

Introduction

The Cummings Life Science Building is an eleven story 162,000 square foot concrete/masonry laboratory and research building. Located at 920 East 58th Street, Chicago, Illinois, this building houses numerous researchers of genetics, microbiology, and cell biology for the Biological Sciences Department for the University of Chicago. In 1999, the University set out to substantially renovate much of this 32 year old building to a modern, flexible research facility. To date, nine phases of work have been completed, entirely renovating approximately 100,000 gross square feet of space on floors 3, 5, 6, 7, 8, 9, a portion of 10, and a portion of the basement. In order to support these renovations, significant upgrades to the buildings infrastructure were required. These infrastructure upgrades include converting the building's main air handling systems to variable air volume, a 215,000 cfm laboratory exhaust system, new radioisotope exhaust systems, a high pressure exhaust riser serving a Biological Safety Level 3 (BSL3) lab, a process chilled water system, new electrical distribution, new reverse osmosis system, replacement of domestic water systems, and integration of a state of the art direct digital Building Automation system to control and monitor the buildings functions. In addition, all mechanical, electrical and plumbing systems were replaced on six and one half floors of space.

Background

Similar to many buildings of this vintage, the Cummings Life Science Building suffered from many engineering systems nearing the end of their useful life. Designed and constructed at a time when energy was inexpensive and plentiful, the original design of the building included five field erected high pressure constant volume air handling units serving a terminal reheat supply air system. Not only were the constant volume systems inefficient, but they were inadequate to handle proper airflows in a modern research laboratory for ventilation rates and the high internal cooling loads from research equipment. Even with high pressure duct systems and supply fan delivering 10+ inches of static pressure, mechanical systems forced low ceiling elevations, often down to 7'-6" to 7'-9", creating a dreary building environment for the occupants. Researchers were unhappy with the poorly controlled air conditioning, lack of daylighting, and overall performance of the building.

Making matters worse, the building's unique masonry structure had imposed a significant impact on the design of the HVAC systems for the building. The exterior of the building includes 40 masonry and concrete shafts. Nearly 200 individual 10"x14" laboratory exhaust risers were routed up these shafts, served by 56 exhaust fans on the 11th /12th floor roofs. Each fan served a small section of the building on four or five floors. As expected, a building with so many fan systems had become difficult to maintain. Many of the 56 individual exhaust fans required significant maintenance, and some of the fans were inoperable, leaving areas of the building without any means of exhaust.

Although research inherently requires flexibility, the infrastructure of the original building was totally inflexible. It became impossible to perform even basic modifications to the building such as adding a fume hood, since there was no infrastructure provisions to serve a new hood. The added cooling load from heavy equipment rooms housing large quantities of



Figure 1-The distinctive concrete columns on the exterior of the building, which house the original lab exhaust riser, presented many challenges to the renovation of the exhaust system.

freezers, coolers, centrifuges, and other equipment were impossible to handle due to the high heat loads produced. Domestic water piping had numerous leaks and was patched in hundred of locations. Complicating basic building modifications was the fact that all domestic water and process systems, such as air, gas, vacuum, and reverse osmosis water were routed at the ceiling below and up-fed to each floor, requiring even simple laboratory changes to affect the research being conducted in the space below.

The problem

When the decision was made to substantially renovate the Cummings Life Sciences Building, numerous design challenges became evident. It became apparent that creative solution would be required, and that these solutions must take into account a strong comprehension of phasing the construction process. Some of the many challenges included:

- The renovation would occur on a floor by floor basis in a building that was 100% occupied and operated 24 hours per day, 365 days per year. Any renovation must therefore have minimal impact on the use of areas outside the area being renovated.



Figure 2 - Originally, the building was served by 56 lab exhaust fans. Each fan served four or five separate floors.

- New engineering systems must permit flexibility to permit changes in the space as the research changes. For instance, it must be easy to add and subtract fume hoods, modify process gases, and add supplemental cooling to spaces as future requirements dictate.
- Higher airflows were required to handle a modern research facility.
- The system would need to incorporate safer capture of fume hoods then was presently occurring.
- The system must be much quieter than the noise currently emitted from the high pressure terminal units.
- The system must be energy efficient.
- The system must be easy to maintain.
- Higher ceiling spaces must be provided to improve the aesthetics of the space and moral of the user.
- Better and more efficient lighting must be provided.
- Additional power must be made available to each floor.
- The building must be completely wired with data/telecom in an organized and flexible manner.

The solution

Because of the arrangement of the original exhaust system within the exterior masonry shafts of the building, it was determined that the exhaust system, much more so than other systems, would have a major impact on any redesign effort. Although each supply air handling unit system was arranged to serve two or three floors, each of the 56 exhaust systems (See Figure 2) served four or five floors. A detailed analysis of the exhaust system and masonry shaft construction which housed the hundreds of exhaust risers was conducted. Many schemes were investigated, including replacing the four to six small exhaust risers in each shaft, one at a time with a large medium pressure exhaust riser. Because of the limited access into the masonry and concrete shafts (each shaft had only a 16" access slot into each shaft at each floor- See Figure 3), the replacement of duct risers within the shafts was discounted not only due to extreme costs, but also due to the effect on shutting down many floors of

the building for extended periods of times while the replacement was made. The scheme that was ultimately determined to be the most cost effective solution with the greatest flexibility follows.

1. A total of four laboratory exhaust fan systems would be installed on the roof of the building. Each fan system would include three fans (or two fans with a space for a future fan- See Figure 4). The fan systems would be located at the four quadrants of the building at the roof level. This permitted their high velocity nozzles to discharge air from the laboratories and fume hoods at the highest point of the building, far away from the outside air intakes for this building as well as all of the surrounding buildings. A 60"x60" coated duct manifold was installed looping the entire roof area near the perimeter. Each of the four lab exhaust fans were connected into this common manifold. All of this work was installed prior to the start of any renovation on any floor.
2. Once this work had been accomplished, each shaft underwent a renovation. This renovation intercepted each of the four to six exhaust ducts at the top of each shaft (See Figure 5), and installed a variable air volume venturi style air valve on each branch duct. The shafts at the roof line included an interior access space approximately 5'x5', allowing the valves to set in a vertical position on top of the exhaust riser it served, in a space protected from the exterior elements. Each air valve was then extended to the new 60"x60" exhaust manifold.
3. Once this work was complete, the exhaust fan(s) serving that shaft were taken out of service and removed. The total time any given building area was without exhaust air never exceeded two to three days. During this first infrastructure phase, each exhaust air valve was temporarily balanced for constant volume, since at this point in time, no renovation of any floor had been initiated.

The renovation of the laboratory exhaust system met virtually all of the requirements imposed for that portion of the system, including:

- Consolidation of 56 poorly functioning exhaust fans into a manifolded system served by four new state of the art exhaust fans.
- Allowing the exhaust system to be converted to variable air volume during the renovation of each floor. This would permit not only conversion of the supply system to variable air volume during the renovation of each floor, but also allow for constant face velocity, variable air volume fume hoods. Numerous studies have been conducted to show that safe fume hood usage requires



Figure 3-A 16" access to each exterior duct shaft was all that was available, limiting options on

constant face velocities across the sash of the fume hood.

- The flexibility of allowing any exhaust duct within the exterior shafts to serve either as general lab exhaust, fume hood exhaust (by the addition of differential pressure controls for low flow alarm) or return air (by connecting the discharge of the air valve to a return air main, rather than to the 60"x60" lab manifold).
- The disruption of installing a new 215,000 cfm exhaust system to the building was minimal, requiring only a two to three day shut down of any given area in the building.
- Permitting a building automation system to provide control of room pressure, and room temperature, as well as the monitoring of overall system airflow, temperatures and remote adjustment of space conditions.

With the renovation of the laboratory exhaust system complete, the building was now ready for floor by floor renovation. The floor was stripped down to the structure. All ceilings, walls, ductwork, lighting, electrical panels, etc. were removed back to shafts. The only thing that remained (temporarily) was domestic water and process gas piping loops, since this piping actually served the floor above, which was to remain in service. Extensive field survey was conducted, and extremely detailed design drawings were prepared. The new design included locating new piping loops for water and gases at a different location than the existing, permitting both loops to temporarily exist while construction was in progress. Once the new loops were in place, pipe branches serving the floor above were converted over to the new piping loops that were installed. These new branches would remain in service, up-feeding the floor above, until such time as that floor was renovated. New piping loops were designed to also serve the renovated floor, eliminating the problem of having piping located in a floor other than the one it serves. In this manner, changes to each lab space can be easily made in the future to plumbing or process systems without affecting other floors.

The supply air on each renovated floor was converted to variable air volume using venturi style air valves with reheat coils. Converting the system to variable air volume permitted nearly 30% greater airflow to any given space, due to diversity in internal and external building loads. Supply air valves were married to their companion exhaust air valves located on the roof, which were installed under the infrastructure exhaust phase of the project. This allowed both supply air and exhaust air to be controlled in unison, based on fume hood and room temperature requirements. This is extremely important in a laboratory



Figure 4-New lab exhaust fans were provided at each quadrant of the building and manifolded together by a



Figure 5-Inside the top of each exterior shaft, 4-6 lab exhaust ducts originally terminated in a plenum. Each plenum was served by one or two of the 56 original exhaust fans. A venturi style air valve was installed on each duct during the renovation, and connected to the new medium pressure lab exhaust system.

environment, where good room pressure control is a must. Because of the extensive field survey which had been conducted, ductwork, piping, cable tray, conduit feeders and the like were highly coordinated during the design phase, resulting in much higher ceilings in nearly all of the areas. Previously, ceiling heights were a maximum of 8'-0", with some areas as low as 7'-6". New ceiling heights, even after including increased air flow rates to the floor, are 8'-6" over nearly 80% of the floor.

One area of the supply air renovation that posed significant challenges was the rebuilding of air handling units. Each air handling unit serves two or three floors. With one floor under renovation, one or two floors of the building still needed to be served by these supply systems 24 hours per day. A unique concept of "slicing the air tunnel in half" was used. An interior partition was installed during a short shutdown. This permitted one half of the air handling unit to be completely taken out of service for renovation, while the other half of the unit still functioned. Since 33% to 50% of the air handling unit capacity was not required while it's associated floor was being renovated, little impact was felt to floors not being renovated during the rebuilding of the air handling units. New outside air dampers, filter banks with prefilters and bag filters, steam coils, cooling coils, coil racks, and drain pans, as well as housing repairs, new fan shafts and bearings, fan motor and a variable frequency drive were installed in each air handling unit. When the first half of the air handling unit was completely renovated, it was activated and the other half of the air tunnel was shut down, completing the renovation of the unit. To date, two of the four main air handling units were renovated in this fashion. An additional unit is scheduled for complete renovation in the winter of 2002/2003.

Although the majority of renovated space in the Cummings Life Sciences Building is laboratory related function, each floor contains a suite of offices, conference rooms, computer labs, and similar "office type" functions. Because of the layout and constraints of the building, these office functions are served by the same air handling systems serving the chemical laboratories

on each floor. Unlike laboratory space, which by their very nature requires that no air be recirculated, office areas which do not communicate directly with laboratory space are safe to recirculate. A unique concept was developed to permit recirculation of these spaces. The only physical duct space in the building for return or exhaust air was within the 40 exterior masonry shafts of the building. During the first phase of construction, all duct risers within these shafts were attached to the new laboratory exhaust system. As each floor was renovated, it became apparent that approximately 15% of the air delivered to the floor could be recirculated, if a method of recirculation could be devised. During renovation, any exterior duct riser within the masonry shaft which served only office related space was disconnected from the general lab exhaust manifold on the roof, and instead connected to a return main running in parallel to the exhaust main (See Figure 6). The venturi style air valve installed in the first phase was retained to permit variable air volume of the offices. This method permits any of the 200+ exhaust risers in the exterior shafts to be converted to return air, merely by disconnecting an estimated ten feet of duct from the exhaust main, and reconnecting it to the return main. Complete flexibility is provided for future use to permit any area of the building to be converted from lab to office (convert exhaust to return air) or office to lab (convert return air to exhaust) by this concept. As much as 60,000 cfm is currently recirculated to main air handling systems using this innovated method of return air. This air would have otherwise been exhausted, increasing outside air cooling and heating loads significantly.

Laboratory spaces often have a need for large walk-in coolers, low temperature freezers, and extensive heavy equipment rooms. This type of equipment rejects a large amount of heat into spaces, which are generally confined. Although serving this heat rejection by increasing supply air to the space is an option, increasing supply air which is generally at 80-90% outside air is an inefficient way to handle this added cooling load. To handle these requirements in a more efficient manner, a process chilled water system was installed in the building. This process chilled water system circulates a water/propylene glycol solution via building risers to serve each floor. Water cooled walk-in coolers and freezers have been specified, and are served by this process cooling system. Heavy equipment rooms are each served by a



Figure 6- Photo after the 56 exhaust fans were demolished, with the building now served by new lab exhaust fans. Round white insulated ducts are return ducts serving certain duct risers within

supplemental process cooling fan coil unit. The ventilation load is still handled by the main supply air system. The process fan coil unit is a way to provide added supplemental cooling using recirculated air. This saves a tremendous amount of cooling energy, since the air circulated by the process cooling fan coil unit does not need to heat or cool outside air in order to handle the load. In addition, a large amount of fan energy has been saved, since low pressure fans within the fan coil unit require far less pressure and therefore horsepower per cfm than a central air handling unit system delivering air from the basement.

The process cooling system is served by three cooling sources. During hot weather when the building chillers are in operation, a plate and frame heat exchanger uses building chilled water as the source of cooling to the process cooling system. As ambient conditions fall below approximately 50 degree F, the need for central cooling is no longer required, and the main building chillers are shut down for the season. When this occurs, the process cooling source is diverted to a roof mounted air cooled chiller. This chiller operates in a highly efficient mode, since ambient temperatures at this point are relatively cool. A third source of cooling has been installed in the form of a dry cooler. Located upstream of the roof mounted air cooled chiller, the building automation system routes process cooling water first through the dry cooler anytime ambient temperature is below the process cooling return water temperature. If the dry cooler is not able to produce enough free cooling, the water/glycol is then routed through the air cooled chiller to provide additional cooling. The dry cooler has been designed to handle 100% of the process cooling load anytime ambient temperature is below 20 degrees F, permitting a 100% free cooling system.

Building and research requirements have grown significantly in the 32 years since this building was first built. The need to handle larger research equipment loads required that additional power be brought to each floor. In addition, certain specialty loads, such as walk in coolers/freezers and various other specialty equipment required a reliable source of power in the event of a power outage. In order to accomplish this, a new 2500 amp 120/208V 3 phase bus riser was installed, and a new electrical closet was created on each floor in a room formerly occupied by remote compressors for old walk in coolers. As each floor was renovated, the entire power system for that floor was converted over to the new bus riser. The original bus risers, which were inadequate to serve the load, were located inside center core shafts of the building, and only accessible from a catwalk system. Eventually, the original bus risers will be eliminated once all of the floors of the building are renovated. New power and lighting panels and distribution have been installed for each floor. Critical power needs have been separated and served by Critical Power Panels. Although currently fed from normal power services, circuiting the distribution into normal and critical needs will allow these critical loads to be easily served by a standby generator, which is part of a future phase of work.

Lighting in the building had previously been via two and four lamp T12 incandescent lighting with magnetic ballasts. Although requiring a huge amount of energy, the lighting system provided poor lighting levels and was outdated, especially in research areas. All new areas have been lit with new T8 lighting with electronic ballasts. Task lighting has been provided at every workstation and research bench. Lighting has been extensively zoned to permit researchers to turn on lighting only in local areas where they are working, should they be working at night or over the weekend. Lighting energy to each floor has dropped by approximately 50%, while at the same time providing a much

higher foot candle level in important areas and a reduction in space cooling requirements.

Many ancillary systems have been installed to meet the specific requirements of the building and specialized areas. A new reverse osmosis system has been installed. The non-recirculating aluminum piping system serving the original reverse osmosis was removed. A new fully recirculating reverse osmosis system was installed, dramatically improving the level of purity of the water. Consolidated dishwashing and autoclave areas were provided, helping to centralize these common elements of the building. An isolated moisture exhaust system was provided for this area. A BSL3 laboratory has been installed on one floor, permitting specialized research into clinical, diagnostic, teaching, and research with indigenous and exotic agents. High pressure dedicated exhaust fans with standby capabilities have been provided to serve the specialized BSL3 hoods in these areas. Room pressure monitors provide local audible and visual alarming, as well as remote BAS alarming in the event of loss of room pressure to this critical space. Multiple radioisotope systems with bag in/bag out HEPA filtration have been installed to serve the numerous radioisotope fume hoods located through out the building.

Conclusion

The renovation of the Cummings Life Sciences Building posed numerous design and phasing challenges. The unique architectural design of the original building coupled with the fact that the entire building needed to remain in service during each renovation phase required innovate solutions and full cooperation between all design and construction team members, including the owner, architect, engineer, and contractor. Initial phases of the project have been operating successfully since June of 2000. The results have been warmly received by the users, and have demonstrated that renovating existing structures for high tech research spaces can be a viable and economical option to building a new facility. This project received ASHRAE Illinois Chapter's 2002 Excellence in Engineering Award for engineering design demonstrating innovative ideas and solutions to problems.

Building Summary

Gross Sqft	162,000 square foot
Number of Floors	12
Total Supply Cfm	245,200 Cfm
Total Lab Exhaust Cfm	215,000 cfm, 10 fans (1 standby) + 2 future
Total Radioisotope Exhaust Cfm	16,000 cfm, 4 fans (2 standby)
BSL3 Lab Exhaust	8,000 cfm, 2 fans (1 standby)
Total tons of cooling	1500 tons
Complete Floors currently renovated	3, 5, 6, 7, 8, & 9
Partial Floors renovated	Basement, 1, 2, 4, 10
Estimated Construction Cost	\$22 Million
Number of phases of renovation	9
Process Cooling Load	65 tons + 65 tons future
Owner	University of Chicago
Architect	OWP&P Architects
Engineer	Ketchmark & Associates, Inc.
General Contractor	Meyne



Figure 7: Typical lab space before renovation. Poor lighting and comfort control as well as low ceiling heights contributed to a poor working environment.



Figure 8: Typical lab space after renovation. Ceiling heights are higher, lighting and thermal comfort has been dramatically increased, while also providing a much safer and energy efficient building.