Children's National Medical Center

Surgery Expansion Phase 1

Senior Thesis Final Report

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Construction Management

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Penn State AE 2008

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children's national medical center

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surgery expansion phase 1 project

project team

owner: Children's Hospital
project manager: KLMK Group, LLC
construction manager: Gilbane Building Company
architect: Wilmot/Sanz Inc
structural engineers: SK&A, P.A.
mep engineers: Leach Wallace Associates Inc

building stats

architect: Karlsberger Architects
size: 902,972 gsf
height: 311' - 11 stories above, 4 below
curtain wall: 1 3/4" tempered glass on steel frame
roof: tar and gravel on tapered insulation

project stats

size: 45,312 sf
project delivery method: cm@risk
construction dates: april 2007-december 2007
estimated cost: $ 10.2 million
location within building: floors 1.5, 2, 2.5 on north side including decontamination building

lighting/electrical

-substation is 4000 A with an 800 A automatic transfer switch to
-480 Y / 277 V 3Ø main power feed
-2 panels removed, 3 removed and reused, 25 new panels installed
-18 new transformers ranging from 112.5 KVA to 100 VA
- emergency generators for renovation are 1360 KW and (3) 900 KW
-all lighting fixtures are to be removed and replaced with fluorescent fixtures

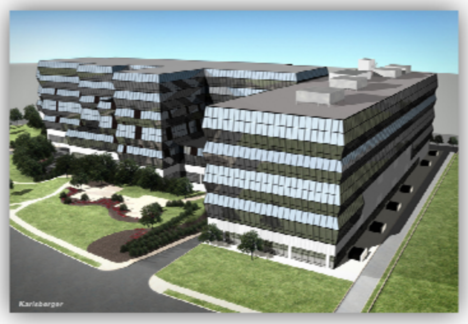
structural

-structural steel in a north-south moment frame
-lightweight one-way concrete slabs on composite deck of varying thickness
-typical 6' cantilever on alternating levels for curtain wall

mechanical

-removal of all existing duct work and piping to be capped and made safe
-installation of new air devices and fixtures
-one new custom air-handling unit of 17,000 CFM max capacity

CPEP address: http://www.engr.psu.edu/ae/thesis/portfolios/2008/akk139



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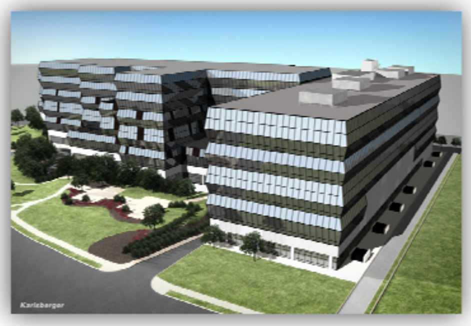

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Acknowledgements

Penn State Faculty

- Dr. John Messner - Construction Management
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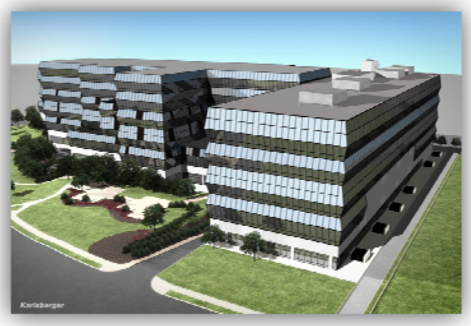
Industry Contacts

- Manfred Leckszas - Gilbane Building Company
- Kyte Picheco - Gilbane Building Company
- Ronald Barnett - Children's National Medical Center
- Todd Brodsky - Gilbane Building Company
- Scott Adams - Deckman Co.

Others

- Kristen Hlopick - Construction Management
- Sarah Burnett - My personal sounding board

Special thanks also to my family and friends for helping me stay motivated and giving me a reason to finish this.



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Executive Summary

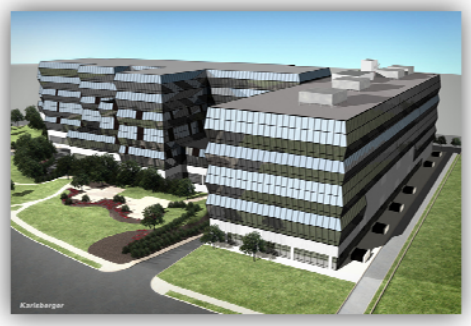
The Children's National Medical Center is a nationally recognized pediatric hospital located in Washington, DC. It is currently undergoing multiple construction projects including the six story east patient tower addition, an underground foundation expansion and the renovation of office spaces into surgical suites. The project being analyzed in this thesis report will be the Surgery Expansion Phase 1 renovation project.

This report will be divided into five sections. A brief summary of the existing building will be provided in the Building History section, followed by project specific information in the Project Overview. The Critical Research piece will discuss how prefabrication can be used to meet Infection Control Risk Assessment (ICRA) requirements. My two breadth studies will be provided in Technical Analysis 1: Resizing Mechanical Fans and Technical Analysis 2: Prefabricated Wall Panels. Backup information, charts and references will be included in the appendices at the conclusion of the report.

For my critical research I created a supplemental guide to the ICRA guidelines used in today's healthcare construction projects. The guide lists methods of prefabrication and their benefits as they relate to infection control on a project.

The first technical analysis is a mechanical breadth focused on resizing four fans being put into place which are designed for future duty. By sizing the fans for the correct demand load, money can be saved both initially and in operating costs.

Technical Analysis 2 is the implementation of prefabricated wall panels in the office spaces of the renovation. A cost and time savings analysis will be incorporated with an acoustical analysis of the system to determine if the walls can be redesigned.



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Building History

A Glance at CNMC

The original building was built in the 1970s, with the addition of the west wing in the 1990s, and the east wing and decontamination building in the last two years.

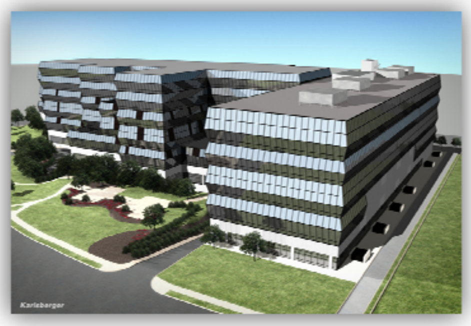
Owner/Occupant	**Children's Hospital**
Square Footage	**902,972 gsf**
Floors	**6** occupied
	5 interstitial
	4 below grade parking

Site Location

Children's National Medical Center is located in the Northwest corner of the District of Columbia. It is on the same campus as the Washington Hospital Center. **Figure A.1** below shows the local vicinity of the building.

Figure A.1: Vicinity Map

Children's National Medical Center



Building Systems Summary

Structure

Original Building – The structure of the original building is structural steel with composite one-way concrete slabs. The bays are 60′ x 30′ typical with the 60′ dimension spanning east to west. Typical finish floor to finish ceiling height is 10′-0″ with 3′-6″ of plenum space to the bottom of the interstitial decking. Interstitial floor to ceiling height is 7′-7″. The typical slab thickness is 6.25″ concrete on metal deck for the occupied floors. The interstitial floors have a 7 ½″-7.5 DC 16/16 cellular metal roof deck with no concrete or finished flooring.

West Wing – The west wing is of identical construction to the original building with exception to a few bays of size 30′ x 30′ in the most northwest corner of the building.

East Wing – The newest addition of the east wing is composed of 30′ x 30′ typical bays. The columns are all of W14 type. The smallest interior beam is a W14x22 and the smallest structural member is a W8x10 beam supporting a 6′-0″ cantilever. A north-south moment frame structure is created by moment connections in the structural steel. The slabs are 3 ¼″ lightweight concrete of 3000 psi strength on 3″ (20 Ga) metal deck.

Mechanical System

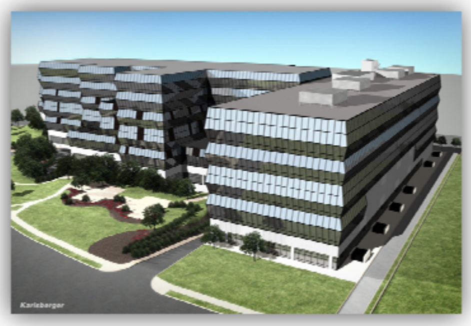
The original mechanical system in the building is complex due to the major changes it has gone through since its conception. It was designed to use interstitial floor levels to house all the components of the HVAC system and allow for more flexibility in changing the layout of each floor. This arrangement has remained primarily intact with the exception of a research lab housed on level 3.5.

Electrical System

The primary feed into the building is 480Y/277 V 3Ø. Main electrical feeds for the hospital are located on the fifth floor. Power is dispersed throughout the building with the use of 2500 KVA network transformers and 4000A network substations housing 3P-800A circuit breakers. The largest emergency generator is 1360 KW, and is supported with multiple 900 KW backup emergency generators.

Curtain Wall

An especially unique feature of the hospital is its accordion style glass curtain wall. Using glass as a façade is atypical in the DC area, and the shape provides a distinct look. All the glass units are fully tempered insulating glass units approximately 21/4" thick. Spandrel units are located at the interstitial levels to hide the unfinished spaces, and all the units are tinted.



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Project Overview

Surgery Expansion Phase 1

Client Information

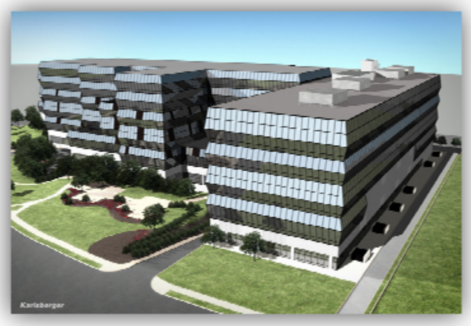
The Surgery Expansion Phase 1 project is an elemental piece of the grand plan for Children's National Medical Center (CNMC). With newer technologies and treatments being discovered, CNMC wants to be able to provide the best services from the best doctors. This renovation is not only a much needed update of older facilities, but also an expansion of capacity for a growing population. The two new operating rooms and support areas are accommodated by the new east addition patient center currently in the final stages of construction.

Cost concerns for this project are few, as the goal is to build top-of-the-line facilities with the best technology available. High quality is the main priority with cost following as a secondary issue. The schedule for this project the second major concern, as the ten (10) month schedule was pushed back repeatedly due to hazardous materials in the original construction. With the newest schedule recently provided, it will be both extremely important and difficult to maintain the schedule and finish the project on time.

Safety concerns for the project lie primarily with infection control and working within an occupied space. There is no exterior staging area so all the work must be performed within the building perimeter, and under the cleanest of conditions. Special considerations and procedures are already in place to prevent the infiltration of dust to the rest of the building, and to maintain a clean work site. Workers have distinct travel paths and operating procedures. To create a limited impact on the surrounding areas specific working hours have been arranged and any major shut-downs for tie-ins to the mechanical system will be performed during night hours.

Noise contamination is a large concern for this project as well. Some departments close to the construction include the Critical Intensive Care Unit (CICU and the Neonatal Intensive Care Unit (NICU). Special demolition and installation procedures have been outlined in the contract to keep noise and vibration to a minimum in these areas.

The phases of the project are designed to reduce the congestion within the occupied hospital during construction. Phase 1A consists of two new operating rooms, locker rooms, and offices and supply areas to support the surgical staff. It also includes the fit-out and renovation of the new decontamination building to achieve occupancy. Phase 1B is the renovation of the on-call nurse's station, registration and reception areas, and waiting areas for the new surgical suites.



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Project Locale

To limit the impact of construction on the hospital the surgery expansion project was split into two phases: 1A, 1B. Phase 1A includes the majority of square footage with the offices being converted to operating and locker rooms, and the decontamination building. Phase 1B contains the renovations being made to the on-call, reception and registration, and waiting areas designated on the second floor. The demolition for both phases will be completed at the same time to limit the hospital's exposure to dirt and dust. Please see **Figure B.1** for the phasing plan and **Table A.1** for more information on the square footage.

Figure B.1: Key Plan

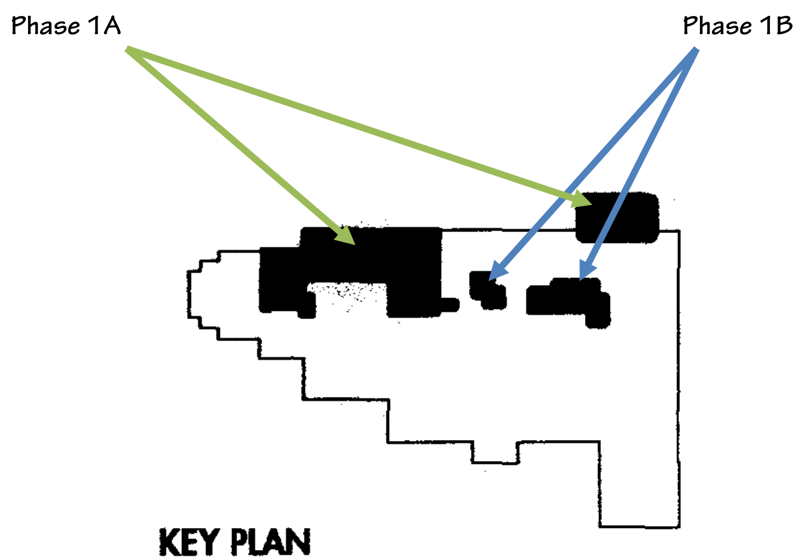


Table A.1: Project Details

Floor	Square Footage	Height
1.5	77,200	7'-7"
2	45,312	14'-0"
2.5	77,200	7'-7"

Demolition

Due to the nature of this project as a renovation in an occupied space, demolition is a special issue. The materials being removed include but are not limited to drywall, finished floors, electrical conduit and panels, telecommunications installations, framework, and mechanical systems elements. A separate contractor was hired for demolition of the general elements, and each specialty contractor is responsible for demolition of materials within their respective bid package. Part of the demolition is to cut, cap and make safe any electrical wiring.

Prior to construction, testing was performed and asbestos was found in the building, which was originally built in the 1970s. The owner was responsible for hiring a certified contractor for abatement before the rest of the demolition and construction could commence.

New Mechanical Work

A large portion of the project is updated the mechanical systems to meet the requirements of operating rooms. The mechanical renovations for the surgery expansion project required the demolition and removal of all duct work, air devices, dampers, valves, fittings, hangers, insulation and piping unless noted. The contractor will cut, cap and make safe at the level of the metal decking any penetrations no longer in use. Most existing thermostats and connections are to be removed as well. The hot and chilled water lines, low pressure steam and medical gas lines are also being removed. Four air-conditioning units are being removed, and replacement for the nitrous oxide manifold is being considered.

All necessary duct work and piping required for the new layout will be installed. A new medium pressure steam line will be installed for sterilization purposes. Special focus will be on the installation of the new air-handling unit custom designed to for the decontamination area. The new unit has a maximum capacity of 17,000 CFM, but it is designed for future use, and will be operating at a maximum capacity of 8,500 CFM at occupancy. Four other new modular air-handling units will be installed for the surgical suites and the support areas.

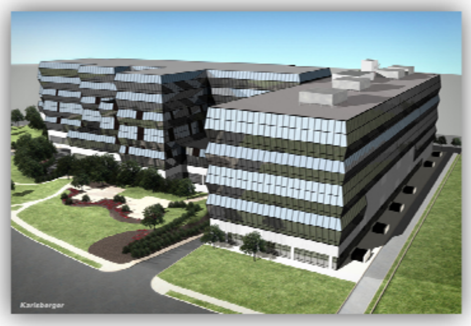
Local Conditions

Parking – Parking for construction on this site is difficult. No contractor vehicles are allowed to park in the garage below the building, and may park in the lay-down areas with permission from the GC. All contractors are encouraged to bring employees to site in large passenger vans, which there are spaces to park on most occaisions. If any separate vehicles need parking, including the GC staff, there is a public garage located adjacent to the Washington Hospital Center one block north. These garages have daily fees, but are usually reimbursable. Alternate metered parking is also located on First Street, NW between Michigan Avenue, NW and Channing Street.

Recycling –The materials recycled from site are glass, metal and wood. Each material is placed in a separate dumpster, and tipping fees depend on the amount of material being removed. Typically a thirty (30) yard dumpster costs $440 dollars plus fuel and DC tax which is 5.74%. One company is paid to provide this service and is called one (1) day prior to date of dumpster replacement.

Project Schedule

The detailed project schedule is supplied in **Appendix A**. The construction was originally scheduled from April 2007 to December 2007. Due to the asbestos found and the requisite abatement the schedule was adjusted to begin in October 2007 to September 2008.



Project Estimates

Note: All cost/square foot calculations use the square foot measurement from Level 2 ONLY.

Actual Building Construction Cost

Construction Cost (**CC**) = **$8,425,866**

Construction Cost/Square Foot (CC/SF) = $185.95/sf

Note: This does not include permitting and asbestos abatement costs.

Total Project Cost

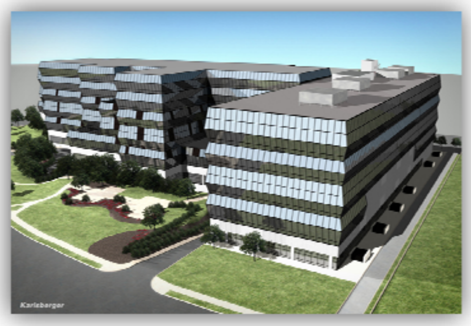
Total Cost (**TC**) = **$10,200,215**

Total Cost/Square Foot (TC/SF) = $225.11/sf

Note: TC=CC+ overhead +fee + contingency + profit.

Building Systems Cost

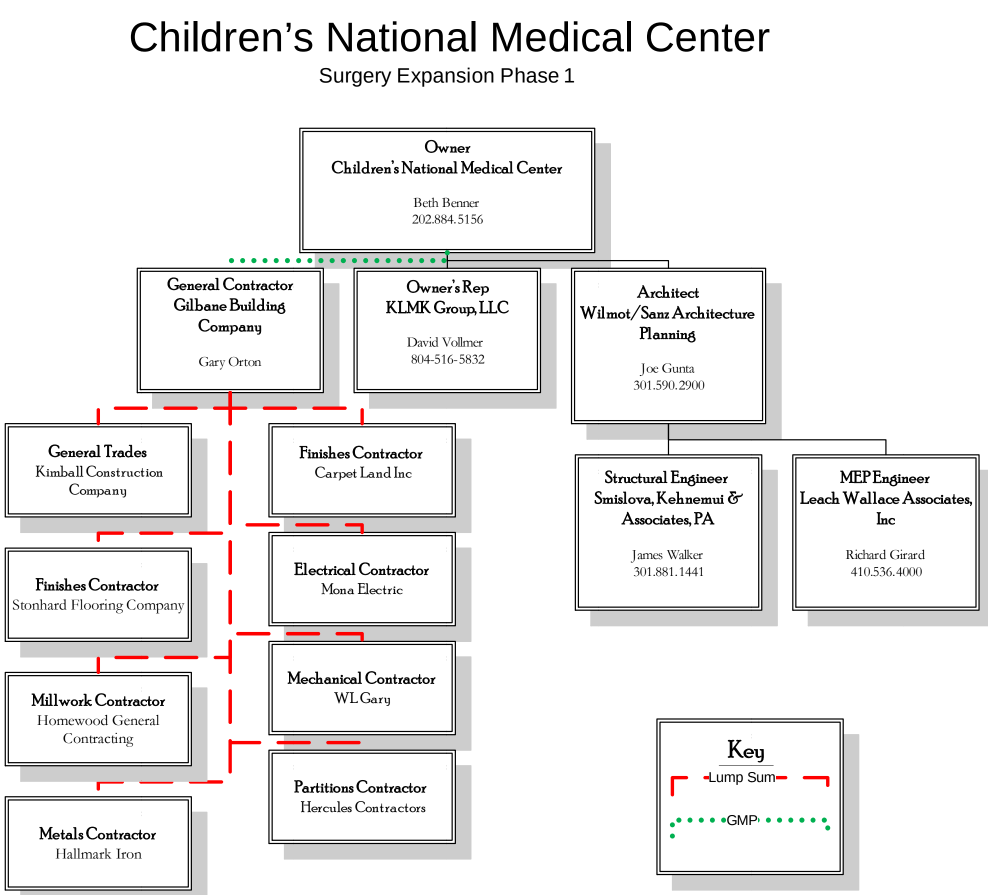
- Mechanical & Plumbing = **$3,165,325**
  Cost/sf = $69.86/sf
- Interior Finishes = **$1,043,463**
  Cost/sf = $23.03/sf
- Electrical = **$2,223,262**
  Cost/sf = $49.07/sf
- Fire Protection & Spray Fireproofing = **$395,202**
  Cost/sf = $8.72/sf
- Structural and Miscellaneous Metals = **$127,641**
  Cost/sf = $2.82/sf
- Demolition and Temporary Partitions = **$298,046**
  Cost/sf = $6.58/sf



Project Delivery System

The surgery expansion project is a design-bid-build delivery method. Gilbane put in a bid to Children's National Medical Center and was awarded the project in the spring of 2007. Negotiations for a GMP contract commenced, while Gilbane bid the thirteen (13) various packages to trade contractors. All of the contracts with trade contractors are lump sum contracts. Children's National Medical Center has an owner's representative of KLMK Group, LLC, specializing in hospital construction, to oversee all of its projects. Prior to construction asbestos was discovered, and the hospital holds a separate contract for the abatement process not shown on the following chart, **Figure C.1**

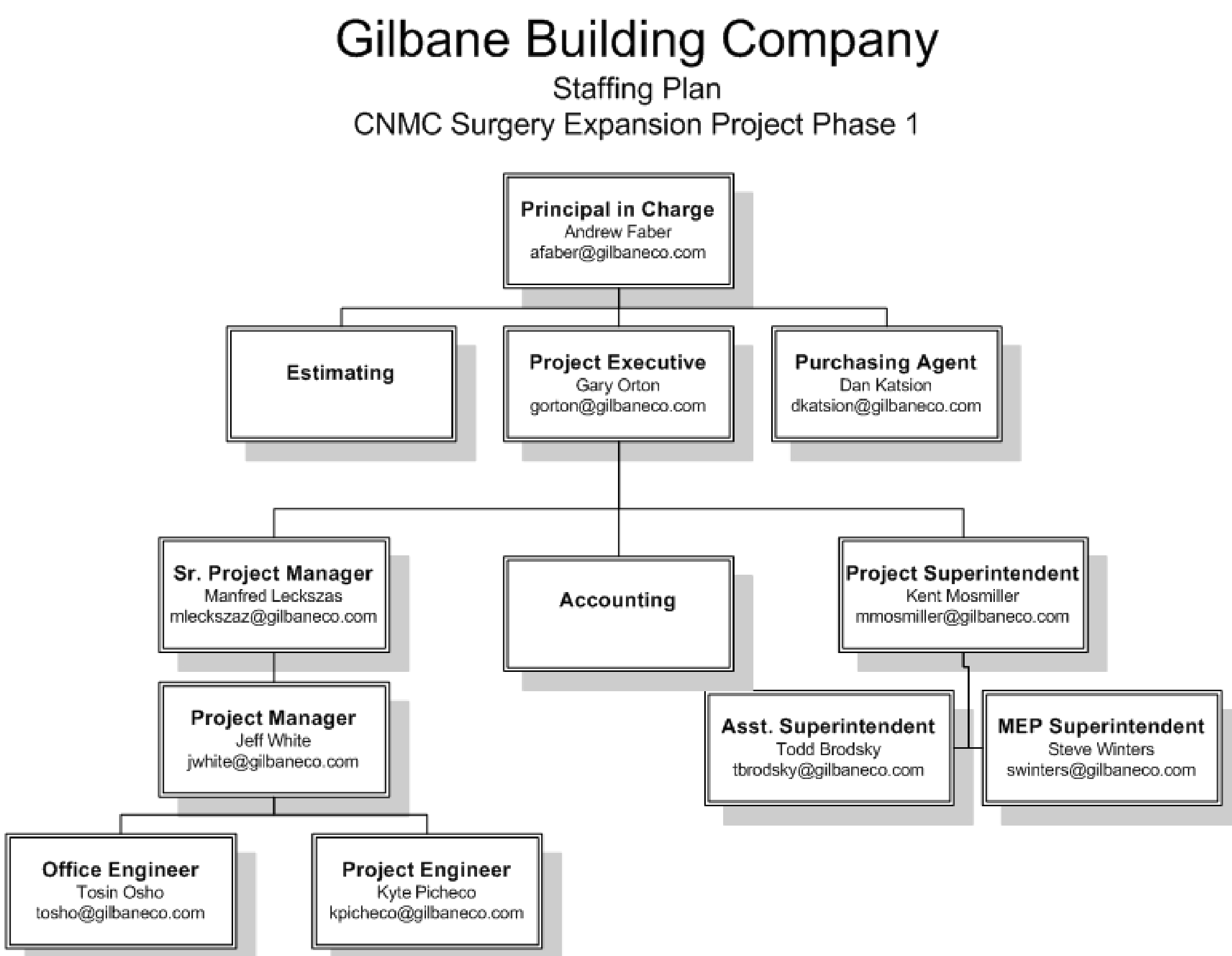
Figure C.1: Contracts Chart

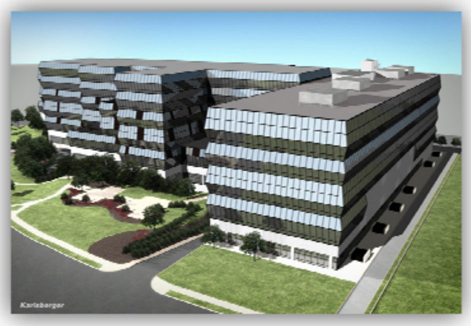


Staffing Plan

The staffing situation on the surgery expansion project is unique. Gilbane Building Company currently has two projects underway at Children's National Medical Center. Both projects share the exact same staff except for the Assistant Superintendent. The temporary offices are located within the available shell space in the hospital, making it easy for the project staff to oversee the construction. No work is self-performed by Gilbane. Please see **Figure D.1** below for the staff organization.

Figure D.1: Staffing Organization Chart





Critical Industry Research

Prefabrication and Infection Control Risk Assessments

Problem Statement

Hospital renovations and expansions are an integral part of maintaining the health care system in the United States. Unfortunately, to meet to the continual needs of the public, these projects must typically be conducted while the rest of the hospital continues to operate. Working in partially occupied spaces is not a new concept for the construction industry however the risk of contamination and infection in an occupied hospital is a particular cause for concern. Renovated hospitals are not the only projects which require an ICRA, in fact all healthcare facilities, new and renovated, require ICRA procedures when under construction. While the implementation of ICRAs in healthcare construction has alleviated many of the problems, there are new technologies which may provide more or better solutions.

Prefabrication is one possible solution to alleviate contamination in occupied and new spaces but there remains little to no information on what extent of prefabrication can be used, and what possible cost and schedule savings may also result.

Research Goal

It is the goal of this research to examine the effects of prefabrication on healthcare projects in relation to the ICRA regulations. The focus of this research is to see if there is evidence in support of using prefabrication methods to reduce infection risks, and if so, which methods are the most beneficial. Possible benefits include better isolation and reduced contamination, schedule reduction, onsite labor reduction, and cost savings.

The research over the coming semester will enable the creation of a guide with prefabrication ideas to implement on healthcare projects where infection control is a major concern. There are practices already in place by certain contracting trades which will provide examples and experience to compare to newer ideas. The guide will be for the use of owners, contractors and facility managers to aid in using prefabrication as a means of better meeting the ICRA guidelines set forth by the American Institute of Architects (AIA).

Research Steps

1. To obtain a true understanding of the current ICRA regulations. Read the guideline established to confirm the feasibility of the research being put to use.

2. Research statistics on healthcare projects to create a firm basis of need and verify the target audience.

3. Contact contractors who are familiar with healthcare projects to obtain different means and methods of construction and prefabrication.

4. Compile data from these contacts to determine how best to format a guide, and to provide further direction on which trades to focus on.

5. Research prefabrication methods provided and any other technology to help maintain ICRA regulations.

6. Determine the format of the supplemental guide based on most advantageous and compatible with the ICRA guidelines.

7. Create the guide for prefabrication in healthcare projects using language friendly to owners, designers, and contractors. The hope for this guide is to create something which can be implemented early in a project for the maximum benefit.

Sample Interview Questions

The letter sent to the industry contacts and their transcribed responses are found in **Appendix B.

Are you familiar with the 2006 ICRA guidelines established by the AIA?

Have you used ICRA guidelines for past or present healthcare projects?

Did you have difficulties in maintaining any of the procedures outlined in your program? If so, what were they, and how did you attempt to solve them?

Was prefabrication used to any extent during your project?

What trades, methods, or specific technologies did you use for prefabrication, and how well did they work?

Do you think fabricating materials and systems off site is a viable option to help maintain the ICRA guidelines?

Did you have problems with construction interfering with the surrounding occupied spaces? If so, what were they, and how large was the impact?

Understanding ICRA

Researching ICRA guidelines was an elementary task, but it truly provided me with a much clearer understanding of what to look for in my research. The construction guidelines are a short document with instructions on how to classify a healthcare project based on type of the work being performed and the area it is to take place in. There are more rules to follow during design for healthcare systems, but focusing on the construction aspect provides a closer look at a unique piece of the puzzle.

The class system is simple but very informative. There are four construction types with a list of what activities fall into each, and are very well defined. Once a type is selected, the patient risk category must be selected. Patient risk is based on the location in a facility, and what health issues a specific group of patients have. With the type of construction and patient risk known, there is a chart which determines what class the construction falls under. The classes each have a set of rules to follow for managing the risk of infection. What I found to be most interesting, was how the rules focus primarily on keeping the site clean and isolated from the other areas. This is essential to reducing infection, but my propositions is less time and money can be spent on cleaning if the design includes prefabrication.

Initial Conclusions

Research into the ICRA guidelines allowed me to determine what benefits of prefabrication align with the spirit and mission of healthcare projects. Using prefabrication on construction sites is known to have distinct advantages; better quality, fewer laborers on site, and savings in labor costs are a few. In a healthcare situation where quality of construction and safety of the patients is paramount, prefabrication seems to be a clear choice. By constructing pieces off site the quality is greatly improved and more uniform which affects the performance of the facility once in operation. Also, laborers do not have to deal with the weather which a major concern for maintaining material integrity in a healthcare facility. Removing the laborers from site also goes with the ICRA guidelines, in that there are less people who may contaminate areas surrounding the construction when they leave the site. One of the major guidelines is how workers leave and enter the site and the clothing they wear. The other major advantage I can think of is ease of scheduling. Especially in renovation projects or projects which are taking place in an occupied space, scheduling activities around the facility schedule can be difficult. Moving larger pieces into the facility requires less time be spent on site, and allows more work to be done in a shorter amount of time which makes working during nights and weekends a litter more palatable.

Another factor to note, which will be presented in the supplemental guide, is prefabrication is not directly applicable to the construction Types A and B due to the nature of the work being performed. By establishing this assumption, I recognize Classes I and II cannot apply prefabrication either. This guide will list prefabrication activities to be used for Class III and IV construction activities, and will note which class the activity falls into.

Research Methods Used

The research methods used to obtain the information were varied and extensive. I started my research by contacting people within the Architectural Engineering department who could offer advice or provide other contact information. Through these individuals I received information, articles pertaining to my search, and the copy of the ICRA guidelines used in this project. Once I felt I understood the guidelines and their intent, I expanded my search to the library search engines and found more articles to apply. These articles were essential to helping me move forward by establishing the feasibility of this study. The next step was to begin interviews, which were conducted via email and telephone.

Interviewees were industry members who had worked on a healthcare project before and were familiar with the ICRA regulations. By utilizing people in industry, I learned what misconceptions exist about prefabrication and why the industry is resistant to fully implementing prefabrication. One interview was with an estimator, and provided particular insight into cost data and what costs the owner is willing to pay for. These interviews also provided me with information about what the largest problems are when maintaining the guidelines and where to begin my research into new methods.

The bulk of my research was conducted via the internet in an attempt to provide a broad range of prefabrication options. Product catalogs and testimonials allowed me to weed out viable options and come up a list of advantages and disadvantages for all the methods mentioned in the supplemental guide.

Standard Prefabrication Techniques

The interviews I conducted provided me with information about what prefabrication methods are currently used most often, and what types of prefabrication might be utilized in the future. Below is a list of these methods.

- Ductwork Prefabrication – Prefabricating ductwork is one of the most typical methods seen today. The quality of the sections is much higher and the work is performed in less time. Working at table height in a fabrication facility increases the quality because workers are not working overhead, which takes more time and energy. Cleaning the ductwork and preparing it for transfer to the site is also more efficient and thorough. The cleaner ducts are a great advantage to preventing infection spread and help to meet the ICRA guidelines.
- Plumbing Prefabrication – Plumbing and piping prefabrication off site is also a common method used. Especially in situations where there are multiple connections in a small area. One example is gang assemblies for restrooms and locker rooms. When fewer connections are made on site there is less welding taking place which reduces the amount of gas released into the space, and there is less packaging debris on site as well.
- Medical Gas Prefabrication – Medical gas requires special pumps and piping to maintain sterile conditions and has strict testing requirements. Fabricating off site reduces the connections made on site and reduces the risk of contamination. It also allows for simpler connection methods to be used and reduces the need for welding on site.
- Modular Buildings – While not applicable to large hospital facilities, modular buildings are a popular method of construction smaller healthcare projects. Private doctors offices, independent labs, clinics and outpatients centers can be constructed as a whole unit or combination of units and relocated once complete.

Untapped Prefabrication Technology

Through my interviews and research, I also discovered new technologies which are not yet widely used in the construction industry, or which may need more development before being used. A list of these methods is found below.

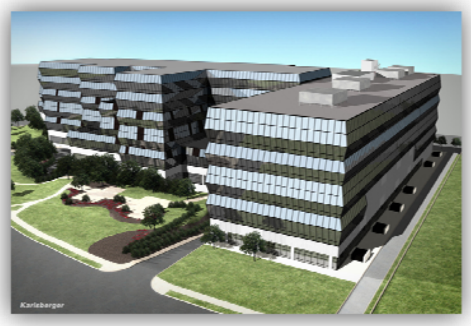
- Wall Unit Prefabrication – One of the major concerns of healthcare construction is dust contamination due to drywall installation and partition construction. The cutting and sanding involved produces a large amount of dust which is handled by the negative air pressure and HEPA filters. Reducing the amount of dust produced on site would be beneficial, and prefabrication wall unit is a viable solution. In one interview it was mentioned this had been attempted, but due to the size restraints for moving the pieces they had to revert back to traditional methods.
- Roof Prefabrication – Prefabricating a roof may seem daunting but is possible, and has distinct advantages for healthcare projects. Work on the interior spaces cannot be performed until the building is completely enclosed to reduce the effects of water penetration. A prefabricated roof takes less time to install on site, has better quality construction especially around the penetrations, and reduces the number of joints made on site. This also has advantages for retrofit, when leaking needs to be stopped.
- Floor and Ceiling Prefabrication – For modular systems prefabricating in large units has the benefits of improved quality and reduced installation time. It also makes repair easier in some applications as more units can be ordered and put into place quickly.

Criteria for the Guide

All the methods examined in the guide were researched for advantages, disadvantages, applications, non-ICRA related benefits and cost. The level of prefabrication is also indicated in the guide, as not all methods are complete assemblies. In order to be considered a prefabricated material, I required the product to eliminate at least one elemental step of its comparable traditionally built system.

Prefabrication Supplemental Guide

The supplemental guide can be found in **Appendix C.**

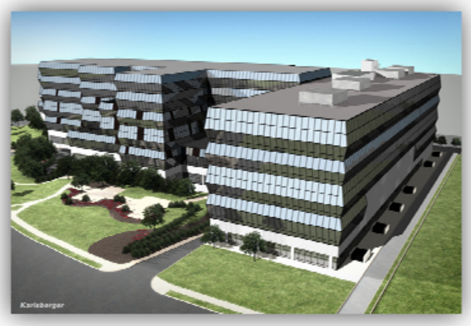


Conclusions

My conclusions for this research are based on the ability of prefabrication methods to alleviate problems typically faced in meeting the ICRA regulations. One important piece of using prefabrication is the when the decision to use it is made. The designers and facility staff are responsible for incorporating ICRA regulations into the contract documents, and should make a decision to use prefabrication early in the project. As with any type of project, prefabrication requires intense planning and the design must facilitate modular systems. It is also essential to specify which materials are to be used, as there are many products with different installation recommendations. The contractor must be aware of this, and plan for prefabrication in their bid.

Another discovery was that most of the hesitancy to use prefabrication systems is largely related to cost. While there are distinct advantages in using prefabrication in healthcare, many owners do not want to pay for it. It is a misconception that prefabrication is more expensive than traditional building methods, but poor planning is largely to blame for this idea. In order for it to be cost effective, it must be implemented early in the design phase, planned extremely well, and scheduled to allow for all the trades to complete their part.

This guide will enable designers, owners and contractors as to choices they have to protect the patients, staff and integrity of a healthcare facility when under construction or renovation.



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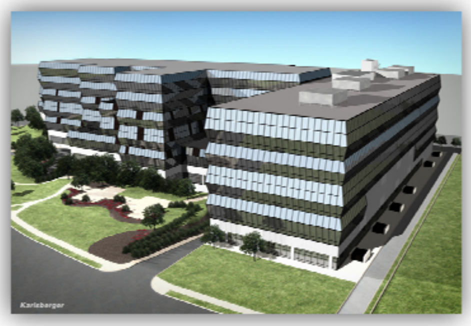


Technical Analysis #1

Resizing Mechanical Fans

Problem Statement

The Surgery Expansion Phase 1 project is one piece of the Children's National Medical Center's large expansion plan. Having recently added a six-floor patient tower, this project is the renovation of some recently vacated spaces. The two new operating rooms and support areas being built require new configurations for the mechanical systems and new equipment. Updating the systems is crucial to meeting demands for the most current technologies and procedures. The plans for expansion are aggressive, but are not yet finalized and may take years to put into place. In this project, several of the elements are sized for future duty, but are too large to operate efficiently at the current demand load. This mechanical breadth will be a value engineering exercise to right-size three mechanical fans which serve the new spaces.

Goal

This analysis will be an exercise in sizing equipment for the current design and determine if the initial savings and reduced operating costs are significant enough to change the equipment specified. I hope the more efficient equipment will result in a significant savings for the owner and have a short enough return period to justify waiting to install the larger equipment.

Research Steps

1. Calculate the current demand loads and compare them to the values provided.

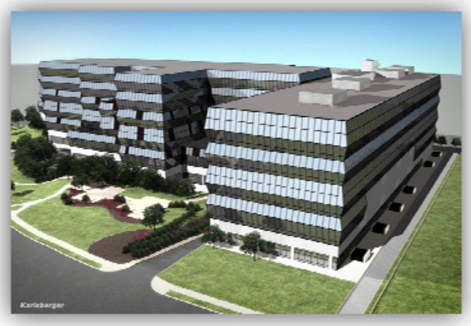
2. Obtain fan efficiencies for the current loads on the original fans.

3. Determine which fans are the most efficient at the current loads to replace the fans as designed.

4. Calculate operating costs for both old and new fans for the next five years and ten years.

5. Obtain cost information from company representative and verify fan choices.

6. Calculate total savings for reducing fan sizes.



Tools Used

- Dr. Freihaut of the AE departments as breadth consultant.
- Twin City Fans- Fan Selector Software
- Deckman Company of Johnstown PA – *for pricing and verification*
- Titus Blower and Fan - Performance catalogue sheets
- Energy Information Administration online

Load Comparisons

Table M.1 shows the design loads as specified on the drawings, the current demand load as stated by the specifications, and the hand calculated loads. More detailed tables with the fan load calculations are provided in **Appendix D**.

Table M.1: Fan Load Comparison Chart

Fan Unit	Location	Design Load		Current Demand Load		% of Design Load	Hand Calculated Load	% of Design Load
		cfm	wg	cfm	wg		cfm	
SF-26B-1 (x2)	DECON	8500	8.5	3685/2960	3.5	21.7	3685	21.7
RF-26B	DECON	15300	3.5	2720/1995	3.5	17.8	2515	16.4
RF-12B	LOCKER	15365	2.5	8450/6220	2.5	55.0	8085	52.6

New Fan Selection

Taking the corrected demand loads, I downloaded Twin City's Fan Selection software. Twin City Fans were the specified manufacturer and to eliminate confusion, I decided to keep the new fans the same. Difficulties in selecting the new fans came primarily from unfamiliarity with the software. The selection software provides all the fans that fit each parameter, and determining the best fan requires the conversion of brake horsepower to kilowatt hours. With the software I was able to obtain a new fan selection for the supply fan and the return fan 12B. Return fan 26B was rejected by the software, with a message that no fans could be found. I decided to find a fan using trial and error, and the fan selected for RF-12B can be set at the RF-26B settings.

With the new loads I looked up the mechanical efficiency of each original fan running at the demand load. The fan selection software allowed me to determine the mechanical efficiency from the fan curves and the operating brake horsepower. All the fan curves are available in **Appendix E**. The next calculation was a simple conversion of brake horsepower to kilowatts and kilowatt hours.

Pricing and Selection Verification

Pricing for the fans is not available with the selection software, so a representative was contacted to obtain the initial cost information. A representative of Deckman Co. in Johnstown, PA provided the pricing information and final specifications on the fans and motors required. I compared my selections with his, and was please to discover I made the correct choices. He also confirmed there were no fans designed to handle the loads for return fan 26B. The fan selector program will not provide a fan to meet the parameters, however, since I had found a fan that could maintain the settings, I decided to follow through with the calculations to see if any money could be saved. The initial cost savings shown in **Table M.2** were not as high as I anticipated, but do save the owner money.

Table M.2: Initial Cost Savings

Fan Name	Fan Type	Cost	Savings
SF-26B-1	EPFN 182, Class III	$2,721.00	
	EPFN 165, Class II	$2,125.00	$596.00
SF-26B-2	EPFN 182, Class III	$2,721.00	
	(eliminated)	$0.00	$2,721.00
RF-26B	TCVX 32B6, Class II	$5,034.00	
	TCVX 21B7, Class I	$4,473.00	$561.00
RF-12B	TCVX 32B4, Class II	$6,037.00	
	TCVX 21B7, Class I	$4,473.00	$1,564.00
		Total Savings	**$5,442.00**

Taking the values obtained from the fan curves and the calculations for kilowatt hours the savings in operating costs were calculated; see **Table M.3.** These operating prices are based on a value of 11.17 cents/kWh reported by the Energy Information Administration for the District of Columbia in 2006. I assumed there will be a 4% increase in price per year, and the fans begin operation in 2008 at a value of 11.61 cents/kWh. The table below only shows the final calculated savings for one year, five years and ten years, the complete spreadsheet can be found in **Appendix F**.

Table M.3: *Operating Cost Savings*

Fan Name	Fan Type	Settings	KWH/yr	Operating Cost		
				1 yrs	5 yrs	10 yrs
SF-26B-1 (x2)	EPFN 182	Design	109787.3	$12,746.31	$66,280.81	$132,561.61
	Class III	Demand	19147.43	**$2,223.02**	**$11,559.69**	**$23,119.38**
	EPFN 165	Demand	21826.77	**$2,534.09**	**$13,177.26**	**$26,354.51**
	Class II		**Savings**	**$311.07**	**$1,617.57**	**$3,235.13**
RF-26B	TCVX 32B6	Design	88091.26	$10,227.40	$53,182.46	$106,364.91
	Class II	Demand	34700.64	**$4,028.74**	**$20,949.47**	**$41,898.94**
	TCVX 21B7	Demand	21761.42	**$2,526.50**	**$13,137.80**	**$26,275.61**
	Class I		**Savings**	**$1,502.24**	**$7,811.67**	**$15,623.33**
RF-12B	TCVX 32B4	Design	66983.34	$7,776.77	$40,439.18	$80,878.36
	Class II	Demand	66591.24	**$7,731.24**	**$40,202.46**	**$80,404.93**
	TCVX 21B7	Demand	50123.14	**$5,819.30**	**$30,260.34**	**$60,520.69**
	Class I		**Savings**	**$1,911.95**	**$9,942.12**	**$19,884.24**

The new supply fan actually shows an increase in cost, while the new return fans show a significant savings. It would be up to the discretion of the owner if they wanted to change the fans from the original design.

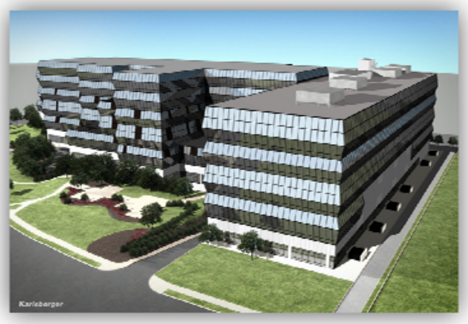
<u>Final Recommendations</u>

Given the lack of information on the development of the future designs, it is difficult to say when the fans need to be called into future duty. If the fans will not be called into the future duty settings within five years, my recommendation to the owner would be to use the new selections for the return fans, keep one supply fan as designed, and eliminate the second supply fan. The locations of the fans are close enough to access if replacement is necessary, and once the higher settings are needed, more work will be done to the mechanical system in the interstitial spaces anyway. However, if the fans will be operating as designed within two years I would recommend installing the original design fans.

Assuming the expansion will not be done within five years, the optimal savings are provided below in **Table M.4**.

Table M.4: Optimal Fan Selection

Fan Name	Fan Type		Initial Cost		1 Year Op. Cost		5 Year Op. Cost	
	Original	New	Original	New	Original	New	Original	New
SF-26B-1	EPFN 182, III	N/A	$2,721.00		$2,223.02		$20,949.47	
SF-26B-1	EPFN 182, III	N/A	$2,721.00		$0.00		$0.00	
RF-26B	TCVX 32B6, II	TCVX 21B7, I	$5,034.00	$4,473.00	$4,028.74	$2,526.50	$20,949.47	$13,137.80
RF-12B	TCVX 32B4, II	TCVX 21B7, I	$6,037.00	$4,473.00	$7,731.24	$5,819.30	$40,202.46	$30,260.34
		Total	**$16,513.00**	**$8,946.00**	**$13,983.00**	**$8,345.80**	**$82,101.40**	**$43,398.14**
		Savings	**$7,567.00**		**$5,637.20**		**$38,703.26**	



Technical Analysis #2
Prefabricated Wall Panels

Problem Statement

A large portion of the renovation project is building new walls for the offices and support areas for the surgical suites going into place. The walls are designed to be stick built with metal studs, drywall, and in some case acoustical batting insulation. During construction a large amount of dust is generated from the drywall construction, and while a negative air pressure machine is being used to control it, a reduction of dust produced would benefit the patients in the surrounding areas by minimizing the risk. This analysis will replace three wall types with hardboard wall panels to reduce the amount of dust produced on site.

Goal

The main goal of this exercise would be to reduce the amount of dust generated on site, which is not directly measureable without extensive testing and is not discussed in the conclusion. Since prefabricated panels are being used, this study will focus on the reduction of project cost and the reduction of scheduled time for the construction of the interior walls. The acoustics of the new wall design will also be calculated to show the new system is acceptable for sound transmission.

Research Steps

1. Determine which wall types can be replaced.

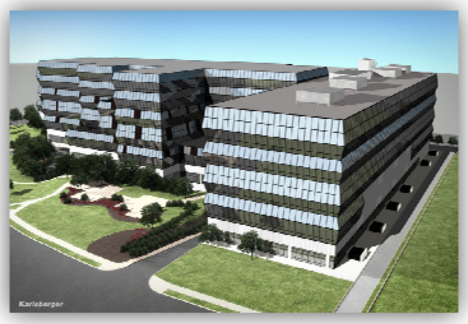
2. Calculate cost, schedule and sound transmission coefficient (STC) for the original wall system.

3. Research and select a wall panel system to replace the original design.

4. Contact manufacturer to determine limitations of the materials and gain better insight into the panel system.

5. Design the new wall system.

6. Calculate the cost, schedule and STC for the new wall system.



7. Compare the results of the new design to the original design and make a recommendation.

Tools Used

- RS Means 2008- Light Construction Costs
- AutoCAD- for detail drawing
- Affordable Building Systems – Prestowall System Manufacturer's Data
- Architectural Acoustics: Principles and Design by Madan Mehta, Jim Johnson, Jorge Rocafort

New Wall System

The new wall system selected to replace the original stud walls is the Affordable Building Systems' Prestowall system. It was selected to serve as the base of the new system due to its ease of construction, superior STC and material properties as a natural product. These panels are still taped and sanded at the edges, and can be finished the same as drywall. The panels will be delivered to the site in pallets of 20; each panel sized 10' x 4' x 2.25" and weighing 160lbs. With the Prestowall system, no studs are needed to hold panels, which already have two vertical electrical conduits installed in each panel. Shipping costs and electrical trade cost savings will not be discussed in this analysis.

While the intent of this study was to replace as many wall types as possible, only three types could actually be replaced. The Prestowall system is not fire-rated, and would require fire-rated drywall to be adhered to it to meet the code. Installing drywall on top of the system defeats the purpose of using prefabricated systems to eliminate dust.

The wall types being replaced are Type 2, Type 3 and Type 3A. Detailed sections for the original and new system design can be found in **Appendix G**.

System Design

Each type of wall will be similar in its new construction to the original. Type 2 will have drywall up to 10 feet and the upper track will attach to metal studs hanging from the upper deck. Type 3 and 3A will also have 10' panels connected to 4' of metal studs, however the metals studs will be have drywall adhered to them, and in Type 3A acoustical batting insulation will be installed. The height of 10' panels is based on the system's capacity and the ceiling height. From the top of the panels there is 4' to the underside of the interstitial decking. This dimension was selected to minimize the amount of drywall cutting, as 4' is the standard width for drywall.

Cost and Schedule Comparisons

The full spreadsheets for cost and schedule can be found in **Appendix H**. A synopsis of the savings is shown in **Table P.1** below. The durations below are calculated as total duration, not billable labor hours.

Table P.1: Cost and Schedule Savings

Wall Type	Original		New System		Savings	
	Cost	Duration	Cost	Duration	Cost	Duration
2	$5,861.16	69.95	$5,150.36	51.59	$710.80	18.36
3	$23,700.18	286.78	$18,622.38	201.36	$5,077.80	85.42
3A	$84,947.66	971.73	$56,594.19	623.56	$28,353.47	348.17
Total	**$114,509.00**	**1328.46**	**$80,366.93**	**876.51**	**$34,142.07**	**451.95**

Acoustic Calculations

Implementing a new wall system with the significant savings shown above requires more analysis than just cost and schedule. The nature of conversations in a hospital and a patient's right to privacy need to be respected, and the walls must do their part. A direct comparison of STC (sound transmission coefficient) cannot be made, so to evaluate the new wall systems, a privacy rating was used. With the privacy rating a partition can be categorized as worse than normal privacy, normal privacy, or confidential. I evaluated the original design walls to provide a baseline and then compared the new system to those results. See **Table P.2** below for the results.

Note the abbreviations used: **STC** – Sound Transmission Coefficient, **RR** – Receiving Room property, **N + 8** – Background Noise in the Receiving Room, **VL** –Voice Level, **SR** – Source Room factor.

Table P.2: Acoustic Comparisons

Source Room	Office	Office	Locker	Locker	Locker	Hall	Bathroom
Receiving Room	**Office**	**Office**	**Staff Lounge**	**Locker**	**Bathroom**	**Office**	**Phys Lounge**
Wall Type	3A	3A	3A	3A	3A	3	3A
Original STC	**49**	**49**	**49**	**49**	**49**	**37**	**49**
Panel STC	**34**	**34**	**34**	**34**	**34**	**34**	**34**
Source Room Area	90	90	468	468	306	40	312
Receiving Room Area	90	90	550	306	312	90	368
Ceiling Height	9	9	9	9	9	9	9
Partition Length	10	9	18	17	17	10	16
Ratio	1	1.1	3.4	2	2	1	2.6
RR	0	0.1	5	2.5	2.5	0	4
N + 8	33	33	38	43	43	33	33
VL	60	60	60	60	60	60	60
SR	8	8	1.5	1.5	3	9	3
Original Privacy	**14**	**14.1**	**30.5**	**33**	**31.5**	**1**	**23**
New Privacy	**-1**	**-0.9**	**15.5**	**18**	**16.5**	**-2**	**8**

The results highlighted in green meet the normal privacy level, which must be greater than 9. The results highlighted in red are worse than normal privacy. All the results shown in blue have confidential privacy rating. Unfortunately, the new wall system does not perform wall acoustically. In an attempt to still use the new panels and improve the acoustics, I contemplated using a second layer of panels in the wall assembly. There are no values shown for these calculations because it quickly became apparent that a second layer increases the cost too significantly to make the system worth using. See **Table P.3** for the second layer cost calculations.

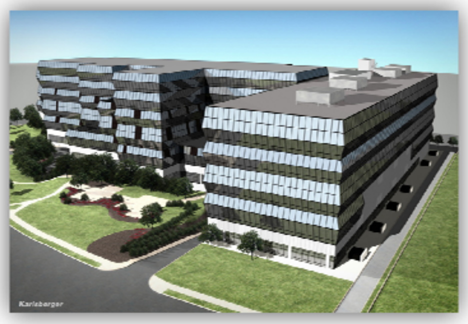


Table P.3: Cost and Schedule for Double Panel Construction

Wall Type	Original		Double Panels		Savings	
	Cost	Duration	Cost	Duration	Cost	Duration
2	$5,861.16	69.95	$6,852.16	96.21	$991.00	26.26
3	$23,700.18	286.78	$31,231.00	330.07	$7,530.82	43.29
3A	$84,947.66	971.73	$91,111.80	996.36	$6,164.14	24.63
Total	**$114,509.00**	**1328.46**	**$129,194.96**	**1422.64**	**$14,685.96**	**94.18**

With this new double panel layering, the cost is increased 13% from the original cost and the schedule is also increased by 7%. These numbers justify not implementing a double panel system since it will not be superior to the original stick built design.

Recommendations

Based on the final results for the Prestowall system, I would have to advise against using the system. If the acoustics could be improved, the cost and schedule savings would be a great advantage for this product. However, since acoustics and speech privacy are an important part for hospital operation there is no variation of this product which supplies the appropriate sound levels and retains the other savings.

Appendix A:

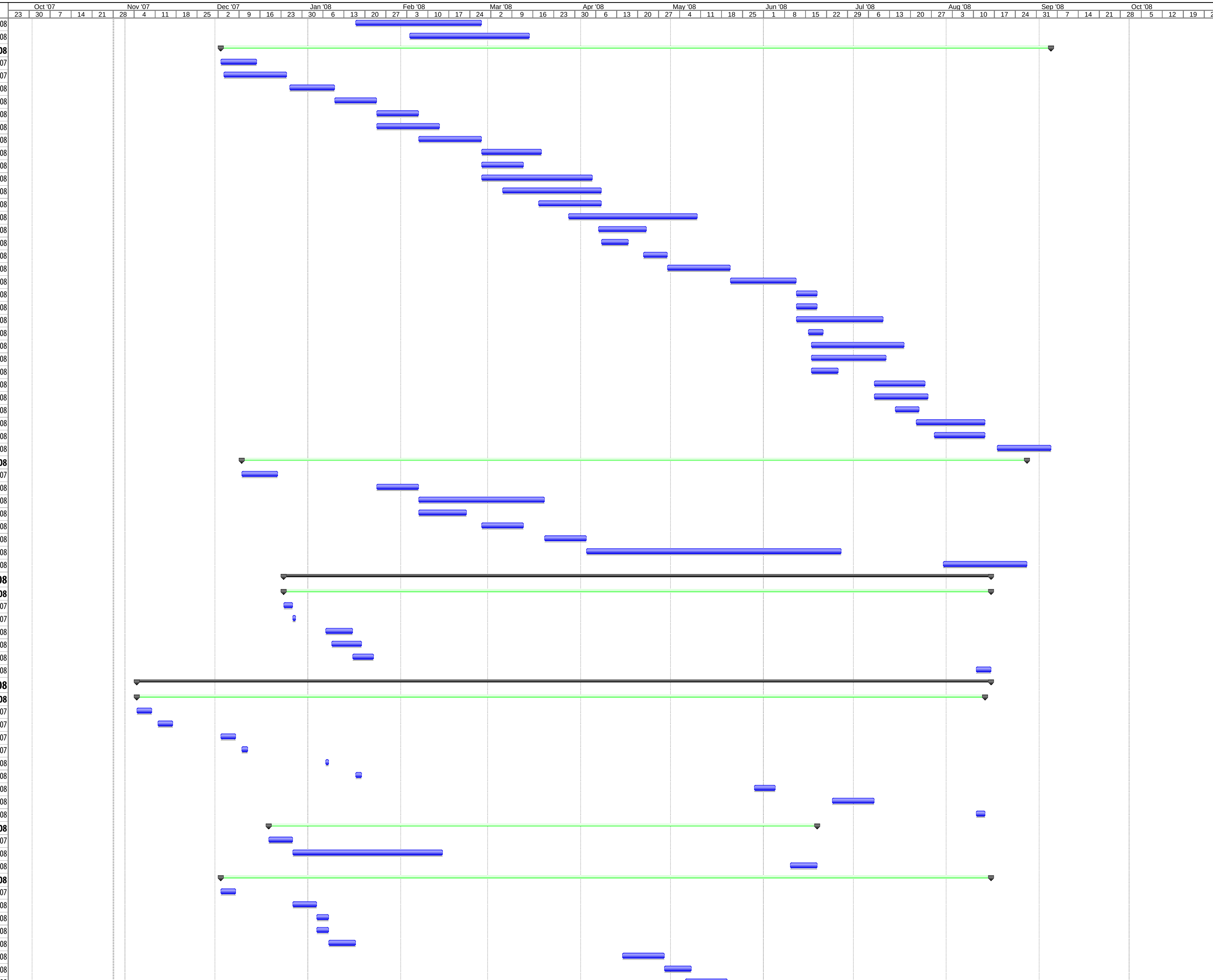
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
1	**Phase 1A**	**245 days**	**Tue 10/2/07**	**Mon 9/8/08**
2	**All Floors**	**114 days**	**Mon 11/5/07**	**Thu 4/10/08**
3	Submit Shut Down Requests	1 day	Mon 11/5/07	Mon 11/5/07
4	Approve Shut Down Requests	10 days	Tue 11/6/07	Mon 11/19/07
5	Cut, Cap, Safe MEP	14 days	Tue 11/20/07	Fri 12/7/07
6	Install ATS and Panel DP, Level 5	4 days	Fri 2/22/08	Wed 2/27/08
7	Pull Backbone Cabling to Level 2.5, 1.5	10 days	Fri 3/28/08	Thu 4/10/08
8	**Level 1.5**	**42 days**	**Mon 11/5/07**	**Tue 1/1/08**
9	Install Nitrous Manifold Circuits and Piping LP1 and LP0	20 days	Mon 11/5/07	Fri 11/30/07
10	Install Medical Gas Piping	10 days	Wed 12/5/07	Tue 12/18/07
11	Install CO, Nitrogen, Nitrous Manifolds LP1	10 days	Wed 12/19/07	Tue 1/1/08
12	**Level 2**	**221 days**	**Mon 11/5/07**	**Mon 9/8/08**
13	Install Trash Chute	5 days	Mon 11/5/07	Fri 11/9/07
14	Cut, Cap Electrical/Power	5 days	Mon 11/5/07	Fri 11/9/07
15	MEP Coordination Drawings	1 day	Mon 11/5/07	Mon 11/5/07
16	Set Up Negative Air	5 days	Mon 11/12/07	Fri 11/16/07
17	Create Demo As-Built Low Voltage	15 days	Mon 11/12/07	Fri 11/30/07
18	Demolition Col 7-11	10 days	Wed 12/5/07	Tue 12/18/07
19	Demolition Col 7-3	10 days	Wed 12/19/07	Tue 1/1/08
20	Frame/Layout Walls Col 7-11	50 days	Wed 12/19/07	Tue 2/26/08
21	Frame/Layout Walls Col 3-7	20 days	Fri 1/4/08	Thu 1/31/08
22	GWB Walls/Ceilings/Bulkheads Col 3-11	55 days	Wed 2/20/08	Tue 5/6/08
23	Install Steel @ Duct Openings Col 3-11	2 days	Thu 1/3/08	Fri 1/4/08
24	Install MEP Col 3-5	12 days	Fri 1/11/08	Mon 1/28/08
25	Install MEP Col 5-7	18 days	Thu 1/17/08	Mon 2/11/08
26	RI Electric in Walls Col 3-7	22 days	Fri 2/1/08	Mon 3/3/08
27	Install MEP Col 7-11	30 days	Tue 2/12/08	Mon 3/24/08
28	MEP OR #12	65 days	Tue 3/4/08	Mon 6/2/08
29	MEP OR #13	56 days	Tue 3/25/08	Tue 6/10/08
30	Sprinklers Col 3-11	20 days	Tue 3/4/08	Mon 3/31/08
31	Data Closet 2633	5 days	Fri 3/21/08	Thu 3/27/08
32	Pull Cables	49 days	Wed 3/5/08	Mon 5/12/08
33	Data Closet 2510A	5 days	Thu 4/10/08	Wed 4/16/08
34	Install Finishes	89 days	Wed 5/7/08	Mon 9/8/08
35	Terminations	23 days	Mon 7/7/08	Wed 8/6/08
36	Install Sterilizer	7 days	Wed 7/9/08	Thu 7/17/08
37	Demolish Tunnel	2 days	Mon 8/25/08	Tue 8/26/08
38	Replace Glass From Trash Chute	1 day	Wed 8/27/08	Wed 8/27/08
39	**Level 2.5**	**243 days**	**Tue 10/2/07**	**Thu 9/4/08**
40	Install Duct Col 9-11	20 days	Tue 10/2/07	Mon 10/29/07
41	Install Risers	45 days	Mon 11/5/07	Fri 1/4/08
42	Demolition	30 days	Fri 1/4/08	Thu 2/14/08
43	Pull Riser Feeder Cables	10 days	Thu 1/10/08	Wed 1/23/08
44	Install Duct and AHUs Col 3-5	67 days	Fri 2/1/08	Mon 5/5/08
45	Terminate Power to AHUs and Fans	5 days	Fri 3/28/08	Thu 4/3/08
46	Mechanical Piping Col 3-11	77 days	Tue 5/6/08	Wed 8/20/08
47	Install Duct and VAV Boxes Col 5-7	26 days	Tue 5/6/08	Tue 6/10/08
48	Install Duct and VAV Boxes Col 7-9	26 days	Wed 6/4/08	Wed 7/9/08
49	Install VAV Boxes and Humidifiers Col 9-11	16 days	Thu 7/10/08	Thu 7/31/08
50	Install Controls Col 3-11	36 days	Wed 6/11/08	Wed 7/30/08
51	Insulate MEP Col 3-11	21 days	Thu 8/7/08	Thu 9/4/08
52	**Elevator**	**214 days**	**Tue 10/2/07**	**Fri 7/25/08**
53	Install Panel and Transformer Level P1	3 days	Tue 10/2/07	Thu 10/4/07
54	Release Elevator Submittal	43 days	Mon 11/5/07	Wed 1/2/08
55	Cut, Cap and Demolition for Elevator Machine Room	42 days	Mon 11/12/07	Tue 1/8/08
56	Reroute Electrical at Elevator	22 days	Fri 12/7/07	Mon 1/7/08
57	Approve Elevator Submittal	20 days	Thu 1/3/08	Wed 1/30/08
58	Instsall Elevator Steel P0-L2.5	10 days	Tue 1/8/08	Mon 1/21/08
59	RI Electrical for Elevator Machine Room	10 days	Wed 1/9/08	Tue 1/22/08
60	Demo Slabs and Metal Deck for Elevator	9 days	Tue 1/22/08	Fri 2/1/08
61	Fabricate and Deliver Elevator	60 days	Thu 1/31/08	Wed 4/23/08
62	Elevator Pit	15 days	Mon 2/4/08	Fri 2/22/08
63	Frame, Install and Finish Shaft Walls	15 days	Mon 2/25/08	Fri 3/14/08
64	Install New Elevator and Equipment	62 days	Thu 4/24/08	Fri 7/18/08
65	Inspect and Test New Elevator	5 days	Mon 7/21/08	Fri 7/25/08
66	**Phase 1B**	**199 days**	**Mon 12/3/07**	**Thu 9/4/08**
67	**All Floors**	**166 days**	**Mon 12/3/07**	**Mon 7/21/08**
68	NTP For Phase 1B	0 days	Mon 12/3/07	Mon 12/3/07
69	MEP Coordination Drawings Col 11-17	1 day	Mon 12/3/07	Mon 12/3/07
70	Fire Alarm Trace and Demo Phase 1B	3 days	Mon 12/3/07	Wed 12/5/07
71	Cut, Cap, Safe Power	10 days	Mon 12/3/07	Fri 12/14/07
72	Backbone Cabling to Levels 1.5, 2.5	5 days	Fri 6/27/08	Thu 7/3/08
73	Terminate Devices Everywhere	16 days	Mon 6/30/08	Mon 7/21/08
74	**Level 1.5**	**75 days**	**Mon 12/3/07**	**Fri 3/14/08**
75	Research Mechanical Col 13-20	10 days	Mon 12/3/07	Fri 12/14/07

Project: Tech 2 Schedule
Date: Sun 10/28/07

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

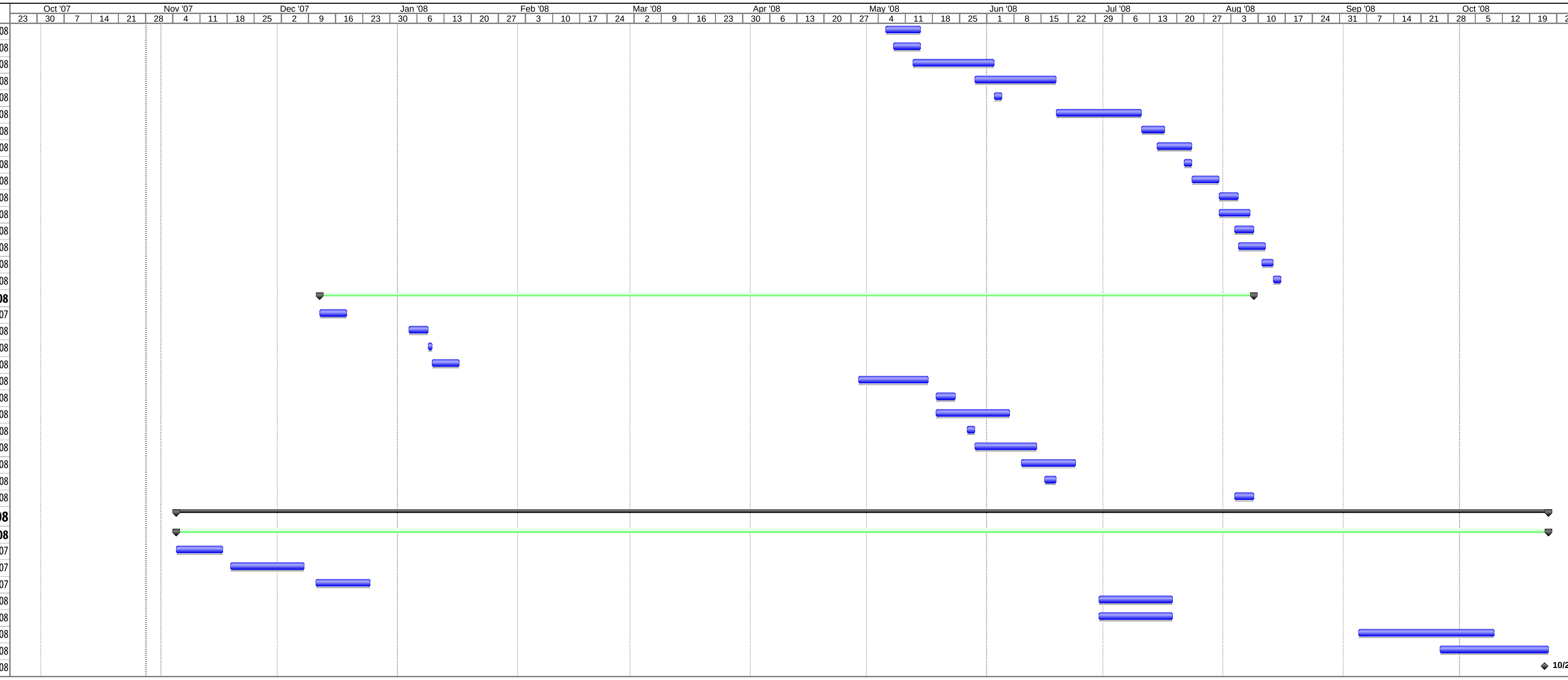
ID	Task Name	Duration	Start	Finish
76	Cut, Cap, Safe Mechanical Col 13-20	30 days	Thu 1/17/08	Wed 2/27/08
77	Install Plumbing Pipe Col 13-17	30 days	Mon 2/4/08	Fri 3/14/08
78	**Level 2**	**199 days**	**Mon 12/3/07**	**Thu 9/4/08**
79	Research Mechanical Col 13-20	10 days	Mon 12/3/07	Fri 12/14/07
80	Create Demo As-Built Low Voltage	15 days	Tue 12/4/07	Mon 12/24/07
81	Demolition Low Voltage	11 days	Wed 12/26/07	Wed 1/9/08
82	Cut, Cap, Safe and Demo Col 13-15	10 days	Thu 1/10/08	Wed 1/23/08
83	Install MEP Col 13-15	10 days	Thu 1/24/08	Wed 2/6/08
84	Layout/Frame Walls Col 13-15	15 days	Thu 1/24/08	Wed 2/13/08
85	Cut, Cap, Safe and Demo Col 15-20	15 days	Thu 2/7/08	Wed 2/27/08
86	Layout/Frame Walls Col 15-20	14 days	Thu 2/28/08	Tue 3/18/08
87	Install MEP Col 15-20	10 days	Thu 2/28/08	Wed 3/12/08
88	Install Sprinkler and Hangers Col 13-20	27 days	Thu 2/28/08	Fri 4/4/08
89	RI Electrical Ceiling and Walls Col 13-20	23 days	Thu 3/6/08	Mon 4/7/08
90	Install Storefront and Glass Col 15-20	15 days	Tue 3/18/08	Mon 4/7/08
91	Pull Wire and Cabling Col 13-20	31 days	Fri 3/28/08	Fri 5/9/08
92	Frame and Finish Bulkheads/Ceilings Col 15-20	12 days	Mon 4/7/08	Tue 4/22/08
93	Install and Finish GWB Walls Col 13-15	7 days	Tue 4/8/08	Wed 4/16/08
94	Install and Finish GWB Walls Col 15-20	6 days	Tue 4/22/08	Tue 4/29/08
95	Prime and Paint Col 13-20	15 days	Wed 4/30/08	Tue 5/20/08
96	Install Ceiling Grid Col 13-20	16 days	Wed 5/21/08	Wed 6/11/08
97	Install Lights/Grilles/Diffusers Col 13-15	5 days	Thu 6/12/08	Wed 6/18/08
98	Sprinkler Drops Col 13-20	5 days	Thu 6/12/08	Wed 6/18/08
99	Prep and Paint Col 13-15	21 days	Thu 6/12/08	Thu 7/10/08
100	Install Lights/Grilles/Diffusers Col 15-20	5 days	Mon 6/16/08	Fri 6/20/08
101	Prep and Paint Col 15-20	23 days	Tue 6/17/08	Thu 7/17/08
102	Install Flooring Col 13-20	19 days	Tue 6/17/08	Fri 7/11/08
103	Install Corner Guards Col 13-20	7 days	Tue 6/17/08	Wed 6/25/08
104	Install Plumbing Fixtures	13 days	Tue 7/8/08	Thu 7/24/08
105	Install Toilet Accessories	14 days	Tue 7/8/08	Fri 7/25/08
106	Terminate Panels Room 2561	6 days	Tue 7/15/08	Tue 7/22/08
107	Test Paging/Fire Alarm/etc… Systems	17 days	Tue 7/22/08	Wed 8/13/08
108	Install Doors/Hardware Col 13-20	13 days	Mon 7/28/08	Wed 8/13/08
109	Install Millwork/Finishes Col 13-20	14 days	Mon 8/18/08	Thu 9/4/08
110	**Level 2.5**	**188 days**	**Mon 12/10/07**	**Wed 8/27/08**
111	Research Mechanical Col 13-20	10 days	Mon 12/10/07	Fri 12/21/07
112	Cut, Cap, Safe Mechanical Col 13-15	10 days	Thu 1/24/08	Wed 2/6/08
113	Demolition Col 13-20	30 days	Thu 2/7/08	Wed 3/19/08
114	Install Duct and Mechanical Piping Col 13-15	12 days	Thu 2/7/08	Fri 2/22/08
115	Cut, Cap, Safe Mechanical Col 15-20	10 days	Thu 2/28/08	Wed 3/12/08
116	Install Duct and Mechanical Piping Col 15-20	10 days	Thu 3/20/08	Wed 4/2/08
117	Insulate MEP Col 13-20	61 days	Thu 4/3/08	Thu 6/26/08
118	Controls for VAV Col 13-20	20 days	Thu 7/31/08	Wed 8/27/08
119	**Decasse Area**	**170 days**	**Mon 12/24/07**	**Fri 8/15/08**
120	**Level 2**	**170 days**	**Mon 12/24/07**	**Fri 8/15/08**
121	Layout/Frame Walls	3 days	Mon 12/24/07	Wed 12/26/07
122	Frame Ceilings	1 day	Thu 12/27/07	Thu 12/27/07
123	Install/Finish GWB Walls	7 days	Mon 1/7/08	Tue 1/15/08
124	Install Ceiling Grid and Tile	8 days	Wed 1/9/08	Fri 1/18/08
125	Prep and Paint Walls	5 days	Wed 1/16/08	Tue 1/22/08
126	Install Millwork	5 days	Mon 8/11/08	Fri 8/15/08
127	**Decontamination Building**	**205 days**	**Mon 11/5/07**	**Fri 8/15/08**
128	**All Floors**	**203 days**	**Mon 11/5/07**	**Wed 8/13/08**
129	Research Mechanical	5 days	Mon 11/5/07	Fri 11/9/07
130	Cut, Cap, Safe Mechanical	5 days	Mon 11/12/07	Fri 11/16/07
131	Fire Alarm Trace/Demo	5 days	Mon 12/3/07	Fri 12/7/07
132	Cut, Cap, Safe Power	2 days	Mon 12/10/07	Tue 12/11/07
133	MEP Coordination Drawings Col 17-21	1 day	Mon 1/7/08	Mon 1/7/08
134	Roof Demolition for EFs	2 days	Thu 1/17/08	Fri 1/18/08
135	Roofing/Flashing	5 days	Thu 5/29/08	Wed 6/4/08
136	Replace Exterior Siding	10 days	Tue 6/24/08	Mon 7/7/08
137	Electrical Testing	3 days	Mon 8/11/08	Wed 8/13/08
138	**Level 1.5**	**131 days**	**Wed 12/19/07**	**Wed 6/18/08**
139	Demolition	6 days	Wed 12/19/07	Wed 12/26/07
140	Install Plumbing	36 days	Thu 12/27/07	Thu 2/14/08
141	Insulate Plumbing Piping	7 days	Tue 6/10/08	Wed 6/18/08
142	**Level 2**	**185 days**	**Mon 12/3/07**	**Fri 8/15/08**
143	Demolish Opening for Stair Tower	5 days	Mon 12/3/07	Fri 12/7/07
144	Demolition	6 days	Thu 12/27/07	Thu 1/3/08
145	Install Steel for Duct Openings	2 days	Fri 1/4/08	Mon 1/7/08
146	Layout Walls	2 days	Fri 1/4/08	Mon 1/7/08
147	RI Electrical Above Ceiling	7 days	Tue 1/8/08	Wed 1/16/08
148	Install Duct	10 days	Tue 4/15/08	Mon 4/28/08
149	Frame Walls/Bulkheads	7 days	Tue 4/29/08	Wed 5/7/08
150	RI Electrical Walls	10 days	Tue 5/6/08	Mon 5/19/08



Project: Tech 2 Schedule
Date: Sun 10/28/07

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

ID	Task Name	Duration	Start	Finish
151	RI Security/Voice Data/etc... Systems	7 days	Tue 5/6/08	Wed 5/14/08
152	RI Sprinkler	5 days	Thu 5/8/08	Wed 5/14/08
153	Pull Security/Voice Data/etc... Systems Cables	15 days	Tue 5/13/08	Mon 6/2/08
154	RI Plumbing	15 days	Thu 5/29/08	Wed 6/18/08
155	Pull Power Wire	2 days	Tue 6/3/08	Wed 6/4/08
156	Install and Finish GWB Walls/Bulkheads	16 days	Thu 6/19/08	Thu 7/10/08
157	Prime and Paint 1st Coat Walls	4 days	Fri 7/11/08	Wed 7/16/08
158	Install Ceiling Grid and Lights	7 days	Tue 7/15/08	Wed 7/23/08
159	Set Lockers	2 days	Tue 7/22/08	Wed 7/23/08
160	Install Flooring	5 days	Thu 7/24/08	Wed 7/30/08
161	Install Grilles/Diffusers	3 days	Thu 7/31/08	Mon 8/4/08
162	Terminate Systems Everywhere	6 days	Thu 7/31/08	Thu 8/7/08
163	Final Paint	5 days	Mon 8/4/08	Fri 8/8/08
164	Install Plubming Fixtures	5 days	Tue 8/5/08	Mon 8/11/08
165	Install Corner Guards	3 days	Mon 8/11/08	Wed 8/13/08
166	Install Ceiling Tile	2 days	Thu 8/14/08	Fri 8/15/08
167	**Level 2.5**	**173 days**	**Wed 12/12/07**	**Fri 8/8/08**
168	Demolition	5 days	Wed 12/12/07	Tue 12/18/07
169	Demolish Opening for AHU Access	3 days	Fri 1/4/08	Tue 1/8/08
170	Install AHU Steel Support	1 day	Wed 1/9/08	Wed 1/9/08
171	Install AHU-26B	5 days	Thu 1/10/08	Wed 1/16/08
172	Install Duct	14 days	Tue 4/29/08	Fri 5/16/08
173	Install VAV Boxes	5 days	Mon 5/19/08	Fri 5/23/08
174	Pipe AHU-26B	15 days	Mon 5/19/08	Fri 6/6/08
175	Install Return Fan	2 days	Tue 5/27/08	Wed 5/28/08
176	Install Power to MEP Equipment	12 days	Thu 5/29/08	Fri 6/13/08
177	Install Controls	10 days	Tue 6/10/08	Mon 6/23/08
178	Terminate Power to Mechanical Equipment	3 days	Mon 6/16/08	Wed 6/18/08
179	Terminate Electrical Panels	5 days	Mon 8/4/08	Fri 8/8/08
180	**Surgery Expansion Project**	**254 days**	**Mon 11/5/07**	**Thu 10/23/08**
181	**All Floors**	**254 days**	**Mon 11/5/07**	**Thu 10/23/08**
182	Release Steel Submittals/Shop Drawings	10 days	Mon 11/5/07	Fri 11/16/07
183	Approve Structural Steel Shop Drawings	15 days	Mon 11/19/07	Fri 12/7/07
184	Fabricate and Deliver Structural Steel	10 days	Tue 12/11/07	Mon 12/24/07
185	Terminate Paging System Everywhere	15 days	Mon 6/30/08	Fri 7/18/08
186	Terminate Power Devices Everywhere	15 days	Mon 6/30/08	Fri 7/18/08
187	Start-Up Testing and Balancing	25 days	Fri 9/5/08	Thu 10/9/08
188	Occupancy Inspections	20 days	Fri 9/26/08	Thu 10/23/08
189	Occupancy	0 days	Thu 10/23/08	Thu 10/23/08



Project: Tech 2 Schedule
Date: Sun 10/28/07

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

Appendix B:

Interview Letter and Transcribed Responses

Andrea Klein
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CPEP Address: http://www.engr.psu.edu/ae/thesis/portfolios/2008/akk139

AE Senior Thesis Research Questions
The research topic I have chosen for my construction management senior thesis is prefabrication and how it can relate to the AIA Infection Control Risk Assessment (ICRA) requirements. My primary focus is in hospital renovations and expansions. I am trying to create a supplemental guide for use in the planning stage of projects to aid in understanding and meeting the ICRA regulations. In order to keep with current trends and to gain further insight into the practical uses I have come up with several questions.

Please take the time to answer any or all of these questions if you can, and pass this survey along to others who might be able to help.

If at all possible I would like to speak with you directly about your answers to the questions. I am available for phone conferences the following times:
Monday 1:00pm-3:30pm, after 4:30pm
Tuesday 12:30pm-2:30pm, after 4:00pm
Wednesday 1:00pm-3:30pm, after 4:30pm
Thursday 9:00am-11:00am, after 4:00pm
Friday after 1:00pm
Please feel free to call or email me to set up a time if you would prefer a specific appointment.

Also, since this is a research project, I would appreciate all answers be provided by the end of the day, **Wednesday, February 20th, 2008.**

Questions
1. Are you familiar with the 2006 ICRA guidelines established by the AIA?
2. Have you used ICRA guidelines for past or present hospital projects?
3. Did you have difficulties in maintaining any of the procedures outlined in your ICRA program? If so, what were they, and how did you attempt to solve them?
4. Was prefabrication used to any extent during your project?
5. What trades, methods, or specific technologies did you use for prefabrication, and how well did they work?
6. Do you think fabricating materials and systems off site is a viable option to help maintain the ICRA guidelines?
7. Did you have problems with construction interfering with the surrounding occupied spaces? If so, what were they, and how large was the impact?

Thank you for all your help, it is much appreciated!

Andrea Klein

Transcribed Interviews

Interview 1

1. Yes
2. Next project
3. Not personally – there are always problems
   - -thesis research was to prove ICRA was not enough
   - -Owner holds ICRA paperwork; CM maintains procedures
4. ICRA costs money to maintain (expensive)
   - -depends on owner and willingness to try
   - -good idea
5. Not well versed
6. Definitely
   - -infection is caused by many things
   - - ICRA is not enough
   - -CM typically pushes past the guidelines
   - -prefab is important to have, but technology is limited
7. Can be shut down for anything
   - -welding fumes
   - -Do what hospital says – affects schedule
   - -sequencing is extremely important

Interview 2

-Every hospital follows and measures ICRA guidelines. The hardest part is maintaining and measuring
-Prefabrication of zip walls in 4' x 10' sheets and attached to metal studs and decking to keep air and dust in place with proper seals
-Typically prefabricated work includes:

- -duct work, must keep the old and new separated (many different systems)
- -anything going through walls or connecting to existing systems is difficult
- - Lots of off hours to prepare and clean the site

-Always interfere with other spaces
-More successful jobs have meetings every morning with the hospital to control complaints continuously instead of weekly
-Can often repipe and renovate patient wings under less stressful conditions

- -gang areas are harder to bring in for a larger system
- -access space is difficult
- -narrower timelines mean more prefabrication
- -lots of repetition in small areas

Interview 3

1. Yes – hospital made CM familiar by going over checklist and rules with the architect and owner
   - -Used the class system Type A-D and Class I – IV
   - - established checklist from the guidelines
2. Yes
3. Yes – always changes with the schedule
   - -the building was on top of the loading dock
   - -shared hallway with the old OR

-partition to underside of structure with negative air was installed on an off day

-Final cleaning was on a Sunday – emergency occurred in the middle and the crew had to make the site safe and leave

4.-6. Tried to prefab some wall systems in sections to reduce drywall dust but had problems getting them into place

- Prefabricated sections in another area of the hospital
- still had to tape, spackle and sand
- timing was a large concern as to when to transport the sections into the space
- possibly use a plastic system with panels and wall interlocking
- negative air machine came with prefabricated duct work

**If the hospital was brand new it would probably work better.

- tried to prefab the steel supports for the overhead unit in the surgical suite (didn't work)
- headwall assembly could not be prefabbed due to testing requirements

7. Absolutely – Dr. preferences are different

- cordless drill
- structural deck work
- Split shift – worked on weekends and around hospital schedule
- better to have surrounding areas relocated or exchange hospitals

8. Yes – Interstitial space

- All work had to be permitted through the hospital with method and type of work
- prevent smoke barrier penetrations whenever possible
- meet with Owner, Arch., and ICRA consultant to fix problems and coordinate

Transcribed Emails

Email 1

1. Yes
2. Yes
3. Can be difficult to maintain dust-tight partitions when overhead MEP work crosses the partition line
   - -used bubble carts outside the partition in those cases
4. Yes- often prefab what we can to minimize work in the occupied hospitals
5. Prefab ductwork, piping assemblies, wire mold assemblies
6. Yes
7. Noise and odors can still bother the patients around the work areas

Email 2

1. Somewhat – We are currently purchasing a project that references these guidelines. We are still in the planning/procurement phase of this design-build project and these guidelines have not been addressed fully at this time.
2. No
3. NA
4. The project we are pursuing is a renovation of an existing hospital, so I am not sure what opportunities we will have to utilize any prefabricated projects
5. NA
6. The opportunity certainly exists to mitigate the risk associated with the ICRA guidelines by utilizing prefabricated products. However, we need to study the cost impact as it relates to conventional construction methods.
7. While scheduling and sequencing the above-mentioned project, we encountered many coordination issues pertaining to maintaining occupied hospital space. One such issue surrounds the fact that the renovation is phase around existing departments as opposed to by wing or floor. A new hospital facility is also being built at the same time on the same campus. These departments need to be relocated into the new hospital facility before they can be renovated.

*Another issue that we ran into was with adjacencies. While the government's schedule may have called for a portion of the third floor to be relocated and renovated (as example), no thought was put into how that affected the floor above or below. It is extremely difficult to completely renovate and existing space without disturbing the space below. Core drilling is just one example of an activity that you cannot do without disturbing stacked areas.

Email 3

1. No
2. Yes. For two projects. In both cases ICRA guidelines were specific to the hospital. The guidelines were written and published by the hospital
3. Yes, most common problem has been maintaining a negative air environment during on-going and ever changing construction. Solutions involved supplying fulltime labor to patch holes to provide permanent seals and temporary partitions.
4. Prefabrications were used on temporary basis, a temporary enclosure with a washable service was prefabricated to provide a seal during wall breakthroughs into existing spaces. Unit was simply place at individual spot and sealed with Tyvek tape.

5. Carpentry trade has been utilized the most to avoid finishing of drywall. Carpenters prefabricated the enclosure mentioned above to avoid doing any finishing, specifically sanding of drywall compound. All plastic zip walls are often used in occupied space to provide a temporary barrier between construction and patients.
6. Yes, the more assemblies you can prefabricate the more compliant you will be. Most ICRA guidelines center around the field work, minimize such items as sanding, welding, brazing, or use of Hilti guns greatly avoid ICRA procedure breaches.
7. The most common problems involve odors, dust, noise, & conditioned air. A key to avoiding all of these is maintaining negative pressure.

Email 4

1. We are familiar with the ICRA requirements and that AIA included ICRA requirements in their 2006 Guidelines for Design and Construction of Health Care Facilities. Additionally, through a long association with the American Society for Healthcare Engineering (ASHE) we assisted in the establishment of their Healthcare Construction Program which has a large focal point, infection control. Since that programs establishment, we have sent numerous of our healthcare construction personnel through that program.
2. Yes, on all new and existing construction. Although this is an Owner driven program, we feel it necessary to do a fair amount of driving ourselves; knowing the consequences, we believe it prudent risk mitigation and protection of our clients. Additionally, we have found that some Owners are not as good at initiating and executing the program as we would like; to the point we have been asked for our documentation for the Owner's use during a JCAHO visit. I have attached (for you use only) a copy of our base SOP regarding infection control which may help better explain our interaction in the IC program.
3. Yes. The ICRA requirements can be difficult to maintain especially when established for critical or acute care areas, however the method of resolving any of these difficulties is always the same. Planning, communication, monitoring , reporting, and follow-up corrections where needed. The necessary manpower for the given process can also present challenges. Specific areas that I observe as the bigger challenges are:

   -Delivery, storage, and installation of HVAC equipment, duct and duct accessories. A major potential source of contaminants that must be maintain clean from delivery through turn-over. To overcome this, we first include this as a necessary step in our QC Plan, then also require that the associated subcontractors do the same in their plan. We will also require their compliance with the advanced level based on the installation; ideally though, this is already a requirement of the contract specifications. We will also have them designate a person or persons to be responsible for the monitoring and reporting of the process. Additionally we perform regular inspections with our forces to ensure that the program is working.

   -Maintaining negative air pressure in construction areas of existing facilities is also another challenge. Most often we overcome this through use of temporary negative air equipment (vented away from any building openings), ante rooms and air pressure monitoring devices. In addition, our process requires regular maintenance and testing of the equipment as well as a two times per day sign off by an assigned person, usually with BBC.

   - Moving debris out and away from the building can be a challenge in an occupied facility. Although new material scraps, etc… are relatively clean, even these must be routed out of the building in a manner that will not contaminate areas or HVAC systems. This problem is compounded with the removal of existing, demolished materials. It is necessary in these cases to not only evaluate the method of transporting the materials out, but you must first evaluate the hazards associated with the materials themselves to ensure that they do not require additional measures of protection. If medical equipment or construction debris from areas of the facility that handle pathogens, etc…, the Owner should identify these additional hazards in the ICRA so that we can adequately plan for it. If we are removing materials that have been contaminated due to mold, in addition we will need to engage other consultants such as hygienists or microbiologists; this may also be a requirement for other contaminants as discussed above. Remember too that some states may have additional requirements. I have attached a sample above.

4. When constructing adjacent to a facility, it is extremely important to ensure that dust and other contaminants created by the new construction do not migrate into the existing area or systems. To resolve this, we have done a combination of additional filtering mechanisms and re-routing of intake air openings. In addition we must monitor to ensure that these means remain operational.
5. To my knowledge, the answer is no, other than self contained, portable, negative air enclosures. These are used within the existing facility, by all trades, while opening ceilings for investigation or adding above ceiling services through the existing portions of the facility. The units are especially practical for smaller work. For larger areas of work, it is generally necessary to provide temporary enclosures.
6. I think this is a worthwhile avenue to explore; again, I am not familiar with this having been done, not to say that it has not. I do think that any time you can minimize the time and exposure within existing facilities and area it is another measure of risk mitigation. I apologize for not having more to offer on this subject.
7. I think I covered the typical problems we encounter in Q3 above. The good news is that we are able to keep the impact to a minimum through our processes – planning , regular communication, regular monitoring, reporting and taking immediate corrective action when needed. In cases where there was potential for long term exposure, we have engaged outside consultants, (industrial hygienist, etc…), to do testing and monitoring and report on the conditions as well as make recommendations if needed. Once the recommended actions are completed, we will retest and conclude with a final report.

Appendix C:

ICRA Prefabrication Supplemental Guide

Prefabrication Supplemental Guide to ICRA Regulations

Initial Observations

Type A – Prefabrication is not applicable due to the nature of the work being performed.

Type B – Prefabrication is not applicable due to the nature of the work being performed.

Type C – Prefabrication can be used for the following:

-New wall construction

-Duct and electrical work above the ceiling

Type D – Prefabrication can be used for the following:

-New construction

-Heavy demolition (this refers to the demolition of prefabricated systems)

Class I – Prefabrication does not apply.

Class II – Prefabrication does not apply.

Class III – Prefabrication can be applied for the Medium, High and Highest risk groups.

Class IV – Prefabrication can be applied for all risk groups and types of construction.

Prefabrication Method	ICRA Class	Advantages	Disadvantages	Savings	Other Notes
Duct Work	III, IV	· Increased quality of product and more thorough cleaning · Easier to maintain wrapped ends · Reduces loose insulation on site and resulting dust	· Moving larger pieces and need to account for size and weight	· Labor cost · Installation time on site	-Requires extra care in coordination and conflict management
Plumbing & Medical Gas	III, IV	· Use of Victaulic and other pressure clamp connection systems · Reduces amount of packaging on site	· Coordination required early in project	· On site labor cost and time	

Wall Panel Systems **(including Vinyl-Faced Gypsum, Demounted Systems)**	III, IV	· Reduce dust on site · Prefinished Options: vinyl, metal, wood paneling · Sound absorption · No studs required (some thicker panel systems) · Improved mold and moisture protection · Handles harsh cleaning materials	· Visible joints (not all systems) · Require special door and window frames · Heavy units to install · Can be difficult to replace and maintain · Vinyl faced unit are difficult to procure	· Labor time · Possible cost reduction	· Best used for offices
Hardboard Panels	III, IV	· Conduit pre-installed · Custom length panels · Typically recycled or organic material · Can be finished the same as drywall · Studs are not always required · Reduced wall thickness	· Studs are required above certain heights (may increase wall thickness) · Requires sanding joints · Panels can be very heavy	· Installation time and cost · Material cost	· Not many manufacturers, shipping costs can be expensive
Ceilings	III, IV	· Multiple applications · Decorative finishes · Can incorporate lighting · Reduces dust on site · Sound Absorptive · Handles harsh cleaning	· Requires special labor · Can be expensive		· Typically custom designed
Flooring	III,IV	· Multiple finishes	· More applicable to residential and recreational uses		
Roofing	III, IV	· Custom design and penetration handling · Good for retrofitting	· Requires special labor · Expensive initial cost		

		· Reduces on site seaming up to 80% · Reduced heat island effect (cool zone) · Warranty			
Modular Buildings	IV	· Only contract with one company · Pre-designed floor plans · Easy to purchase · Multiple suppliers · High quality monitoring	· Limited size · Less flexibility · Heavy shipping costs		

Appendix D:

Fan Load Calculations

SF-26B-1

Diffuser Model	cfm	Type	Size		Neck
			Width	Depth	
300RL	235	5	10	6	8
300RL	240	5	12	10	8
300RL	175	5	10	6	8
300RL	170	5	10	6	8
300RL	170	5	10	6	8
300RL	160	4	8	6	6
300RL	175	5	10	6	8
300RL	160	4	8	6	6
300RL	95	4	8	6	6
300RL	85	4	8	6	6
TDC	200	3	10	8	
300RL	130	4	12	8	6
	180		10	6	
300RL	100	4	8	6	6
300RL	310	6	12	14	10
300RL	100	4	8	6	6
300RL	185	5	10	6	8
300RL	100	4	8	6	6
300RL	125	4	8	6	6
300RL	95	4	8	6	6
	495		12	10	
Total	**3685**				

Fan RF-26B

Diffuser Model	cfm	Type	Size	
			Width	Depth
350RL	245	11	10	10
350RL	245	11	10	10
350RL	320	11	10	10
350RL	475	11	10	10
350RL	95	9	8	6
350RL	200	10	10	6
350RL	165	9	8	6
	180			
350RL	95	9	8	6
	495			
Total	**2515**			

RF-12B

Diffuser Model	cfm	Type	Size	
			Width	Depth
350RL	170	9	8	6
350RL	475	12	14	14
350RL	240	10	10	6
350RL	260	11	10	10
350RL	315	11	10	10
350RL	165	9	8	6
350RL	160	9	8	6
350RL	90	9	8	6
350RL	260	11	10	10
350RL	160	9	8	6
350RL	165	9	8	6
350RL	180	9	8	6
350RL	165	9	8	6
350RL	90	9	8	6
350RL	90	9	8	6
350RL	105	9	8	6
350RL	170	9	8	6
350RL	90	9	8	6
350RL	90	9	8	6
350RL	90	9	8	6
350RL	90	9	8	6
350RL	90	9	8	6
350RL	150	9	8	6
350RL	210	10	10	6
350RL	405	11	10	10
350RL	300	11	10	10
350RL	235	10	10	6
350RL	590	12	14	14
350RL	360	11	10	10
350RL	290	11	10	10
350RL	405	11	10	10
350RL	475	12	14	14
350RL	475	12	14	14
350RL	480	12	14	14
Total	**8085**			

Appendix E:

Fan Curves

In Order:

SF-26B-1 (Design)

SF-26B-1 (Demand)

SF-26B-1 (New Selection)

RF-26B (Design)

RF-26B (Demand)

RF-26B (New Selection)

RF-12B (Design)

RF-12B (Demand)

RF-12B (New Selection)

85

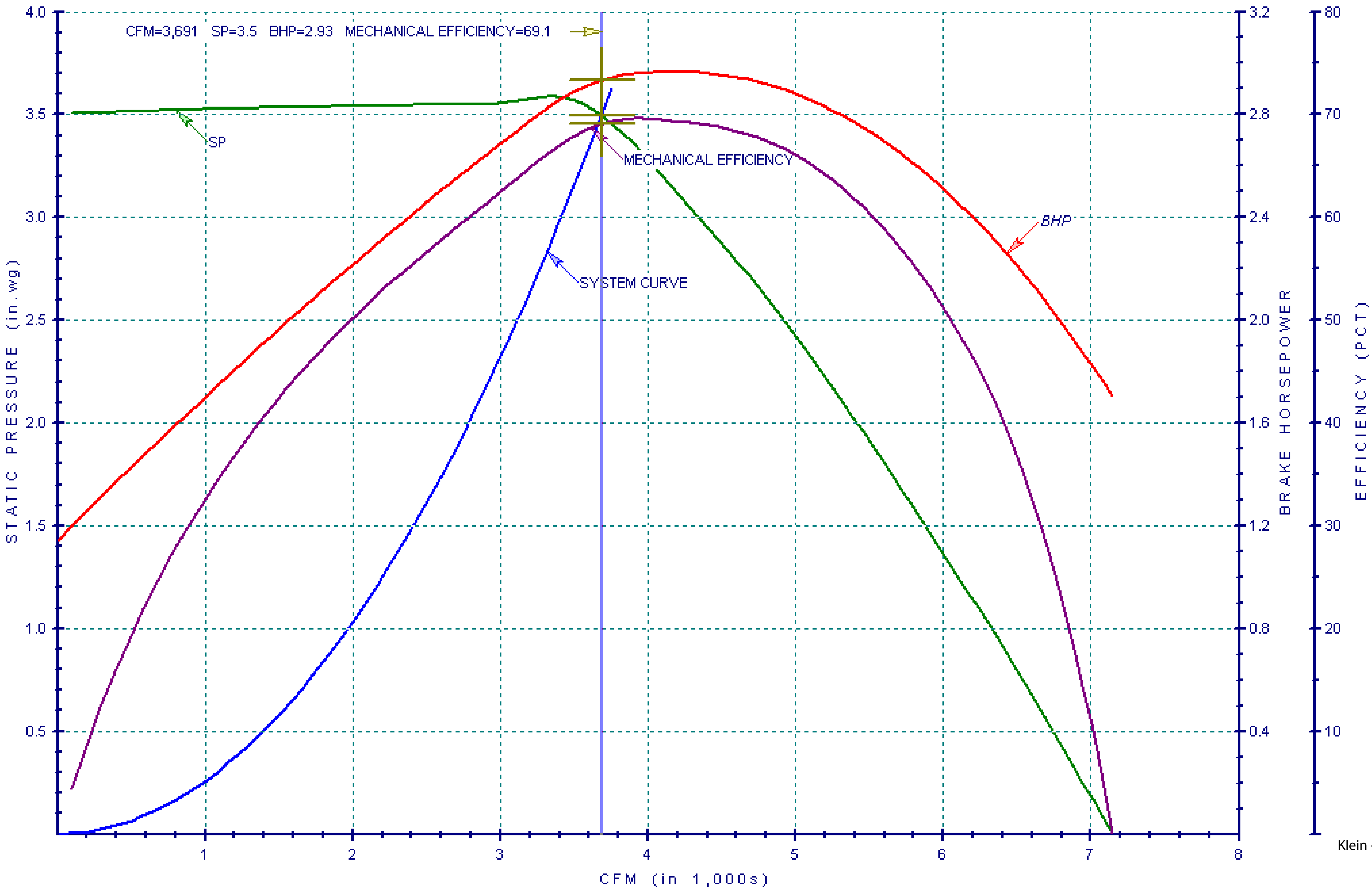
Customer:	Fan Tag: RF-12B	CFM: 3,685
Job ID:	Model: 182 EPFN	SP: .... 3.5 in.wg
		RPM: 1884

BHP: 2.93

Outlet Velocity: . N/A

Density: 0.075

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



Sound Power Level

Octave	In/Out
1	76 / 82
2	81 / 84
3	90 / 90
4	82 / 85
5	75 / 81
6	74 / 79
7	71 / 73
8	65 / 66

in db re 10^{-12} watts

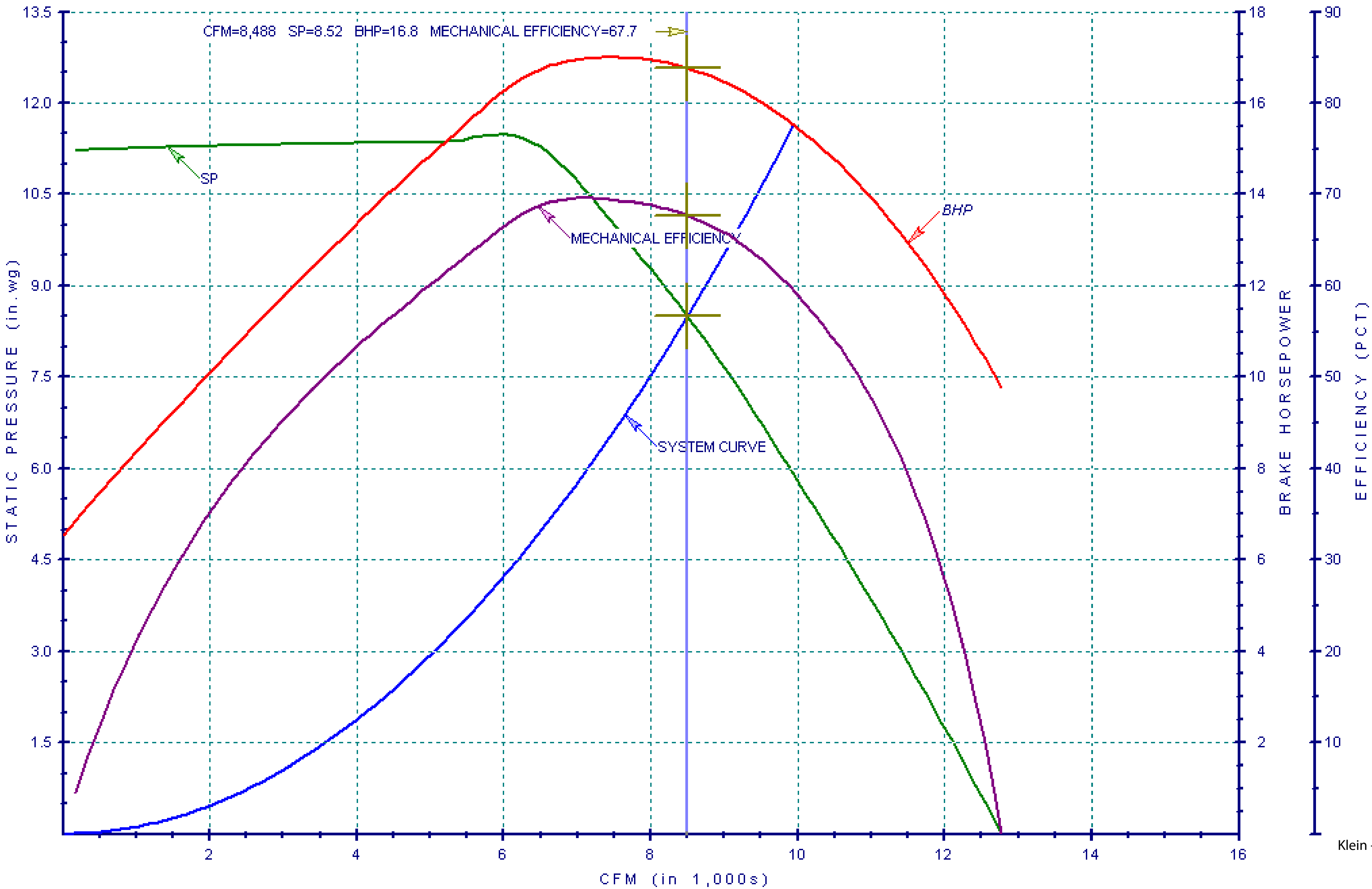
Klein - 21/36

3/31/2008 00:31 . #4

102

Customer:	Fan Tag: SF-26B-1
Job ID:	Model: 182 EPFN

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



CFM:	8,500
SP:	8.5 in.wg
RPM:	3371
BHP:	16.77
Outlet Velocity:	N/A
Density:	0.075

Sound Power Level

Octave	In/Out
1	92 / 92
2	92 / 92
3	97 / 98
4	103 / 104
5	94 / 99
6	88 / 96
7	87 / 92
8	83 / 87

in db re 10-¹² watts

Klein - 22/36

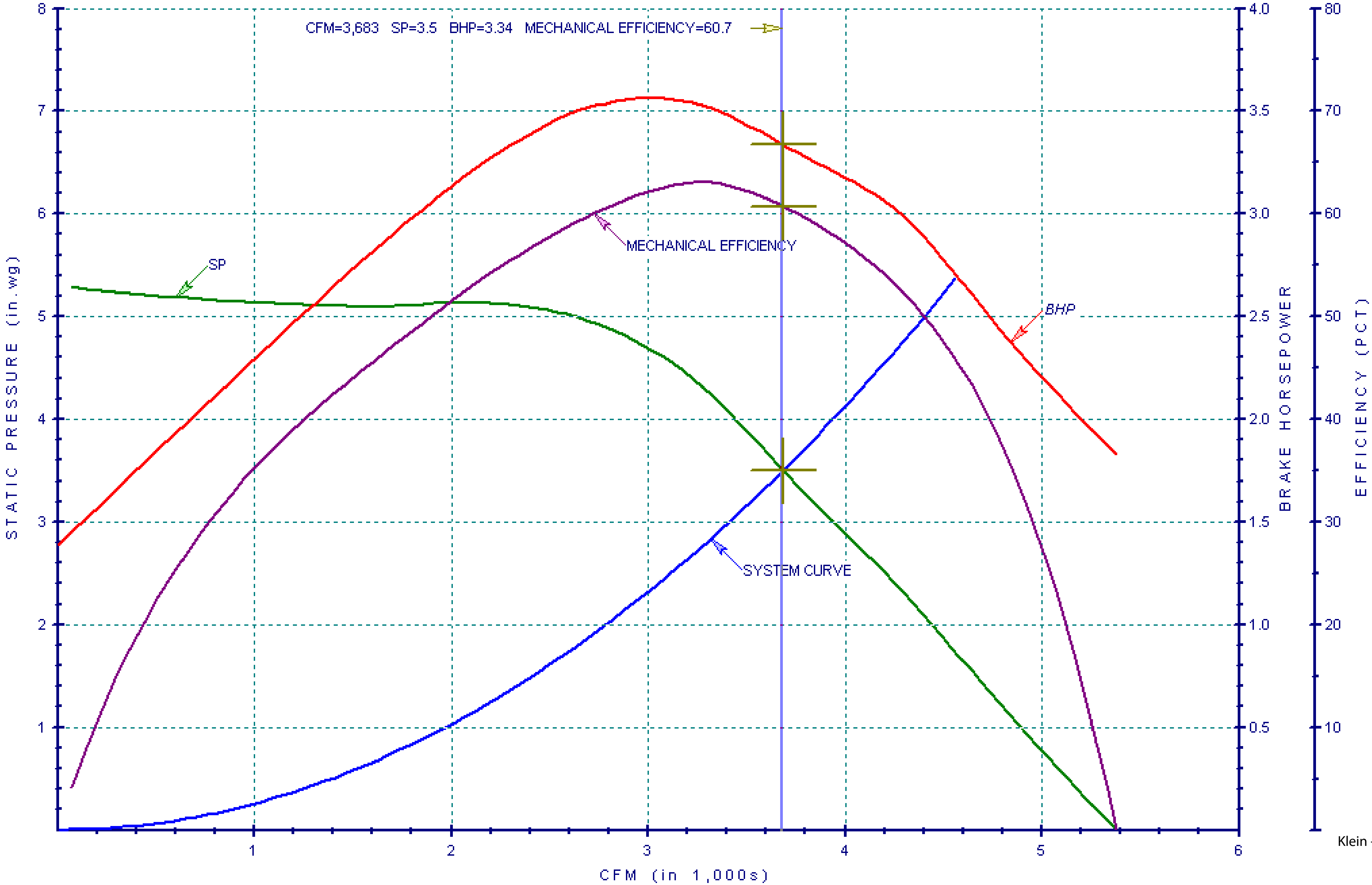
3/31/2008 00:28

89

Customer:	Fan Tag: SF-26B-1	CFM: ______ 3,685
Job ID:	Model: 165 EPFN	SP: ____ 3.5 in.wg
		RPM: ______ 2683

BHP: _______	3.34
Outlet Velocity: _	N/A
Density: ____	0.075

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



Sound Power Level

Octave ____	In/Out
1 _______	81 / 82
2 _______	82 / 84
3 _______	89 / 90
4 _______	89 / 90
5 _______	78 / 85
6 _______	79 / 86
7 _______	80 / 84
8 _______	75 / 79

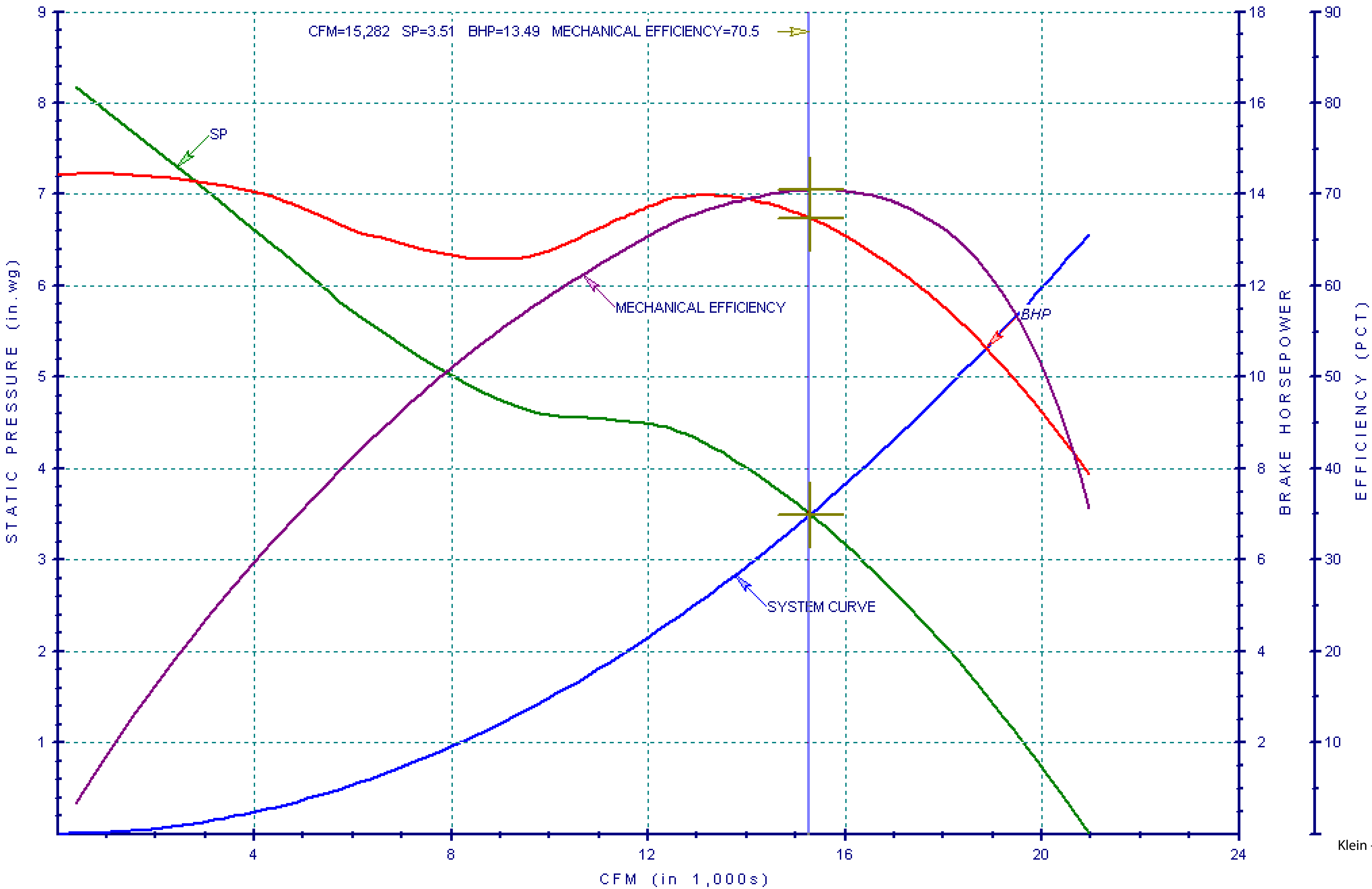
in db re 10^{-12} watts

3/31/2008 00:29

98

Customer:	Fan Tag: RF-26B
Job ID:	Model: 32B6 TCVX

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



CFM:	15,300
SP:	3.5 in.wg
RPM:	1899
BHP:	13.48
Outlet Velocity:	2,697
Density:	0.075

Corrected for:
Blade Angle 30°

Inlet Sound Power

Octave	Level
1	91
2	92
3	95
4	95
5	93
6	89
7	85
8	82

in db re 10^{-12} watts

Klein - 24/36

3/31/2008 00:33

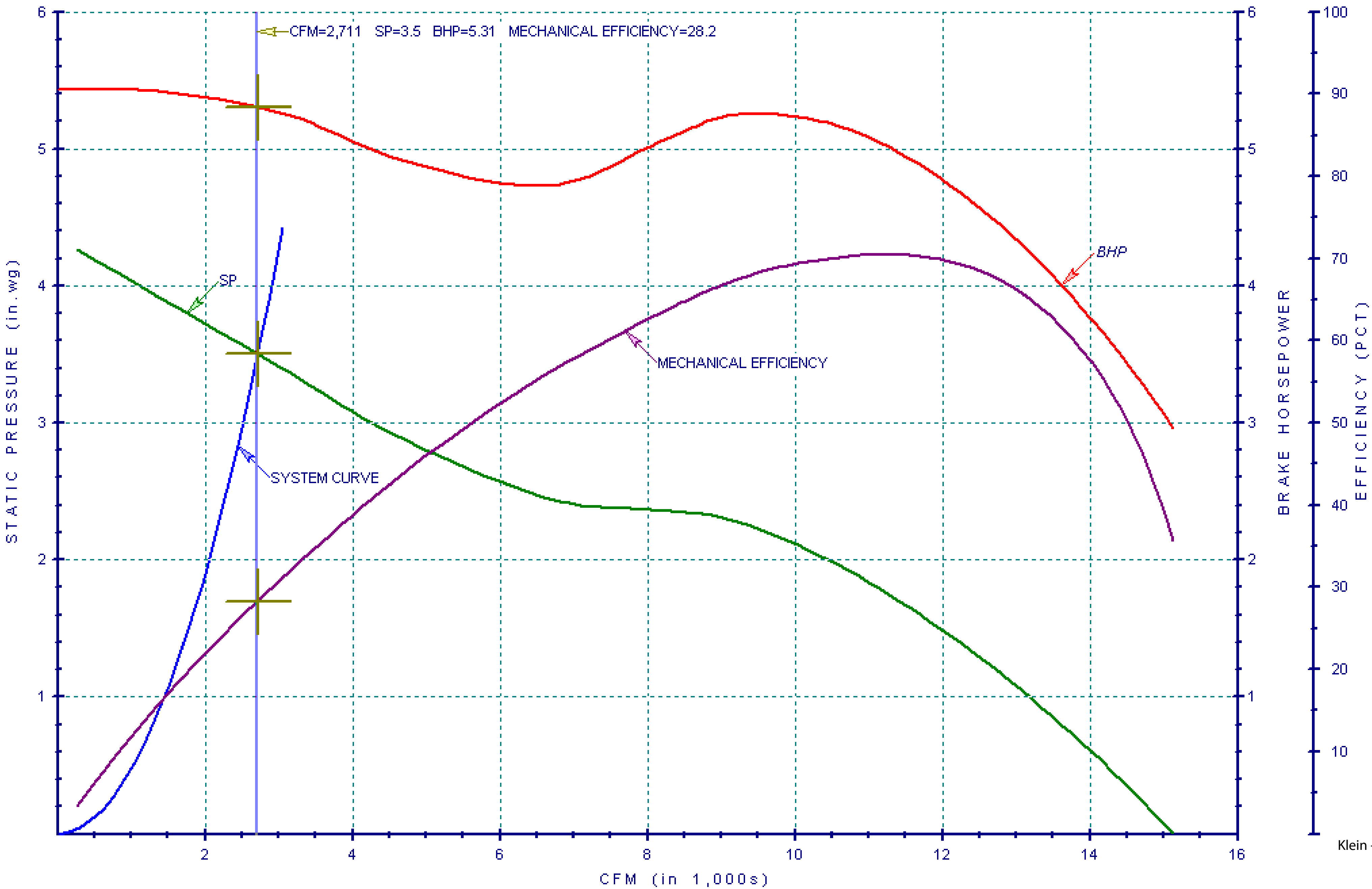
Customer:	Fan Tag: RF-26B
Job ID:	Model: 32B6 TCVX

89

CFM:	2,720
SP:	3.5 in.wg
RPM:	1371
BHP:	5.31
Outlet Velocity:	480
Density:	0.075

Corrected for:
Blade Angle 30°

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



Inlet Sound Power

Octave	Level
1	88
2	88
3	88
4	87
5	84
6	79
7	73
8	71

in db re 10-¹² watts

Klein - 25/36

3/31/2008 00:35 #6

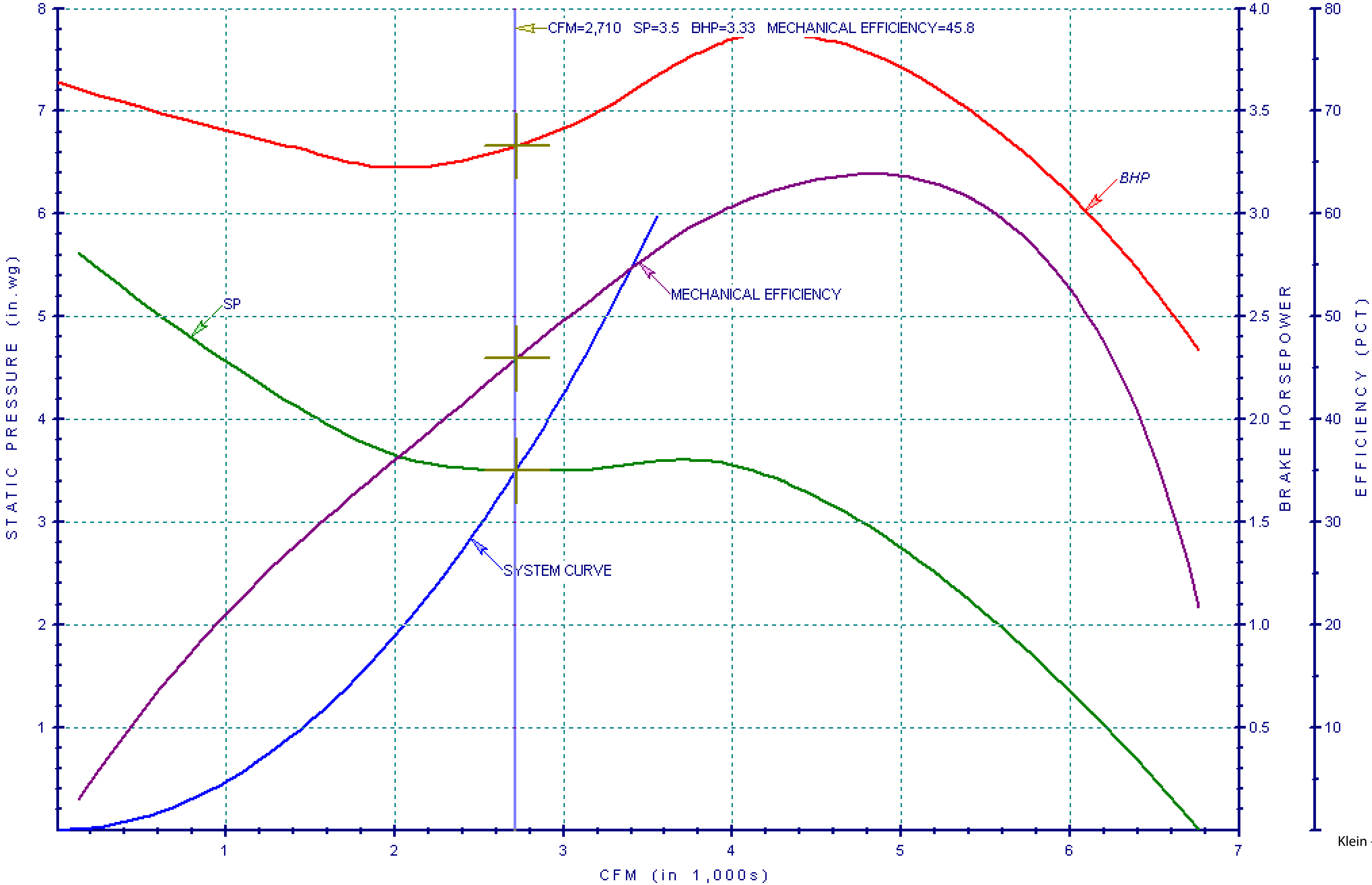
Customer:	Fan Tag: RF-26B
Job ID:	Model: 21B7 TCVX

91

CFM:	2,720
SP:	3.5 in.wg
RPM:	2404
BHP:	3.33
Outlet Velocity:	1,111
Density:	0.075

Corrected for:
Blade Angle 30°

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



Inlet Sound Power

Octave	Level
1	86
2	85
3	88
4	89
5	87
6	82
7	78
8	76

in db re 10-¹² watts

Klein - 26/36

3/31/2008 00:20 #3

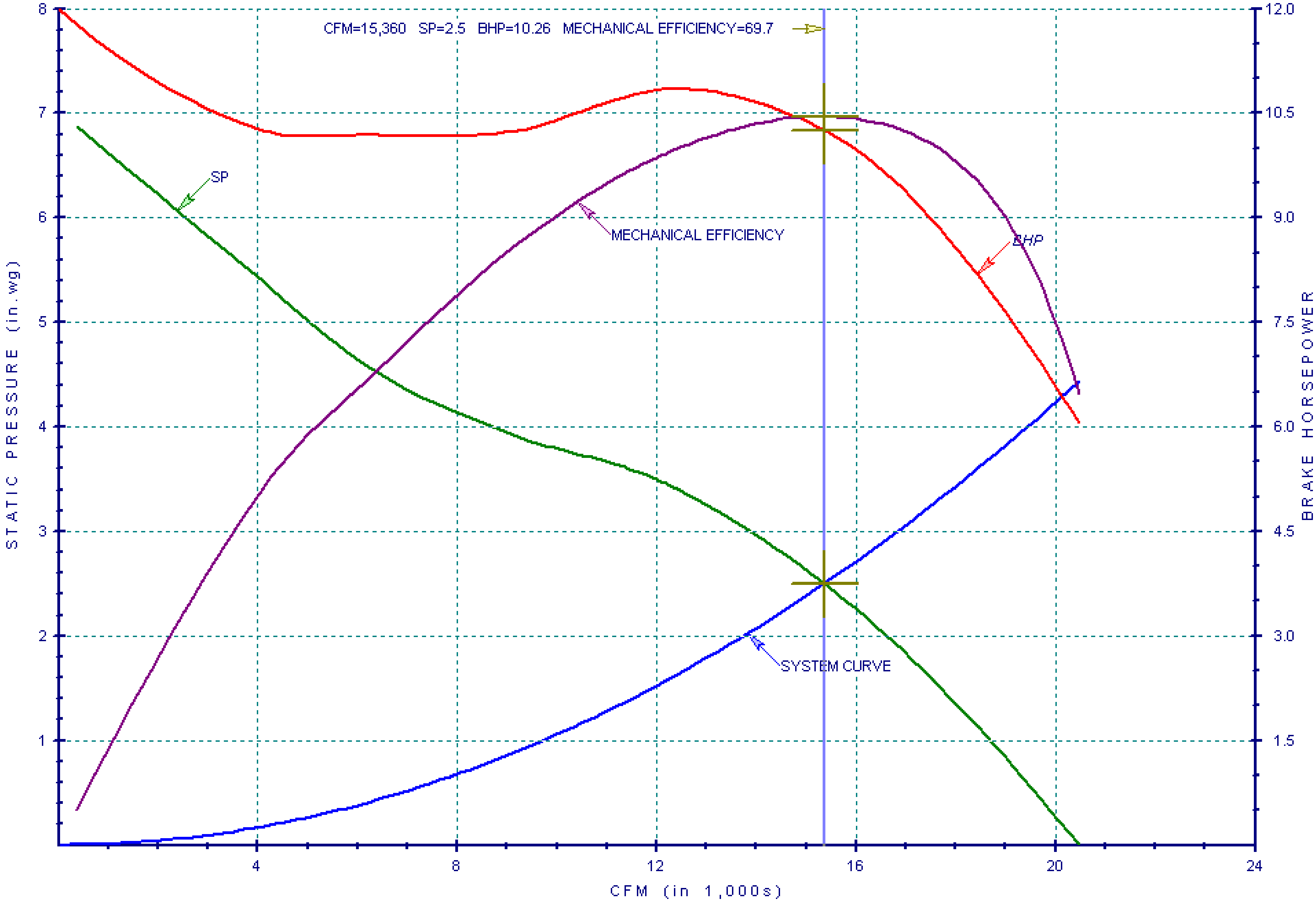
91

Customer:	Fan Tag: RF-12B
Job ID:	Model: 32B4 TCVX

CFM:	15,365
SP:	2.5 in.wg
RPM:	1955
BHP:	10.25
Outlet Velocity:	2,709
Density:	0.075

Corrected for:
Blade Angle 30°

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



Inlet Sound Power

Octave	Level
1	88
2	89
3	92
4	88
5	86
6	81
7	79
8	78

in db re 10-¹² watts

Klein - 27/36

3/31/2008 00:39

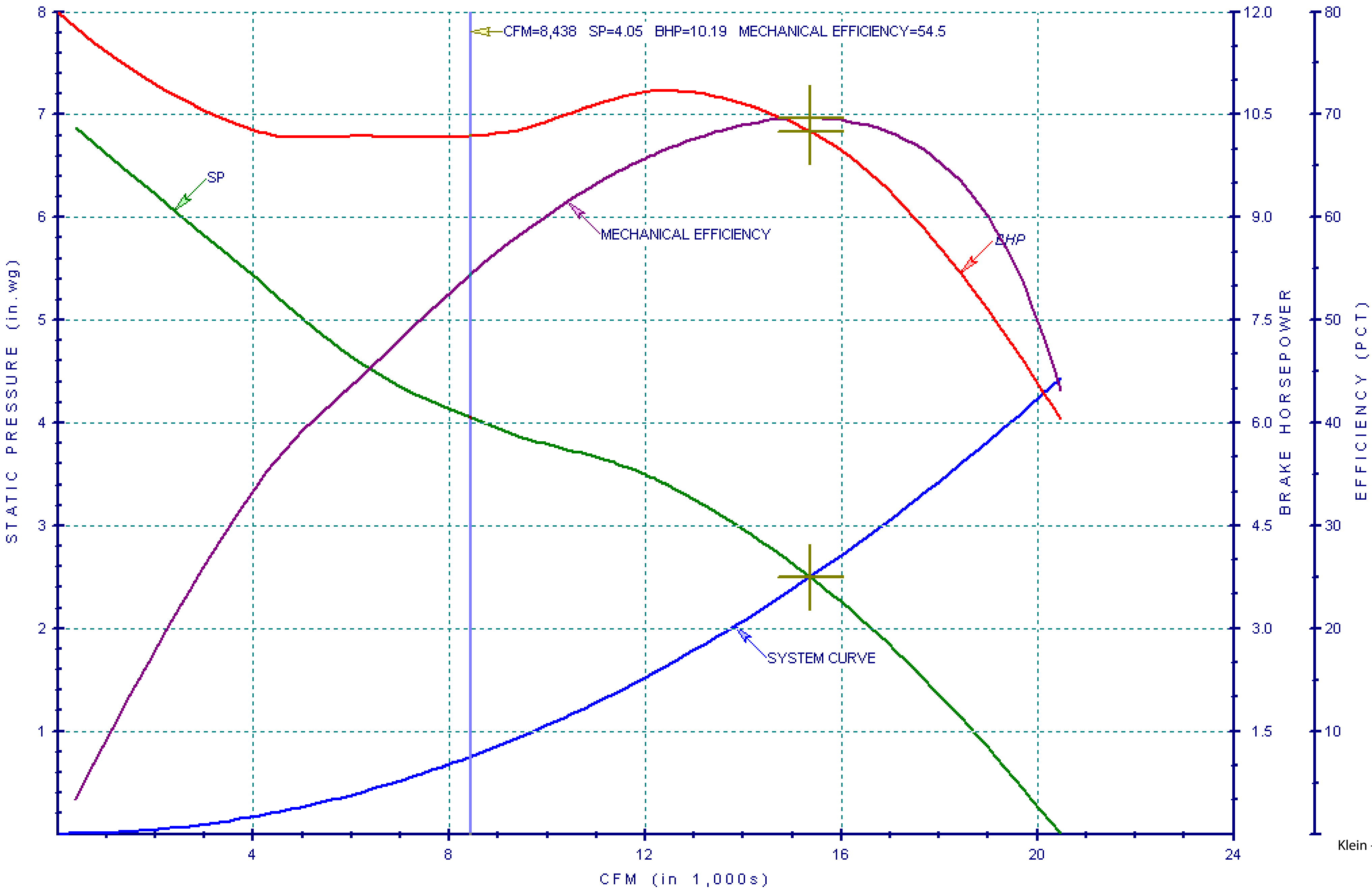
Customer:	Fan Tag: RF-12B
Job ID:	Model: 32B4 TCVX

CFM:	15,365
SP:	2.5 in.wg
RPM:	1955
BHP:	10.25
Outlet Velocity:	2,709
Density:	0.075

Corrected for:
Blade Angle 30°

91

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



Inlet Sound Power

Octave	Level
1	88
2	89
3	92
4	88
5	86
6	81
7	79
8	78

in db re 10-¹² watts

3/31/2008 00:48

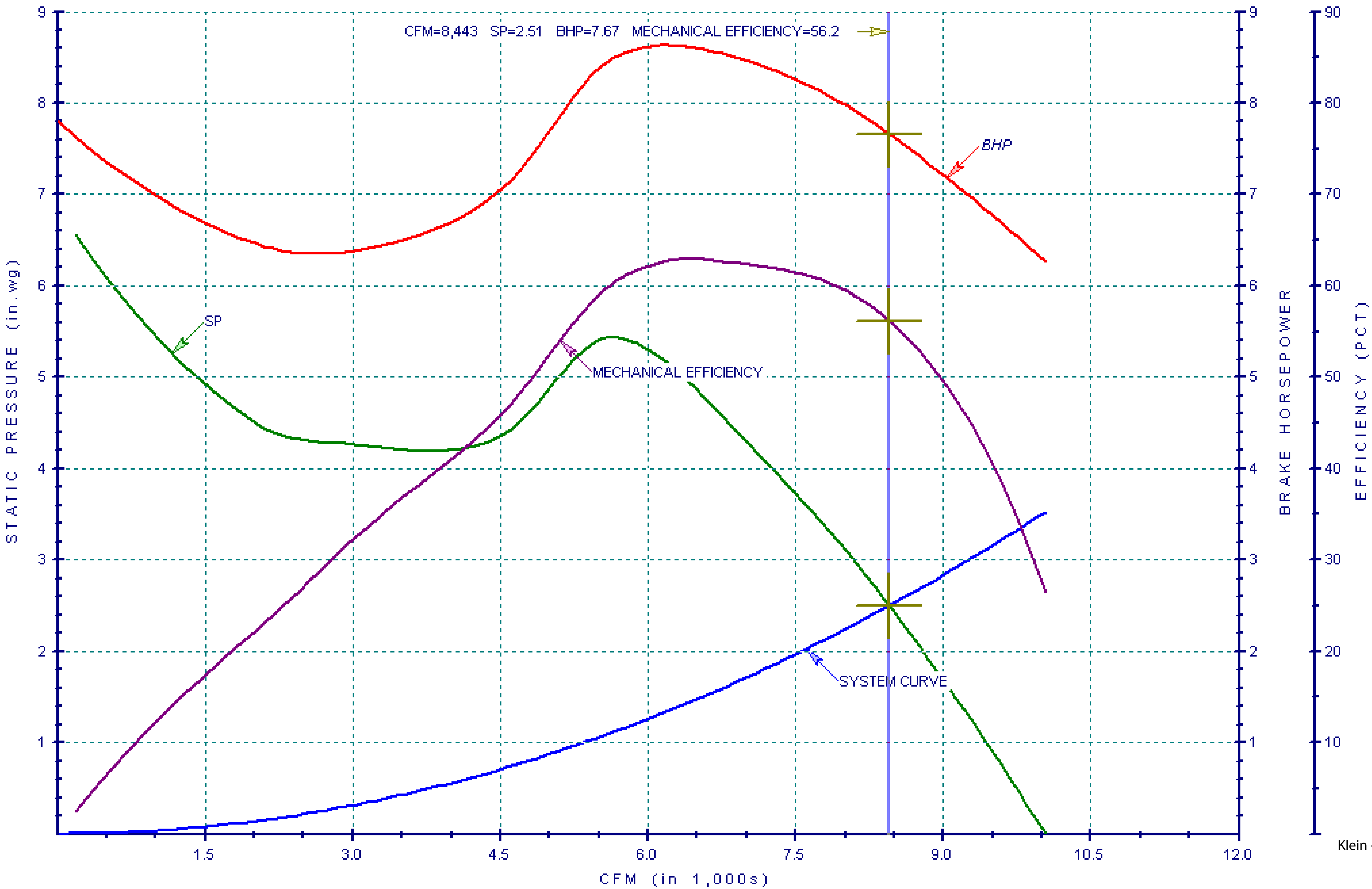
97

Customer:	Fan Tag: RF-12B
Job ID:	Model: 21B7 TCVX

CFM:	8,450
SP:	2.5 in.wg
RPM:	2738
BHP:	7.67
Outlet Velocity:	3,452
Density:	0.075

Corrected for:
Blade Angle 40°

TWIN CITY FAN AND BLOWER PERFORMANCE CURVE



Inlet Sound Power

Octave	Level
1	87
2	86
3	92
4	94
5	93
6	89
7	84
8	83

in db re 10-[12] watts

Klein - 29/36

3/31/2008 00:41

Appendix F:

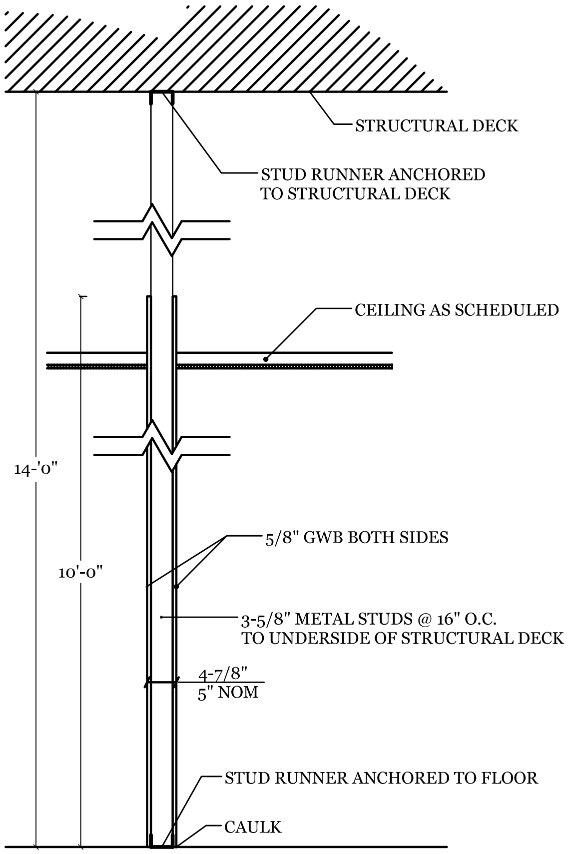
Complete Operating Costs Sheet

Fan Operating Cost Savings

Fan Name	Fan Type	Settings	Load		Mechanical Efficiency	BHP	KWH	KWH/yr	Operating Cost		
			cfm	*wg*					1 yrs	5 yrs	10 yrs
SF-26B-1 (x2)	EPFN 182	Design	8500	8.5	67.71	16.8	12.53	109787.3	$12,746.31	$66,280.81	$132,561.61
	Class III	Demand	3685	3.5	69.13	2.93	2.19	19147.43	**$2,223.02**	**$11,559.69**	**$23,119.38**
	EPFN 165	Demand	3685	3.5	60.76	3.34	2.49	21826.77	**$2,534.09**	**$13,177.26**	**$26,354.51**
	Class II							**Savings**	**$311.07**	**$1,617.57**	**$3,235.13**
RF-26B	TCVX 32B6	Design	15300	3.5	70.51	13.48	10.06	88091.26	$10,227.40	$53,182.46	$106,364.91
	Class II	Demand	2720	3.5	28.2	5.31	3.96	34700.64	**$4,028.74**	**$20,949.47**	**$41,898.94**
	TCVX 21B7	Demand	2720	3.5	45.8	3.33	2.48	21761.42	**$2,526.50**	**$13,137.80**	**$26,275.61**
	Class I							**Savings**	**$1,502.24**	**$7,811.67**	**$15,623.33**
RF-12B	TCVX 32B4	Design	15365	2.5	69.97	10.25	7.65	66983.34	$7,776.77	$40,439.18	$80,878.36
	Class II	Demand	8450	2.5	54.5	10.19	7.60	66591.24	**$7,731.24**	**$40,202.46**	**$80,404.93**
	TCVX 21B7	Demand	8450	2.5	56.19	7.67	5.72	50123.14	**$5,819.30**	**$30,260.34**	**$60,520.69**
	Class I							**Savings**	**$1,911.95**	**$9,942.12**	**$19,884.24**

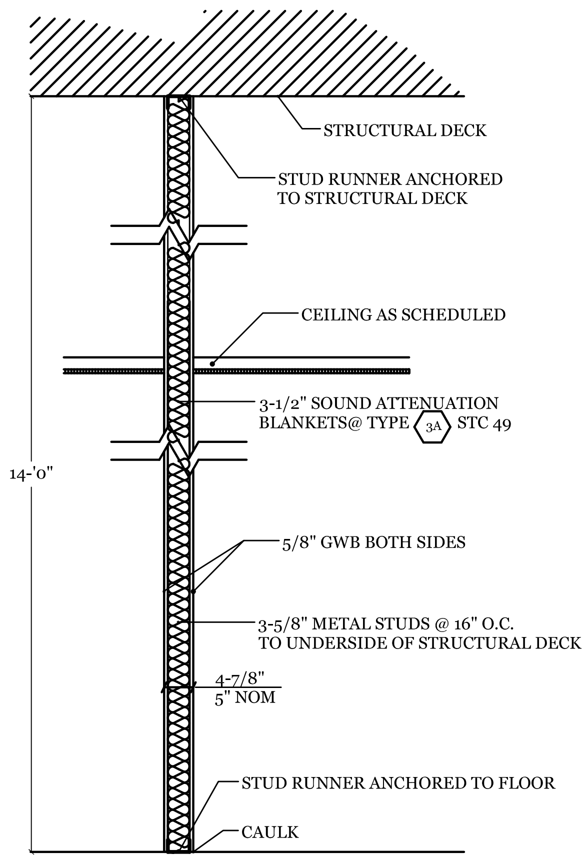
Appendix G:

Detailed Original & New Wall Sections



2 NON-RATED PARTITION

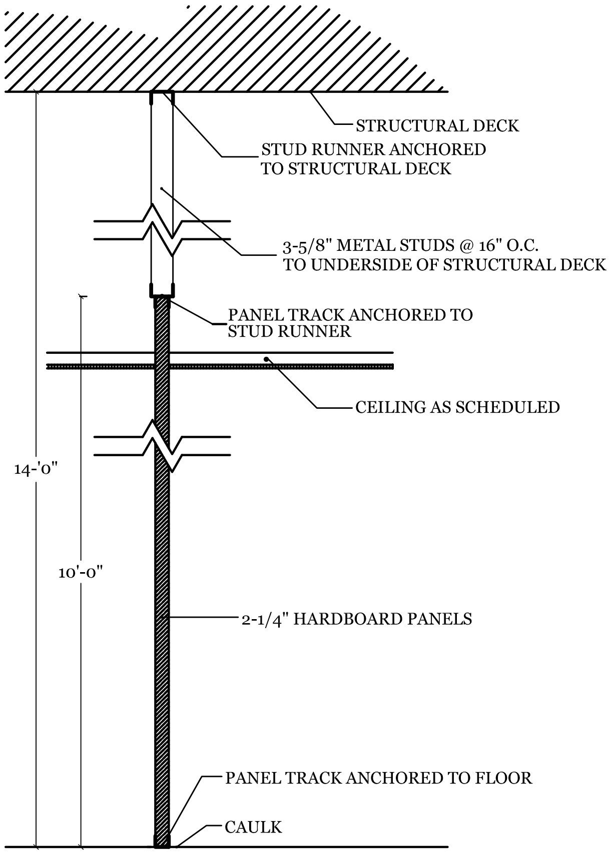
SCALE 3/8" = 1'-0"



3 3A NON-RATED PARTITION

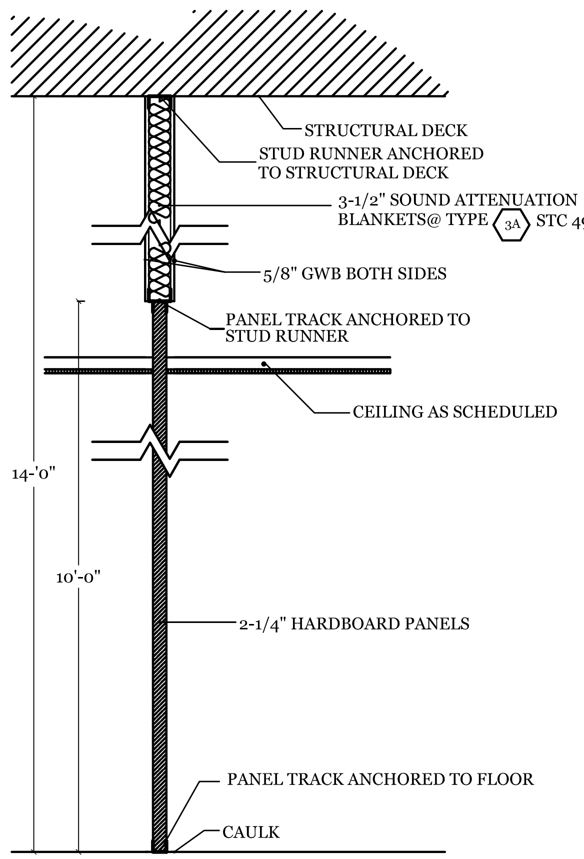
SCALE 3/8" = 1'-0"

ORIGINAL WALL SECTIONS



2 NON-RATED PARTITION

SCALE 3/8" = 1'-0"



3 3A NON-RATED PARTITION

SCALE 3/8" = 1'-0"

NEW DESIGN WALL SECTIONS

Appendix H:

Full Cost & Schedule Spreadsheets

New Panel System Calculations

Wall Type	Wall Element	Qty	Linear Feet (lf)	Height (ft)	Area (sf)	Unit Cost	Cost	Labor Rate (hrs/unit)	Installation Time (hrs)	Crew Size
2	Panels Mat'l	40	160	10	1600	$1.75	$2,800.00			
	Panels Labor		134			$12.70	$1,701.80	0.333	44.62	2
	Studs		134	4	536	$1.21	$648.56	0.013	6.97	2
3	Panels Mat'l	110	440	10	4400	$1.75	$7,700.00			
	Panels Labor		386.5			$12.70	$4,908.55	0.333	128.70	2
	Wall Assembly		386.5	4	1546	$3.89	$6,013.94	0.047	72.66	2
3A	Panels Mat'l	290	1160	10	11600	$1.75	$20,300.00			
	Panels Labor		1119.5			$12.70	$14,217.65	0.333	372.79	2
	Wall Assembly		1119.5	4	4478	$3.89	$17,419.42	0.047	210.47	2
	Insulation		1119.5	4	4478	$1.04	$4,657.12	0.009	40.30	1
						Total	**$80,367.04**		**876.52**	