground piping was selected instead. In the process of lining the pipe, the machine was caught on imperfections in the failing piping and got stuck. A long, unplanned outage ensued to dig down to the pipe to remove the lining equipment and replace the broken section. The pipe was several feet below the surface of the floor, so shoring of the excavation was required. This was not a quick fix. The unplanned outage impacted facility operations for weeks.

Leaks in sanitary piping above the kitchen are particularly painful. The kitchen must be completely shut down. Alternative plans for providing food to the patients must be put in place. Bringing in a temporary kitchen and getting it approved by the authority having jurisdiction takes time. In this case, the local building department and the state had to approve the project. Temporary kitchen rentals are fairly expensive, but for a long outage, they are a necessity.

In order to replace the sanitary piping in a patient bathroom, the fixtures must be removed and a couple of walls need to be cut open to access the piping. If the fixtures are relatively old, plan to replace the fixtures since you have to pay for the labor for installation anyway. If the finishes in the bathroom are relatively old, consider renovating the bathrooms while replacing the sanitary piping. On the other hand, if you are renovating a bathroom, replace the sanitary piping while you have the walls open. The incremental cost of replacing the piping of a renovated bathroom (even if the piping is at the end of its life) will save the facility in the long run. Unplanned outages, infection risk and bad patient experience due to a sanitary riser failure can be very expensive. In addition, finishes for a newly renovated space won't have to be torn apart and redone just to replace sanitary piping. Additionally, unless there is a significant amount of attic stock of the existing tiles, a similar tile must be selected to try to coordinate with the existing finishes. It never looks as good as the original.

Since sanitary piping runs in concealed locations, unexpected problems inevitably arise. Code deficiencies, water damage and asbestos are a few. Condensate drain lines for fan coils may be directly connected to the sanitary system. There are two potential code issues with this scenario. An air gap is required between the unit and the connection to the riser. The second is that depending upon the jurisdiction, condensate drain lines may not be allowed to be connected to the sanitary system. Some jurisdictions allow it and others require rerouting the line to the storm system. In the case of water damage, moist drywall may develop mold and mildew inside the walls, which requires specialized care. This is also a liability if the mold impacts the health of the hospital employees or patients. If the flooring has water damage and needs to be removed, this is a common location for asbestos. Sometimes, flooring is laid on top of older flooring that contained asbestos. Removing the two layers of wet flooring will require abatement of the asbestos.

Lesson 6 Lessons Learned

- ***Don't wait too long to replace failing sanitary piping. Phase the work slowly over a series of 10 years before it becomes an emergency. Combine sanitary piping replacement with other major renovation work.***
- ***Don't line pipes in questionable condition. If you think that it might break during the lining process, plan to replace it.***
- ***Try not to run sanitary piping over kitchens, or at least not over the service line or cook line. In new construction, try to design kitchens in a one-story section of the building so that there is no overhead sanitary piping.***
- ***Try not to run sanitary piping over operating rooms. In new construction, consider designing operating rooms for locations with no floors above or at least no patient rooms above where patient bathroom sanitary piping is required.***
- ***Consider combining a renovation of the kitchen during a sanitary piping replacement project. With the amount of disruption to the kitchen, it is easiest to relocate the kitchen to a temporary kitchen and upgrade the 30 to 40-year old kitchen at the same time as the sanitary piping running above and below the kitchen.***
- ***Consider replacing sanitary piping anytime that a construction project exposes concealed sanitary piping. It is the easiest time to replace it.***
- ***Keep an overall map of what sections have been replaced and when.***
- ***Maintain a high contingency fund for unforeseen conditions – asbestos, latent code deficiencies, latent pipe deterioration, unexpected outages, water leaking into the excavated soil, as-built drawings not matching the existing conditions, water damage, etc.***
- ***The installation team should be comfortable to mention other potenial issues in concealed locations. Are the potable water lines in good condition? Is the framing still in good condition? Is the sheetrock in good condition? Is mold forming? Is the exhaust ductwork full of dust? Addressing out of scope issues during a construction project should be considered since it the least expensive time to remediate the deficiencies.***

Lesson 7 – Curb Height

Scenario

Selecting the appropriate curb height for an air handling unit or an exhaust fan is difficult since the actual roof insulation is concealed. There are code requirements for the height of the curb above the surface of the roof.

In one project, I installed a new hazardous exhaust fan for a hospital in Florida. The minimum requirement at the time for the height of the curb above the roof surface was 8". In addition, code required that roof-mounted mechanical equipment have a Miami-Dade Notice of Acceptance (NOA) that ensured that the equipment would withstand a hurricane. Two major exhaust fan manufacturers built the type of fan I needed with the specific hurricane rating that I needed. I specified an 18" curb because I had run into trouble in other projects where the curb wasn't tall enough for the roof insulation and still meet the code requirement of 8" above the roof surface. The contractor did not submit the basis of design. He submitted the other manufacturer with an 12" curb because that manufacturer only has a hurricane rating for the 12" curb. It doesn't have the rating for their 18" curb. I rejected the selection and the contractor ultimately selected the basis of design.

When the curb arrived on site and the roofing was cut back, it was determined that the roofing insulation in that location was a staggering 11" deep. That means that the fan was only about 7" above the roof surface. After discussing the issue with the authority having jurisdiction, we were allowed to use the 18" curb.

Lesson 7 Lessons Learned

- ***If the thickness of the roof insulation is unknown, don't use less than an 18" curb.***
- ***The height of the roof insulation varies across the roof depending upon the sloping of the roof towards roof drains. Even if the thickness in one location is known, the thickness in another place can be vastly different.***

Lesson 8 – Authority Having Jurisdiction (AHJ) Pet Peeves

Scenario

In Florida, the Agency for Health Care Administration (AHCA) is one of the authorities having jurisdiction. They are mostly focused on health and safety. The local building department ensures that construction is built to code and the fire marshall ensures that the fire safety measures are appropriate. Sometimes the purview of various AHJs overlap. Sometimes they agree and sometimes they disagree. This makes satisfying all parties a challenge. I have found that the most frequent disagreement is regarding fire alarm devices. AHCA will not want devices in locations that the fire deparment will want devices. One option is to ask the two departments to talk with one another and come up with a concensus. This is the best option. I have heard of some contractors making changes for one AHJ and then putting everything back for the other AHJ once they make their comments. This method is not recommended. Both inspectors are trying to ensure that the hospital is safe. Additionally, during future inspections, more rework will be required. The hospital will be constantly adding and removing devices every year. Getting a concensus in writing is the best solution in the long run.

I have found that each year and with each new surveyer, the pet peeves change. In one year, sound transmission is important. In another year, infection control risk assessments are the hot topic. As the inspectors or surveyors have annual training, new topics will be at the forefront of their mind when they walk through projects.

Each surveyor also has certain things that he or she would look for. All AHCA surveyors seem to be diligent to check the fire alarm shutdown. If an air handling unit is replaced, they will check the functionality of the duct smoke detectors, the interlock between related exhaust fans and the functionality of the fire/smoke dampers and smoke dampers, if the duct smoke detector initiates an air handling unit shut down. If the duct smoke detector only creates a trouble indication, they will use a space smoke detector or a pull station to initiate a shut down. They will also ensure that the hazardous exhaust fans in the area do not shut down upon a fire alarm activation. If a space is renovated, the space smoke detectors and pull stations will be checked. Some surveyors will also check the function of the tamper switch at the test station, even if no work was done at the tamper switch. AHCA has a history of only accepting inititaion from a smoke can. Magnet inititaion has not always been allowed. Some surveyors are allowing magnet initiation if the device is listed for such testing.

One surveyor always wanted to check the condensate trap height leaving the air handling unit, whether or not the air handling unit had been replaced.

Access to duct smoke detectors became a hot topic at one point. The AHCA surveyor would check to see if the access door for the duct smoke detector existed, and then whether it was large enough to access, maintain, and inspect the tube inside the duct.

Surge suppression for circuits leaving the building was a topic for which many people had a different interpretation as to where the surge supression should be located. Should it be outside at the device? Should it be at the point that the circuit leaves the building? Should it be at the panel? Should they be installed in more than one location? In situations like this, it is important to discuss the issue with the AHJ prior to completion of the design to minimize rework at the end of the project.

Proper sealing of rated walls is another pet peeve of AHCA. Even if the penetrations are existing, they will encumber the current project with the requirement of fixing holes and improperly sealed penetrations. The use of stickers at each penetration noting the date, the person who sealed the penetration, and the Underwriter's Laboratories, Inc. (UL) number of the penetration detail used minimized questions during the survey.

Unlike a local building department that is able to be on site frequently, AHCA is only conducting site surveys one week out of three. They are unable to see much of the work in progress. For example, when a roof is open to make the attachment from a roof curb to the roof structure, the roof cannot be kept open for 3 weeks waiting for AHCA to inspect. In cases like these, AHCA will accept pictures of the attachment. If pictures were not taken, they have been known to require that the roof be reopened in order to inspect the attachment.

Another hidden condition, where pictures are very helpful is in the case of louvers. In cases where a Miami-Dade NOA is required, the sticker showing the certification can sometimes be installed on the side of the louver, which will be hidden once it is installed. Taking a picture of this sticker prior to installation can save a lot of headaches during the site survey.

Lesson 8 Lessons Learned

- ***Discuss areas of possible conflict with the appropriate AHJ prior to construction.***
- ***Discuss issues with multiple possible interpretations with every appropriate AHJ prior to construction. Get the final interpretation in writing.***
- ***While having the interpretation in writing will not save you from the possibility of the AHJ changing its mind later, it may help argue your position.***
- ***Learn the pet peeves of inspectors/surveyors that you deal with regularly and take steps to make sure that your quality control procedure includes those items in the check list.***
- ***Pre-test the fire alarm system prior to inspection by the AHJ. The contractor should test it and then the design team should witness the test prior to the AHJ arriving. Check air handling unit shutdown, smoke damper closure (visually and physically inspect the position of the damper, not just the acutator position), and associated exhaust fan shut down. Check annunciation at the fire alarm front end for proper annunciation for the device triggered.***
- ***Bring a can of smoke and a magnet to the survey so that the AHJ can select from either method. Feel free to recommend the team's preferred method, but be ready with both, in case.***
- ***Pay attention to trap depth in new air handling units. Calculate the appropriate height for the curb and baserail to provide additional space so that a dirty coil, a miscalculation or a future air handling unit replacement will not require slab cutting to provide the appropriate trap depth.***
- ***Design the location of the duct smoke detector in a place where an access door can be installed and reached easily. Ensure that the access door is large enough for someone to view the smoke detector tube and touch it to clean and maintain the device.***
- ***Don't forget about surge supression devices for all circuits leaving the building: exterior lights, exhaust fans, rooftop air handling units, rooftop package units, air-cooled chillers, controls, exterior signage, cooling tower fans, etc.***
- ***Discuss the location of surge suppression with all AHJ that will have an opinion on the matter. Obtain a concensus, in writing, if possible.***
- ***Check any rated walls that your project will impact both before construction and after construction. Seal any penetrations with a UL listed detail appropriate for that type of penetration prior to AHJ survey/inspection. Don't miss corridor walls where electrical conduit is run.***
- ***Require that any contractor that seals a penetration in a rated wall to install a sticker next to the penetration listing the UL detail, date and person who made the installation.***
- ***Take lots of pictures, particularly showing hidden conditions.***

Lesson 9 – Low Floor-to-Floor Height

Scenario

If you were to design a hospital from scratch, the architectural team may select 16 feet floor-to-floor to accomodate all of the ductwork and other utilities. With energy code requirements and fully ducted supply, return and exhaust requirements, more space is required than was needed in years past. This makes renovation a tricky business.

There are cases of buildings that were originally designed to be a hotel or a nursing home that were converted into a hospital. Hotels and nursing homes are known for relatively low floor-to-floor heights. When these buildings were originally designed decades ago, high pressure ductwork and/or plenum supply and/or plenum returns were more common. This becomes a nightmare for converting the systems to meet today's codes and standards of care.

In some cases, it is impossible. One option is to continue "repairing" the existing sytem so that it doesn't have to be brought up to code. The other option is to build a new hospital and sell the existing building to a company that would like to have a hotel or nursing home in that location. The first option is not as safe for the patients as the second option, but the second option is very costly. If there is available real estate, a third option is to move functions around. For example, if an operating room suite is in an area with 12 feet floor-to-floor, a new surgery suite could be built and pre-op/post-op could be moved into the old surgery suite. If pre-op/post-op was in an area with 10 feet floor-to-floor, administrative offices could be moved into that space.

Lesson 9 Lessons Learned

- ***Design new buildings with adequate floor-to-floor height to accommodate future code changes during renovations.***
- ***Identify functions in existing hospitals that are located in spaces with inadequate above-ceiling space. Make long-term plans to change the function of those spaces into functions that do not require as much above-ceiling space.***

Lesson 10 – Chilled Water Flow and Load Inconsistencies

Scenario

There are three major types of pumping systems. In a constant volume primary chilled water system, the same constant flow runs through the chiller and out to the air handling units. The three-way valves at the air handling unit vary the flow through the coils. Chillers are turned on as the load increases. This is a robust and simple control strategy, but it is energy inefficient. In a primary-secondary chilled water system, the constant volume flow through the chillers is decoupled from the flow to the air handling units. The variable flow to the air handling units varies with load. Two-way valves at the air handling units vary the flow through the coils. This saves significant energy, but the control strategy is a little more complicated. A decoupler pipe is needed between the primary and secondary loops to decouple the loops. In a variable primary system, the flow through the chillers varies with the load requirement at the air handling units. Again, the two-way valves at the air handling units vary the flow through the coils. A bypass is required in this situation to ensure that minimum flow through the chillers are met. This is the most energy-efficient option, but it carries some risk. If the controls are not operating properly and the safety switches malfunction, the chillers can be damaged from low flow.

In theory, the benefit of a primary-secondary chilled water pumping system is that the required flow through chillers is decoupled from the flow to the air handling units. In one hospital, the peak load at the air handling units was about 600 tons. The facility had a 200-ton, 300-ton, and a 400-ton chiller. In theory, only two chillers ever needed to run, but in a few remote locations, the space conditions became too hot if the differential pressure setpoint was set at a reasonable pressure. In order to keep the spaces cool, the facility needed to run the secondary pumps to maintain an extremely high differential pressure setpoint. When this happened, the secondary pumps pulled water through the primary pumps and pumped too much water through the chillers. This caused the discharge water temperature to increase. The rest of the building started to suffer and the third chiller was also necessary to run.

One or two poorly functioning coils can waste significant energy at the chilled water plant. The facility had no funds to replace the air handling units, so the facility lacked the redundancy that they had hoped for and spent unneccessary funds on electricity.

Lesson 10 Lessons Learned

- ***Pre-test the space load prior to design of chiller plant retrofits (do not assume that the control system is reading accurately).***
- ***Identify poorly functioning air handling units prior to design. Encourage the facility to replace those units prior to the chiller plant retrofit.***
- ***Check the local utility's rebate program for potential additional funding.***

Lesson 11 – Terminal Unit Replacement Issues

Scenario

In hospitals, constant air volume boxes are often used to maintain pressure relationships. In some locations, variable air volume boxes are installed to save energy. In either case, there comes a time when replacement or retrofit of the boxes is necessary.

In some cases, the existing pneumatic controls limit the control system and provide a blind spot. Pneumatic terminal unit controls are unable to provide feedback to the control system. The control system is only able to tell the box what to do, but the box is unable to feedback and tell the control system what it IS doing. It would be like telling your child to do his or her homework, but you having no way to see if he or she did it. One option to address this issue is to retrofit just the controls. The other option is to replace the box altogether.

The above-ceiling space in many hospitals is very crowded. Replacing just the controls can even be difficult. Replacing the entire box is sometimes almost impossible without relocating many services that were installed below the box.

In one project, the budget could only afford replacing the controls. In another project, the boxes were gutted and the system was converted into a constant volume system. In another project, the boxes were replaced, but significant reconfiguration of the services above the ceiling were required.

In one project, new variable air volume boxes were installed and the heaters often failed. The air flow switch was checked and replaced. It was later determined that the heaters were not installed in the correct orientation. The air flow switch was not able to function properly in that orientation.

Lesson 11 Lessons Learned

- ***In new construction, design the location of terminal units close to the ceiling so that other piping and conduit cannot be installed below it.***
- ***Consider replacing the controls for a terminal unit only in ceilings that are crowded.***
- ***Ensure that electric heaters are installed in the right direction.***
- ***In new construction, encourage the architect to provide adequate above-ceiling space for current needs and future renovations.***

Lesson 12 – Existing Conditions Conflict with Current Codes

<u>Scenario</u>

Sometimes existing conditions make meeting current code impossible or nearly impossible without significant renovation. In the case discussed earlier where a hotel was converted into a hospital, the floor-to-floor height for the operating rooms was less than 10 feet. The supply diffusers were in the sidewall. Codes have changed since that design. Overhead laminar flow diffusers that cover most of the operating theatre is now required. A 7-foot ceiling in an operating room is not practical. The adjustible surgical lights would not fit to be able to articulate well between the ceiling and the surgeons‘ heads. This leaves very little room for above-ceiling ductwork.

What do you do when the existing conditions pin you between a rock and a hard place? Sometimes you have to make difficult decisions. Sometimes, the required modifications to existing infrastructure are not economically feasible. In this case, with the extent of many existing conditions that didn’t meet current codes, the hospital was closed.

Another example is an existing chiller plant that was housed in the basement, below the current 100-year flood plain. While it would have been possible to construct a new chiller plant in another location on the campus, the cost associated with this option would have been astronomical. This hospital dealt with this issue by installing flood dams on all of the lower level doors. In case of a hurricane or other impending flooding conditions, the facility had the ability to slide the flood dams into framing that was installed on each door. Thinking outside the box is critical for retrofit conditions.

Lesson 12 Lessons Learned

- ***In new construction, design infrastructure knowing that more stringent requirements will be put in place in the future. Plan for additional physical space and capacity (i.e. floor-to-floor dimensions, mechanical room space, electrical room space, electrical panel physical space and load capacity, air handling unit capacity, ductwork capacity, piping capacity, pump capacity, land acreage, etc.)***
- ***Install mechanical and electrical infrastructure (i.e. chillers, boilers, generators, fuel tanks, main switch boards, transfer switches, service entrance panels, etc.) well above the 100-year flood plain.***
- ***For existing facilities, think outside the box.***

Lesson 13 - Asbestos

<u>Scenario</u>

According to the Environmental Protection Agency (EPA) Actions to Protect the Public from Exposure to Asbestos, asbestos-containing materials started to be banned in 1973. (2020) Below is a table summarizing the material and the year it was banned.

Year	Materials
1973	“Spray-applied surfacing asbestos-containing material for fireproofing/insulation“
1975	Asbestos pipe and block insulation (i.e. insulation for boilers and hot water tanks)
1977	Artificial fireplace embers and wall patching compounds
1978	All other spray-applied surfacing materials
1989	New applications for asbestos
1990	Spray-on application of materials containing more than 1% asbestos
2019	“Discontinued asbestos products cannot be be reintroduced“

It is possible that any facility may contain asbestos, but more attention should be paid to any facility constructed prior to 1989. Hospitals and other facilities that were originally built during this era should have a National Emission Standards for Hazardous Air Pollutants (NESHAP) Report. A NESHAP report or an asbestos survey should be conducted prior to any construction project on an existing building.

According to Overview of the Asbestos National Emission Standards for Hazardous Air Pollutants (NESHAP), “Air toxics regulations under the Clean Air Act specify work practices for asbestos to be followed during demolitions and renovations of all facilities, including, but not limited to, structures, installations, and buildings (excluding residential buildings that have four or fewer dwelling units). The regulations require a thorough inspection where the demolition or renovation operation will occur. The regulations require the owner or the operator of the renovation or demolition operation to notify the appropriate delegated entity (often a state agency) before any demolition, or before any renovations of buildings that contain a certain threshold amount of regulated asbestos-containing material. The rule requires work practice standards that control asbestos emissions. Work practices often involve removing all asbestos-containing materials, adequately wetting all regulated asbestos-containing materials, sealing the material in leak tight containers and disposing of the asbestos-containing waste material as expediently as practicable, as the regulation explains in greater detail. (2019)

At the start of any project, even before the engineer does a site survey, the engineer should ask for a copy of the latest asbestos survey or NESHAP report. If asbestos is known to exist within the project area, care must be taken not to disturb any asbestos-containing materials. If the abestos status is unknown, do not disturb any materials.

If an environemental scientist has been hired, and he or she has gathered samples and run a report, the local authority having jurisdiction may challenge the report and require that additional samples be tested. For example, in a lobby renovation project that I worked on, during demolition, the City challenged the NESHAP report. The NESHAP report included test results for duct mastic, pipe insulation, and fire-proofing, but the mastic behind the bathroom mirror had not been tested. The City shut the project down until the bathroom mirror mastic had been tested. The mastic came back negative for asbestos, but due to an abundance of caution, the City wanted to make sure that nothing was missed. Asbestos-related hazards are taken very seriously.

During demolition, it is not uncommon for suspicious materials to be exposed. Behind walls and above ceilings, duct mastic, pipe insulation and fireproofing abound. Environmental scientists will often identify those locations as potential hot spots and request that they be given the opportunity to test those materials once the wall or ceiling is removed. This may require an additional day to be added to the schedule. If asbestos is detected, the outage will be longer.

Lesson 13 Lessons Learned

- ***Request existing NESHAP reports or asbestos surveys prior to any renovation project.***
- ***A project-specific NESHAP report should be generated prior to any demolition.***
- ***A project-specific NESHAP report will address all materials that are planned to be in the scope of the project. If an issue arises in the project and additional scope is added to the project, the new area will need to be surveyed for asbestos.***
- ***Plan additional time into any project for potential asbestos-related delays, particularly if suspicious materials may be hidden in concealed locations.***

Lesson 14 – Filter Fan Units

<u>Scenario</u>

Pharmacy intravenous compounding clean rooms are classic locations for installation of filter fan units. Pharmacy compounding clean rooms require high air change rates and well-filtered air. The best option is to filter the air at the room in addition to at the air handing unit. Fan filter units provide high-efficiency particulate air (HEPA) or ultra-low particulate air (ULPA) filtration at the room, but ensures that as the filter loads with dirt and debris, the air flow will remain at a constant velocity. The filter fan unit has a filter and a fan in the unit directly above the ceiling.

In spaces where cleanliness is paramount, hard ceilings or sealed lab grade ceilings are required. In either case, getting above the ceiling to maintain the filter fan unit is not convenient. Selecting filter fan units with room-side replaceable filters and motors is highly recommended.

Due to high volumes of air flow requirements, the air change requirement may be much higher than the air flows needed for space comfort. To save energy, some fan filter units can be fed from the air handling unit and others can just recirculate room air. Ducted recirculation is required.

Test and balance of fan filter units is different from most other devices. The test and balance agent must balance the system with the filter removed and the fan filter unit motor off. The fan in the fan filter unit is intended to only provide enough static to overcome the static pressure of the filter as it loads (becomes dirty). Once the system is balanced, the filter is replaced and the fan is ramped up to maintain the design airflow. Pay attention to the airflow limits associated with the filter fan units. In order to maintain laminar flow, a certain range of airflows are required.

If the filter fan units are relatively close to electric reheat coils, the pressure in the duct at the electric reheat coil will be nearly neutral, which is not enough to activate the flow safety switch protecting the reheat coil. Another type of safety switch may be required to get the electric reheat coil to engage. This lesson was learned from a very cold pharmacy compounding room!

Lesson 14 Lessons Learned

- ***Use filter fan units for spaces where cleanliness and constant air flow are required.***
- ***Install hard ceilings in spaces where cleanliness and pressure relationships are paramount.***
- ***If the air change rate requirement exceeds the air flow needed for adequate space temperature, consider using recirculating filter fan units ducted to low returns.***
- ***Ensure that the test and balance agent knows how to properly balance a filter fan unit. A pre-construction conference is one method to ensure that the test and balance agent is familiar with the required test and balance procedure.***
- ***Utilize hot water reheat coils in series with filter fan units, if possible. If electric reheat is required, select a flow safety switch for the heater that is dependent upon flow, not duct pressure.***

Lesson 15 – Smoke Dampers

Scenario

Smoke dampers are installed in ducts that penetrate a smoke barrier. It prevents smoke from traveling from one smoke compartment to another. The damper is controlled by either pneumatic or electric actuation. When an air handling unit shuts down, for any reason including maintenance and fire alarm, the smoke dampers should also close.

Sometimes walls are rated for fire and smoke. In that case, the damper will have two forms of actuation. For the fire rating, a fusible link will melt at high temperatures closing the damper. The smoke damper portion of the damper is closed via a pneumatic or an electric actuator.

Installing and appropriately setting the high and low duct static limit switch is particularly important if the ductwork contains fire and/or smoke dampers. In one installation, the static pressure switch was not installed properly. When the fire/smoke dampers in the roof, directly below the unit closed, the air handling unit didn't turn off. The air found its way under the roof membrane and blew the roof up like a balloon. The ensuing roof repair was costly.

In several other installations, the timing between the unit start-up/shut-down and the closure of the smoke dampers caused issues. If the dampers don't open quickly enough upon unit start-up, the safety switch will shut the unit down. There are couple of ways to address this issue. Particularly if the fan is controlled by an across-the-line starter, the signal should be sent to the dampers first. Once the dampers signal that they are fully open, the unit can be started. If the fan is controlled by a variable frequency drive, the ramp speed can be slow to match the speed of the damper actuation.

In reverse, the fan should shut down first followed by the damper closure. For larger fans, the inertia of the fan may cause it to continue spinning for several seconds after it is turned off. A delay on the closure of the dampers may be required.

Delays in the damper actutor are possible for electric and pneumatic actuators.

Smoke dampers should be avoided in duct design, where possible. Smoke dampers require periodic maintenance and testing. When testing the dampers, visual and physical inspection of the position of the damper, both in the open and closed position is recommended, not just the position of the actuator.

Smoke dampers should be installed in locations that are accessible. Contractors installing utilities after the ductwork is installed should be mindful of clearance requirements for accessing smoke dampers.

Lesson 15 Lessons Learned

- ***Minimize the number of smoke dampers required in ductwork by providing separate air handling units for separate smoke compartments.***
- ***Keep an extra actuator in stock on site.***
- ***Even in situations where a quick air handling unit replacement are required, ensure that the high and low duct pressure safety switches are properly set and***

- ***coordinated with the speed and sequence of opening and closing the smoke dampers prior to leaving the unit running for the day.***
- ***Do not allow conduit or piping to be installed below the fire or smoke damper access door, limiting access for proper maintenance and testing.***

Lesson 16 – Pump Control

Scenario

This is the story of an important lesson that a young controls sales engineer learned. The facility type is unknown, but it did have a chilled water plant. The controls were inadvertantly set up so that the chilled water pumps ran at all times. When pumps run, there is a certain amount of heat lost into the fluid. Over time the water increased in temperature so much that the refrigerant in the chiller boiled and blew the refrigerent relief rupture disk. Since it was not a relief valve that would reclose once the pressure was relieved, the rupture disk had to be replaced.

Lesson 16 Lessons Learned

- ***Ensure that pumps shut down within a few minutes of the chillers turning off if there is no other means of cooling, such as a water-side economizer.***
- ***Provide a safety switch that will shut down the pumps if the chilled water exceeds a certain temperature threshold.***
- ***Provide refrigerant relief valves instead of refrigerant relief rupture disks, where possible.***

Lesson 17 – Like-for-Like Replacement

Scenario

In this story, there was a hospital that had some capital to spend near the end of the year. They decided to replace multiple air handling units, and at least get the units delivered by the end of the year. This did not provide very much time to select the proper equipment. A test and balance firm was hired to measure the performance of each air handling unit that needed to be replaced. The problem with this tactic was that the air handling units were not in good condition, the reason that they were being replaced. The measured performance was substantially reduced in comparison to the original design. The reduced performance became the selection criteria for the new air handling units.

The undersized air handling units had a hard time blowing enough conditioned air to the end of the run. Even with the variable air volume boxes not all requiring full flow at once, the spaces were starved for air.

Lesson 17 Lessons Learned

- ***If as-built drawings are not available for equipment replacement, redesign the load instead of relying on current capacity.***
- ***If there is not enough time to do proper due diligence, you may end up spending more money in the long run.***

Summary

Throughout this lesson, you have had a chance to learn from other people's experiences in hospitals. Most of these lessons can be transferred to other types of design and construction projects.

While shame may frighten you from sharing your experiences with others, develop a culture of life-long learning with your collegues so that they and you may all benefit from each other's experiences without having to learn all of the lessons the hard way.

The benefit of learning lessons the hard way, by making mistakes, is that you are less likely to repeat the mistakes. A personal experience is a better teacher than if you only heard about someone else's experience.

Engineering is a complex and important field that impacts all of society. In our effort to provide safe, comfortable environments for occupants, we need to use all of our resources to provide the best product possible. Sometimes, that means that we need to review each other's work or share lessons learned with each other with humility. The purpose is not to degrade one another, but to provide safety for society and prudent use of money and resources for our customers.

References

EPA Actions to Protect the Public from Exposure to Asbestos. (2020, March 20). Retrieved August 28, 2020, from https://www.epa.gov/asbestos/epa-actions-protect-public-exposure-asbestos

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Lessons Learned from Hospital Projects - Quiz

Updated: 11/28/2020

1. True or False? Design and install electrical panels with additional margin between the amp interrupting capacity of the panel and the available fault at that panel.

   a. True
   b. False

2. True or False? Under-size exhaust fans to allow for leaky construction?

   a. True
   b. False

3. True or false? Plan for something to go wrong in forecasting outage durations.

   a. True
   b. False

4. Which types of rooms have critical pressure requirements?

   a. Operating rooms
   b. Isolation rooms
   c. Pharmacy compounding clean rooms
   d. All of the above

5. According to the lesson, avoid installing sanitary piping above which types of spaces?

   a. Operating rooms
   b. Kitchens
   c. Offices
   d. both a and b

6. True or false? If the certification sticker on a louver will be hidden after it is installed, you should take a picture of the sticker prior to installation.

   a. True
   b. False

7. Which type of pumping arrangement decouples the primary and secondary loops?

    a. Constant volume primary pumping
    b. Variable volume primary pumping
    c. Primary secondary pumping
    d. Both a and b

8. What is a benefit of using constant air volume boxes?

    a. They take up less above-ceiling space than ductwork.
    b. They help maintain pressure relationships.
    c. They are less expensive than ductwork.
    d. Ductwork heaters can only be installed with a constant air volume box.

9. Which of the following statements would the author NOT agree?

    a. Install mechanical infrastructure well above the 100-year flood plain.
    b. Install electrical infrastructure well above the 100-year flood plain.
    c. Design infrastructure larger than current needs to allow for future needs.
    d. It is not wise to think outside the box.

10. Which of the following building materials may contain asbestos?

    a. Fireproofing
    b. Boiler insulation
    c. Piping insulation
    d. All of the above