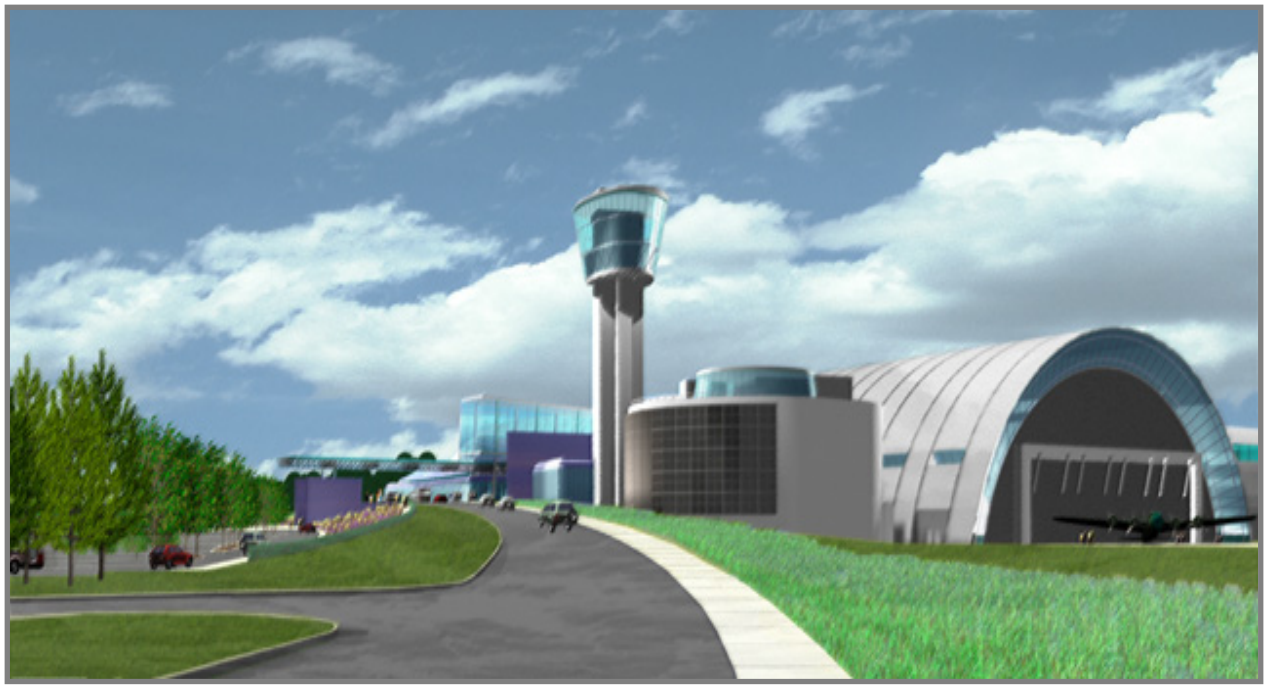
STEVEN F. UDVAR-HAZY CENTER
NATIONAL AIR AND SPACE MUSEUM



IMPROVING SAFETY AND SUSTAINABILITY

CRAIG DUBLER

ARCHITECTURAL ENGINEERING THESIS
CONSTRUCTION MANAGEMENT
SPRING 2004

Steven F. Udvar-Hazy Center

National Air and Space Museum

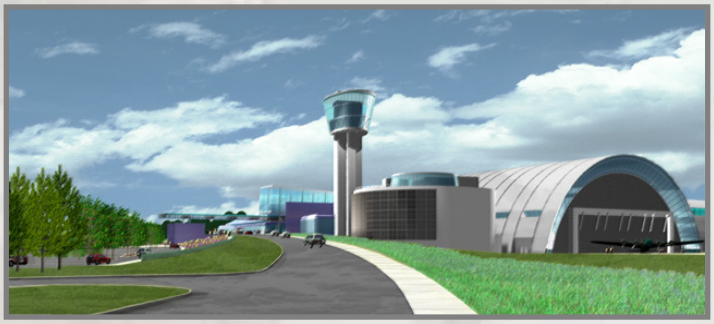
Chantilly, Virginia

Project Team

Owner: Smithsonian Institute
Architect: Hellmuth, Obata + Kassabaum
CM Agency: Parsons Brinkerhoff
GC: Hensel Phelps Construction Company
Mech. Contractor: John J. Kirlin
Elec. Contractor: M.C. Dean
F.P. Contractor: Capitol Sprinkler

Project Overview

Size: 470,000 Square Feet
Cost: $125,000,000
Delivery Method: Deign-Bid-Build
Project Duration: 30 Months
Design includes: Main Exhibition Hangar, Public Amenities, IMAX Theater, and Observation Tower



Structural System

Main Hangar – Arched tri-truss steel system that ties into cast-in-place thrust blocks; drilled caisson foundation
Public Amenities & IMAX Theater – Steel skeleton with slab on metal deck; spread footing foundation
Observation Tower – Steel system encased in concrete; spread footing foundation

Lighting / Electrical System

- Hangar is equipped with a 39-watt ceramic metal-halide system along with 90 percent reflective ceilings to conserve light
- Public Amenities contains a 32-watt florescent lighting system
- 4000A Total Amps
- 13,200V supply stepped down to 277/480 and 120/208 for distribution
- 64,000 linear feet (12 miles) of Walker duct

Mechanical System

Reheat Air System containing:
3 - 200-400hp gas-fired steam boilers for heating
4 - 500-760 ton centrifugal chillers for cooling
4- Huge AHUs generate mixed air to main hangar
9 - Indoor air handlers supply to public amenities
27 - Ice Storage Tanks pass cold air to chillers
9.8 - Diameter of largest return duct (in feet)

Craig Dubler
Construction Management Option
http://www.arche.psu.edu/thesis/2004/crd137

TABLE OF CONTENTS

Appendices:

Index of Tables and Figures:

EXECUTIVE SUMMARY

The following Architectural Engineering senior thesis project focuses on methods of improving the design and construction of the Steven F. Udvar-Hazy Center located in Chantilly, Virginia. The analysis performed focuses on the following four topics: value engineering, constructability, schedule reduction, and research of developing methods.

The first analysis examines the sequencing of the main hangar steel construction. This process is very important since it is a large portion of the overall project, as well as the most complex. To eliminate problems during construction, a 4-D model of the steel erection has been assembled and reviewed.

The second analysis looks at implementing a 4D model into the safety plan. This model specifically identifies where and when activity hazards occur in the Main Observation Hangar. This was done by breaking the Main Hangar into eight areas, simulating what activities will be working in these areas, and then listing the hazards that go along with these activities. After the model was created, an interview was conducted to determine if the safety plan could actually be implemented.

The third and final analysis deals with improving the sustainability in this new facility. This is performed in two different areas: the water retention and mechanical systems. To improve sustainability in the water retention system, a porous pavement system is proposed. This system allows for a more natural draining, and eliminates a huge water basin. To decrease the energy use of the mechanical system, an enthalpy wheel is sized for the air handling unit that controls the air flow into the IMAX theatre auditorium.

PROPOSAL

Analysis I – 4-D CAD – Main Hangar Steel

Rational: Since the planning and construction for the Main Hangar Steel is very complex, it poses problems for production as well as safety. Therefore, a 3-D or 4-D CAD model would be very beneficial to help simplify the process. This helps eliminate production problems as well as safety problems for the steel subcontractor.

Objective: To build a 4-D model to show the steel sequencing including cranes to help eliminate safety and production problems.

Methods: I would like to start by researching the usefulness of 4-D Cad and then relate that to the steel sequencing. I decided to show the crane placement in order to give the feel of how the structure is actually built. This is important because it give the steel subcontractor an idea on how the steel should be laid out before erection.

Result: I expect that the Model will be very useful in understanding the construction sequence. This is turn will help everyone involved in the steel construction to understand the progress of the structure in a given time.

Concerns: I am uncertain that I can get useful feedback from the construction industry on 3-D or 4-D CAD feasibility.

Analysis II – 4-D Safety Plan

Rational: Safety is a very important part of all projects. This is especially true for the new Air and Space Museum. This is due to a number of reasons such as: the building is complex, half the workforce is Hispanic, and the insurance is controlled by the General Contractor. This is called and CCIP or Contractor controlled insurance plan. An important part of this is if the project is not safe, the GC is liable to lose money.

Objective: To construct an effective 4-D model that shows safety hazards that are prevalent in the Main Hangar construction.

Methods: In constructing this model, the first step is to identify hazardous activities in the main hangar. This will be done by reviewing the job hazard analysis that was submitted by each subcontractor. After the hazards are determined, a 4-D model will be created to show where these hazards are occurring and at what time. Finally, the feasibility of the Model will be tested through and interview with the safety director on the project. Also, it would be beneficial to know if any accidents occurred according to the developed safety plan.

Result: I expect that the Model will be very useful in understanding the safety hazards within a particular area. I would like to back this up with and interview from the contractor determining its feasibility.

Concerns: I am uncertain the way that to effectively show where the hazards are located in a 4-D Model.

Analysis III – Sustainable Redesign

Site Water Retention Redesign (Option I)

Rational: The existing water retention is made up of three large storm water management ponds. This not only looks bad, but is a wasteful means of site water run-off.

Objective: To redesign the site water retention system to include a more sustainable way to disperse excess site water.

Methods: In order to carry out this analysis, I will need to research systems that are more sustainable such as porous pavement and proper site water run-off. After the methods are researched, I will compare the differences between the two systems.

Result: I expect to find that the redesign of the site water retention will save money due to the elimination of the retention pond excavation, as well as being environmentally friendly.

Concerns: I am uncertain that the soil type will allow for porous pavement.

Mechanical System Redesign (Option II)

Rational: The existing mechanical system for the Public Amenities was created with only cost in mind. This means that the system in place serves its purpose, but has the opportunity for improvement.

Objective: Can the Mechanical system located in the Public Amenities Areas be redesigned to allow for sustainability? If so, can the cost be kept to a minimum?

Methods: In order to carry out this analysis, I will need to research systems that are more sustainable without decreasing the constructability.

Result: I expect to find that the existing mechanical system can be upgraded to a more sustainable system without eliminating its constructability.

Concerns: I am uncertain that I can redesign the system with minimal costs.

After both systems have been redesigned, I intend to analyze the total cost of the redesigns. Hopefully, they will balance out with the increase cost of the mechanical system as opposed to the saving of the porous pavement

Analysis	Analysis Description	Area 1	Area 2	Area 3	Area 4	TOTAL
I	Steel Sequencing		15	15	5	35
II	4D Safety Plan		5	5	25	35
III	Sustainability Redesign	20			10	30
		20	20	20	40	100

Area 1: Value Engineering Analysis
Area 2: Constructability Review
Area 3: Schedule Reduction / Acceleration Proposal
Area 4: Research and Development Methodology

BUILDING INTRODUCTION

Occupant: Smithsonian Institution

Function: National Air and Space Museum

Size: 470,000 square foot

Number of Stories: Main Exhibit Hangar – 10 Stories
Observation Tower – 16 Stories
Public Amenities – 2 Floors
IMAX Theater – 5 Floors

Primary Project Team:

Architect – Hellmuth, Obata + Kassabaum (HOK)
http://www.hok.com/

Construction Manager – Parson Brinckerhoff Construction Services
http://www.pbworld.com/

General Contractor – Hensel Phelps Construction Company
http://www.henselphelps.com

Mechanical Contractor – MC Dean
http://www.mcdean.com/

Electrical Contractor – John J. Kirlin, Inc.
http://www.johnjkirlin-inc.com/

Steel Contractor – ADF International, Inc.
http://www.adfgroup.com/english

Construction Dates: April 2001 – December 15, 2003

Cost Information: Overall Project – $309 million
Building incl. Construction - $125million

Project Delivery Method: Design – Bid – Build

Architecture

The design of the Air and Space museum contains four major components:

- The Main Exhibit Hanger consists of an arched Tri-truss design, hanging mezzanine walkways, counter-weighted Exhibit doors, and a rubber membrane roof.
- The Space Hanger, which will contain the Space Shuttle Enterprise, consists of a "space frame" truss design, sliding exhibit doors, rubber membrane roof, and metal panel exterior.
- The Observation Tower is an egg shaped design that is fastened above a twelve-story shaft. The egg exterior is made up of angled glazing and metal panels. The shaft is also wrapped in metal panels.
- Public Amenities including: classrooms, a retail shop, a restaurant, and an IMAX theater. The exterior consists of metal panels, curved glazing, and metallic ceramic tile.

The building envelope is made up of a combination of glazing, custom metal panels, and ceramic tile.

Major National Code: BOCA (1996)

Zoning Requirements: Must abide by Dulles International Airport Zoning

OWNER PROFILE

The Smithsonian Institution is the world's largest museum complex and research organization. Composed of 14 museums and the National Zoo in Washington, D.C., and 2 museums in New York City, the Smithsonian's exhibitions offer visitors a glimpse into its vast collection numbering over 142 million objects.

Since the opening of the original Air and Space Museum, the Institute has been planning on building a facility like the Steven F. Udvar-Hazy Center. Less than 10 percent of the National Collection of artifacts that reflect the history of flight are on display at any one time at the Museum in Washington, DC. Also, very large machines, like the Space Shuttle *Enterprise*, can never be trucked into the city.

On this project, Smithsonian is looking for a state of the art; high quality building that is able to preserve their remaining artifacts. This is shown in the amount of time, and money that was spent in design and planning of the new Air and Space Museum. Another issue that is important to SI is safety. This was a big criteria in selecting a general contractor for the job. The contractor that was chosen, Hensel Phelps Construction Company, has one of the best safety ratings in the industry.

Keys to completing this project to the owner's satisfaction integrate quality of work, and deadlines for completion. Superior quality is of course important for a museum that will hold a huge part of aviation history. Also, deadlines must be met to open the building on the 100th year anniversary of man's first flight. This means that the building must not only be complete, but the artifacts must be in place for the grand opening in honor of the Wright brothers' first flight at Kitty Hawk, North Carolina. The doors are set to open on December 17, 2003.

SYSTEMS ANALYSIS

Electrical: The system consists of a 13,200V supply stepped down to 277/480 and 120/208 for distribution. The supply is carried under the slab in the Main Hangar through Walker Ducts. This allows for artifacts to be set up anywhere throughout the Hanger by coring through the slab and into the duct.

Lighting: The Main Hangar is equipped with a 39-watt ceramic metal-halide system along with 90 percent reflective ceilings to conserve light. The Public Amenities areas contain a typical 32-watt florescent lighting system.

Mechanical: All areas in the museum use a reheat air system. In the Public Amenities, variable air volume (VAV) boxes are situated in the plenum and control the air volume to each room. The mixed air in the Main Hangar in generated by four massive air-handling units (AHU). Heated air is produced by three 200 - 400hp gas-fired steam boilers, and chilled air is produced by four 500 – 760 ton centrifugal chillers along with 27 ice storage tanks.

Structural: The Main Hangar consists of an arched tri-truss steel system that ties into cast-in-place thrust blocks. The foundation for each trust blocks is a set of three 42” diameter drilled caissons.
The Public Amenities’ system is a steel skeleton, with slab on metal deck, which is supported by spread footings.
The Observation Tower is made up of a steel skeleton encased in concrete. The foundation is a 32” mat slab.

Fire Protection: The Hazy Center is protected 100% by a sprinkler system. Also, the steel in the public amenities is fireproofed using spray on fireproofing to a two-hour rating. Due to the large amount open space in the Main Hangar, the steel does not have to be fireproofed.

Transportation: There are a total of ten elevators and eighteen sets of stairs in the new Air and Space Museum. This includes an elevator to the top floor of the Observation Tower, and mezzanine walkway throughout the Main Exhibit Hangar

CONSTRUCTION CONSIDERATIONS

SUBSURFACE AND SOIL CONDITIONS

The new Air and Space Museum (Steven F. Udvar-Hazy Center) is located on the grounds of the Washington Dulles International Airport. In total, 30,000 Cubic Yards of soil was removed from the site. Because of the size of the site, most can be stock piled and used later, but some will need to be trucked away to an adjacent site.

Prior to the contract being awarded, Smithsonian Institute hired Patton, Harris, & Rust to perform boring samples on site. The results of the soils report concluded that a creek once flowed through the site. Riverbed sand was found in some of the borings. As a result, the soil was classified as a type C, and caissons had to be drilled for the Main Hangar foundation. For reasons like this, it is important to conduct a soils report prior to bidding on a project.

If a soils report is not drawn out, there are many risks involved in the projected cost of a buildings foundation. Although, a differing site conditions (DSC) clause can be placed in a contract to mitigate a contractor's risk for unforeseen site conditions. As for the new Air and Space Museum, Hensel Phelps contains this clause in their contract. This basically assures the contractor compensation from the owner in the event unforeseen conditions, not discovered prior to bidding, are encountered. A DSC clause is important because these conditions often lead to delays and impacts, which can dramatically increase the costs of completing a project.

When excavation began onsite, a large site wall was built for soil retention. The wall was later used as a structural exterior wall for the first floor of public amenities. Also, in order to control erosion and settlement on site, silt fences and temporary filter barriers were placed around the site perimeters.

PROJECT COST EVALUATION

Actual Building Construction Cost (CC):	$125,000,000
Total Square Foot (SF):	470,000 SF
Construction Cost per Square Foot:	$266/SF
Total Project Costs (TC):	$309,000,000
Total Project Cost per Square Foot:	$657/SF
Major Building Systems Costs:	Costs are confidential as per request of Hensel Phelps Construction Company.
Design Costs:	$8,000,000

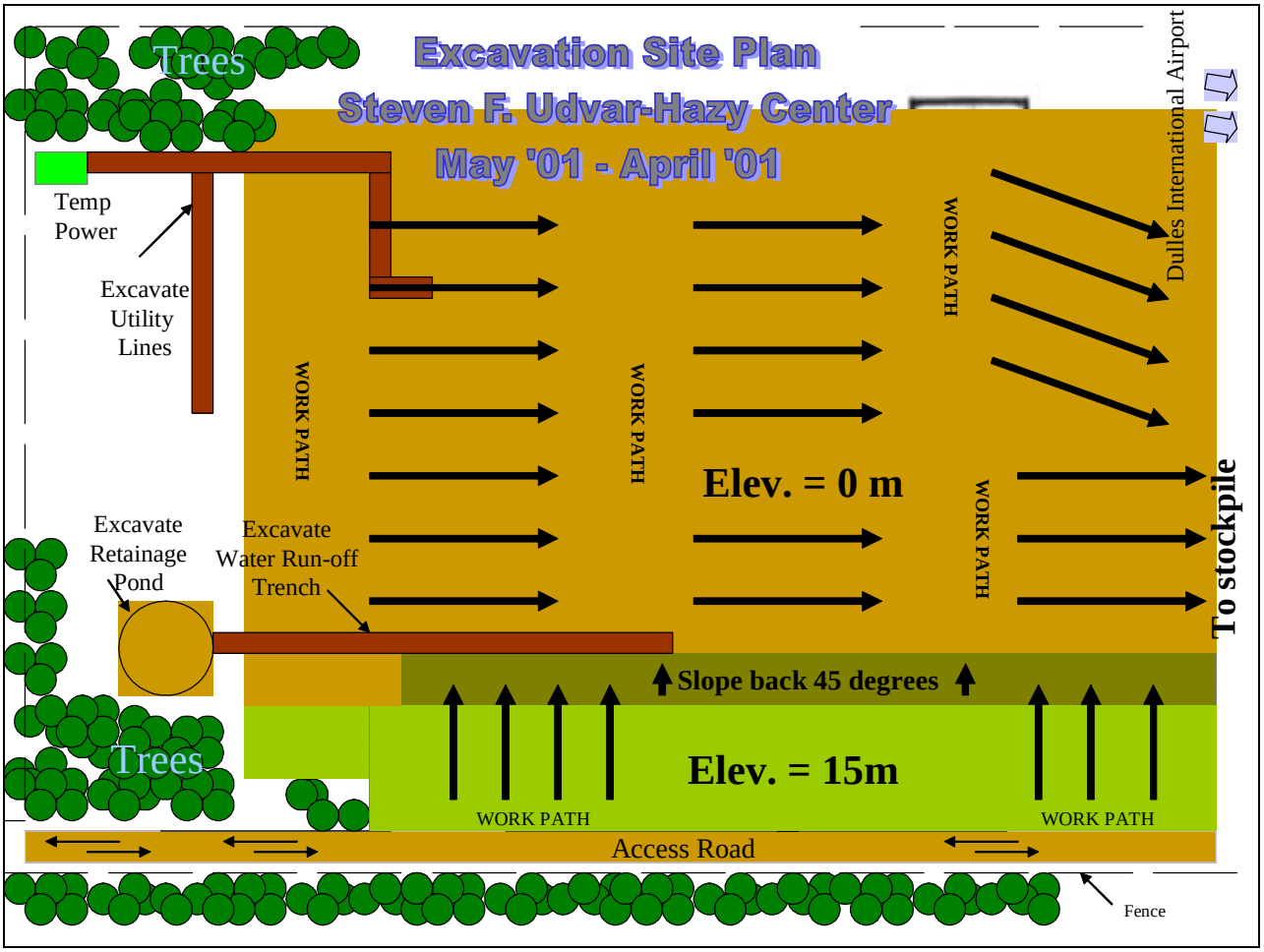
LOCAL MARKET CONDITIONS

The current labor market in the Northern Virginia area is very diverse. Skilled workers for most trades can be found relatively easily. This has a lot to do with the workers wanting to stay close to home rather than travel into the District of Columbia, where most of the larger scale projects are located. Since most buildings around the Chantilly are constructed out of concrete, labor unions are used when looking for steel erecters, pipe fitters, and bricklayers.

Another advantage of working outside the city is that project sites, for the most part, are not nearly as congested. This leaves adequate room for employee parking, and material staging. This also allows for the delivery sequence to be a little more lax.

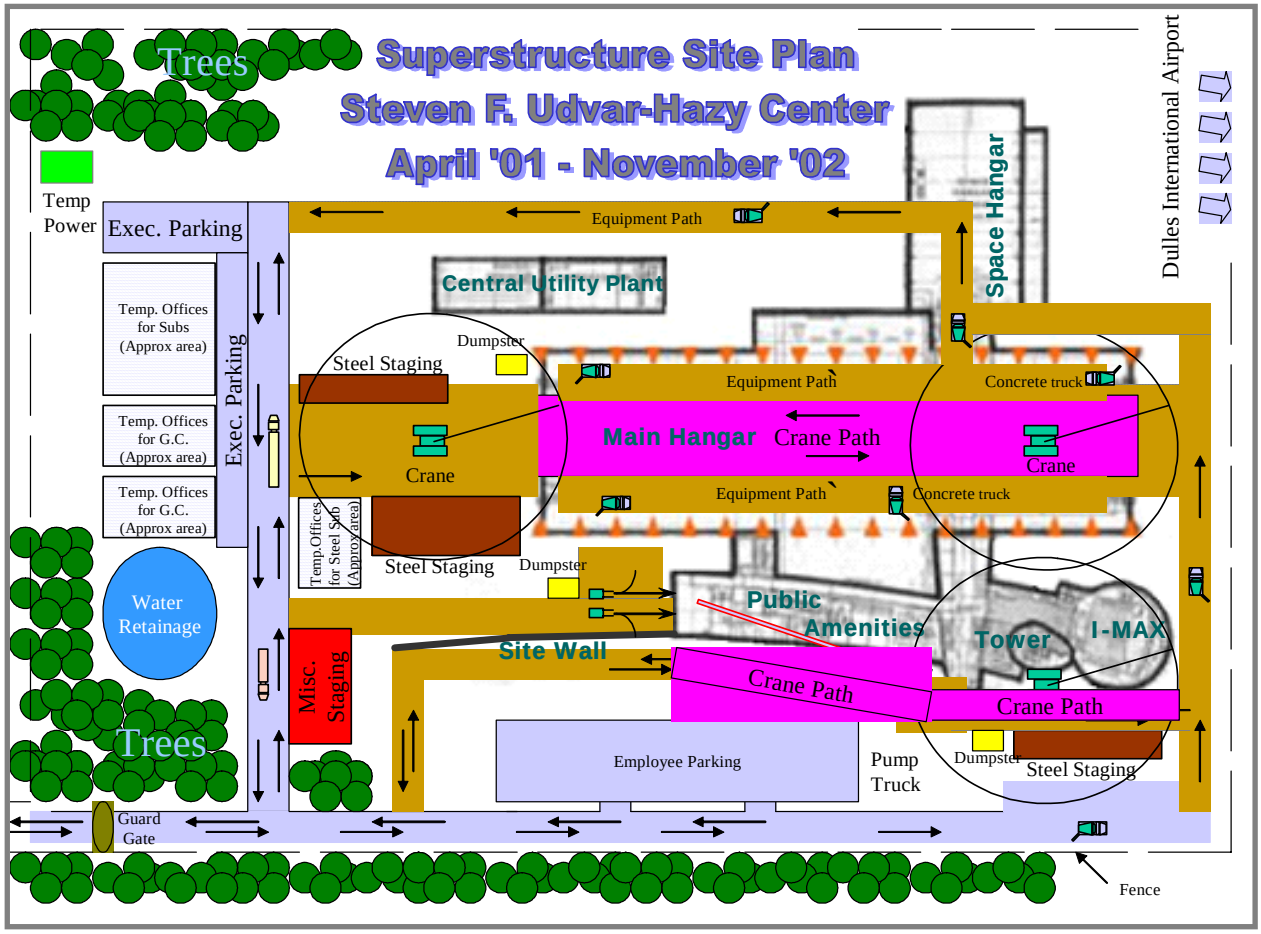
SITE LAYOUT PLANNING

Excavation Phase



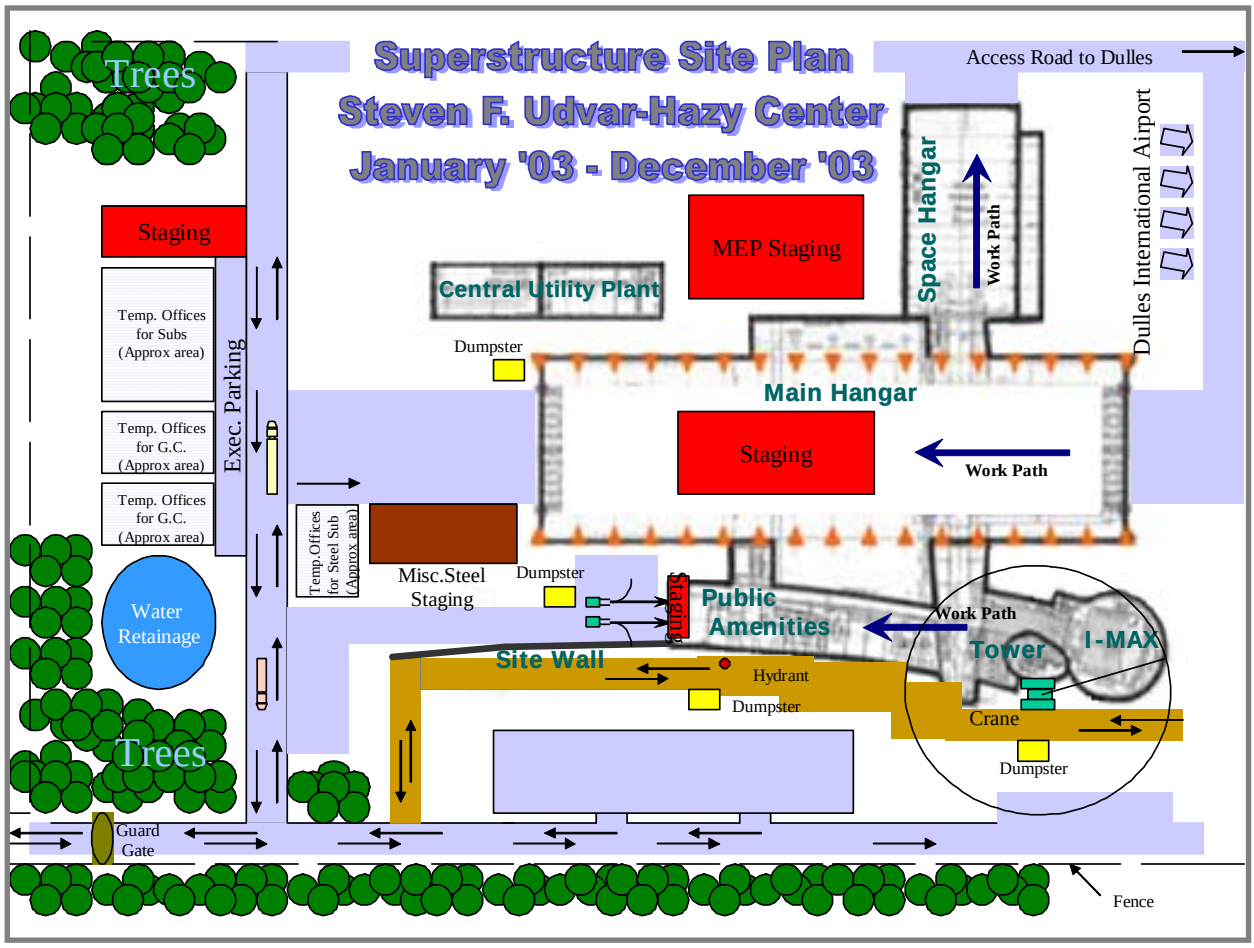
- Equipment used for mass excavation includes: 3 scrapers, 4 Bulldozers, 1 Track hoe, along with 4 dump trucks
- A drainage system along with water retention ponds were constructed for water run-off
- In total 30,000 Cubic Yards of soil was excavated from the site.
- Because of the size of the site, most can be stock piled and used later, although about 35 percent will need to be trucked away to an adjacent site.

Superstructure Phase



- Site is not very congested, which allows for staging of materials
- Site can get muddy, so materials should be elevated
- Construction path starts from right to left according to crane paths above
- For the Main Hangar Construction 2 Crawler Cranes will be used
- Steel for Main Hangar is delivered and erected in pieces
    - Connections are bolted to save time and allow for adjustments
    - Two cranes are needed to walk center section into place
- Tower is built in three sections up to 5th Floor
    - "Egg" on top is erected prior, then lifted by crane into place

Finish Phase



- Site starts to get congested when site construction begins
- Planes are brought in from Dulles on the access road
  - Site must be clean for planes to taxi
  - Parking is limited due to Media
- Tower and Theater finish materials are delivered to floors by crane
- Crane is also used for pouring site walls
- Staging must be moved when site work progresses

ANALYSIS I: SEQUENCING OF MAIN HANGAR STEEL CONSTRUCTION

Background

The steel erection is by far the most crucial activity on the Steven F. Udvar-Hazy Center. It account for nearly 20 percent of the total construction cost. A lot of this has to do with the complexity of the Main Hangar steel. The Main Hangar is made up of a tri-truss arched steel system. This can be seen below in Figure 1. In order to erect this, each truss must be broken into three sections. The three sections consist of an east and west side truss as well a mid truss as shown going in below.

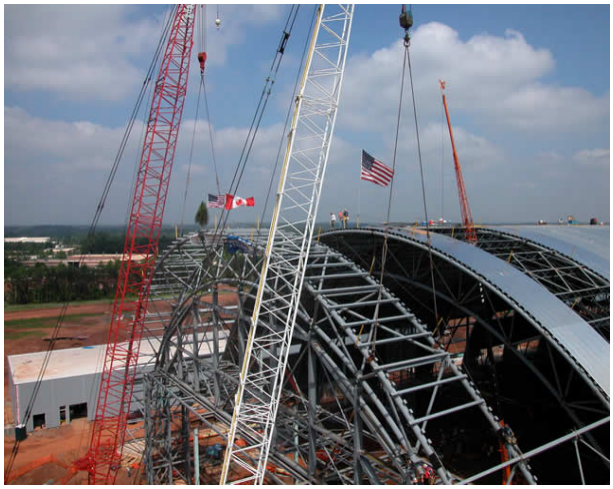


Figure 1: Raising the final steel truss (Smithsonian)

Besides being expensive, the main hangar steel erection process is also complex and unsafe. The total duration from getting steel onsite to topping out is a little under six months. This is not a long time to erect this huge amount of steel. Also, many safety precautions must be taken to insure minimal accidents. In order accomplish all of this, it is crucial that the Main Hangar steel erection is planned out well.

In order to inform the owner as well as other subcontractors on how the erection is to take place, a sequencing plan is drawn out. In this sequence plan the steel contractor needs to show how the steel is to be broken into sections and put into place. It also needs to specify what equipment is being used. This plan also assures the steel erector that the task at hand can be accomplished. This is important due to the fact that the steel erection is crucial to every other subcontractor in the Main Hangar.

Proposed solution: 4D Steel Erection Sequence

As explained above, the steel erection sequence plan that was constructed by the steel contractor shows how the arches are broken up, and what equipment will be used to erect the hangar. This is an acceptable way of letting the owner, subcontractors as well as the steel erectors themselves of how the steel is to be put into place. However, this plan is constructed with a 2D drawing and it does not show exactly where and when each arch will be erected. This is where 4D CAD can help the situation.

A 4D model is a combination of a 3D and time. Basically, the 4D CAD software takes a 3-D object, and links it to a CPM schedule activity. The result is a simulation of the building construction and the dates attached to it. Such a model allows planners of the construction process to visualize the activity as it would have actually been built (Koo).

In order to model the steel erection sequence in 4-D, a 3-D model was created first. It is important that the objects are grouped according to erection. Next, a separate CPM schedule is created according to the structural erection specifically in the Main Hangar area. This was a challenge on the Udvar-Hazy Center since the main schedule of the entire project contained over 4700 activities. The next and final step is to import both the 3D objects and schedule and link the two together. This is why organization is a very important part in 4D modeling. It is wise to plan out how erection process before the model can be created. Another reason on why it is beneficial for the steel erector to construct the model simulation. It gives you a great perspective on how the Hangar steel is to be erected and if the erection is possible.

Results: 2D vs. 4D

Please reference Appendix A for a copy of the 4D Steel Sequencing as well as a copy of the sequencing schedule.

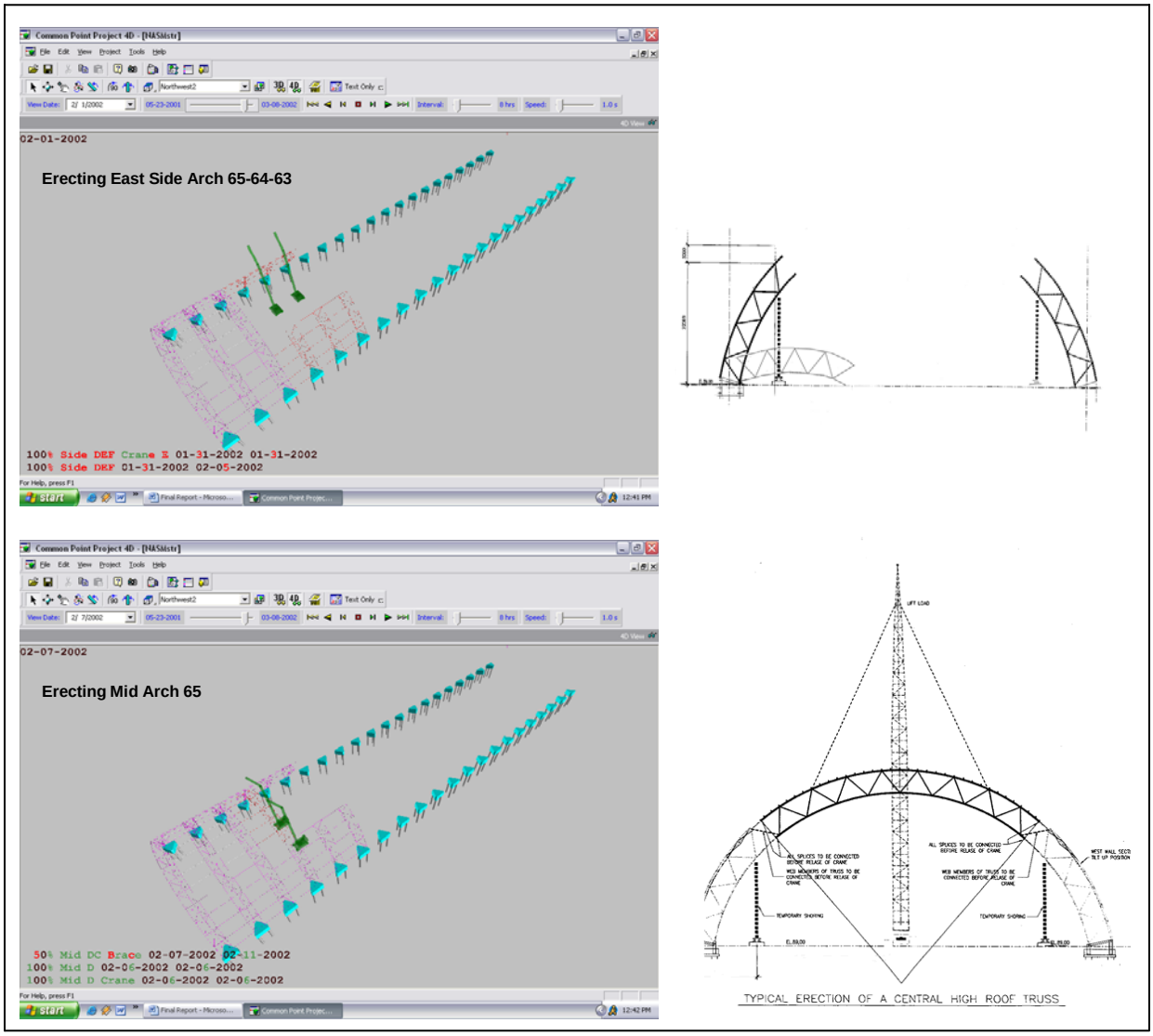


Figure 2: Comparison between 4D and 2D Erection Plans (Smithsonian)

Comparison

As seen on the previous page, 4D CAD give the observer a completely different perspective of the steel erection process. This is important for a number of reasons. First, it allows the steel contractor to present their plan to the owner. This at times can be challenging because some owners are inexperienced and have a tough time understanding a construction process. When the owner looks at the 4D model, they might have questions, but the process does not have to be explained nearly as much.

The next advantage of the simulated erection plan is that is keeps all contractors as the same page. They are aware of where the steel is to be erected and what time. It gives them a sense of space. This also ties into the safety plan, which is described below. The subcontractors understand where materials can and can not be delivered due to the steel erection. Most importantly, it lets the steel contractor know, in order to keep with the schedule, what percentage of the structure has to be completed at what time. For example, looking at the figure 2 above, the first three trusses are scheduled to be set as of February 2, 2001.

The final reason why the model is important is that it forces the steel erector to ask questions about the erection sequence. What is meant by this is that when the erection process is viewed in 4D, questions will be brought up on how the steel in lifted into place, tied together, or even what safety equipment is needed for the task? Workers can imagine themselves putting the structure together when they see the model. This causes them to think about erecting the steel before they are put into that situation.

ANALYSIS II: DEVELOPING A 4-D CAD SAFETY PLAN

Background

The most important aspect to any construction project should be safety. This is especially true for the Steven F. Udvar-Hazy Center. Safety management is important for a number of reasons. First, the shear size and shape of the building lead to tough projects for the construction team. Next, activities that needed to be performed were among the most dangerous in the industry. Another aspect of this project is that half of the workforce is Hispanic, and understands little English. Finally, this project was a Contractor Controlled insurance plan or CCIP for short. This means that if all goes well with little accidents, the general contractor has an opportunity to make money.

The new Air and Space Museum is a state of the art facility that hosts 470,000 square foot of floor space. Included in this is a huge Main Hangar that is almost 1000 feet long, 230 feet wide, and 90 feet high. With an area this size, it is easy to get distracted from the task at hand. Other design obstacles include the round Imax Theater, curved Public Amenities area, and the egg-shaped Observation Tower, which stands 150 feet from the ground floor. With all of this to construct, it is a tough task to keep free from accidents.

Another reason that safety management is important to this project is the difficult activities that take place. The most crucial, as explained above, is the steel construction. With over 6500 tons of steel, 3500 in the Main Hangar alone, it has proven to be a great challenge to manage the safety of construction. This is why it is important that the steel subcontractor make clear how the process is to take place. The 4-D CAD that was shown earlier is a great example of this.

The next reason that safety is important is language barriers. This is explained in more detail under the research section of the paper. However, it can not be stressed enough how important good communication is on a jobsite. Because the site is half Hispanic, relaying a message just got a little bit harder. Also, when signs are put up, and jobsite meetings are held, everything must be translated into Spanish.

The final reason to evoke jobsite safety is that the General Contractor handles the insurance for all workers onsite. This can be considered the most important reason due to the fact that if the jobsite is unsafe, the GC can end up loosing money in injury claims. This means that a lot of pressure is put on them to manage the safety well. In order to do this, they need to take any means necessary to eliminate accidents.

Proposed Solution: Implement Simulated Safety Plan

As research has shown, in order to eliminate accidents, we must first identify where accidents are most likely to occur. This is the purpose of the 4D CAD safety plan. For more information on the feasibility of the simulated safety plan, please refer to the research section starting on page 38.

The first step that was taken in developing a 4D Safety plan involved determining what area the plan should entail. A space that involves too many trades can be very confusing and not an effective form of a 4D safety plan. Knowing this, the Main Hangar was chosen due to the large area and easily distinguished zones. The next step was to determine what trades will be working in the defined area. The trades selected are as follows: Steel erection, Roofing, Fire Protection, Mechanical, Glazing, Electrical, Metal Studs, Painting, and Concrete.

After the area and activities were defined, the next step was to identify what hazards are associated with each trade. This can be accomplished by reviewing a subcontractor's job hazard analysis, which are shown in Appendix B, or looking at the Occupational Safety and Heath Administration (OSHA) website. Both gave very good insight on the hazards that each subcontractor needs to worry about. Other hazards that need to be considered are those involving bystanders or workers in the same area. Basically, this means any hazard that is air born, or lies on the ground.

After hazard information had been collected, it was then time to develop the 3D model. When creating the model, it was important that each activity be color coded in order to link them to their specific hazard. This is accomplished through the "Safety Plan Legend," which is a summary of the hazards, linked by color coding, prevalent to each trade. Each hazard is then described in detail according to the "Specific Job Hazard Analysis." Each of these can be found in Appendix C. Another important aspect of the

3D model is how the Main Hangar is broken into six sections. The divisions are known as Area 4-9, four being the Northeast corner and nine the southwest. It is also important the trades are shown where they are working in the different areas. For example, the glazing activity only takes place around the edge of the Hangar, as opposed to the fire protection taking up the entire area. It is crucial that this be shown in order for actual hazard location.

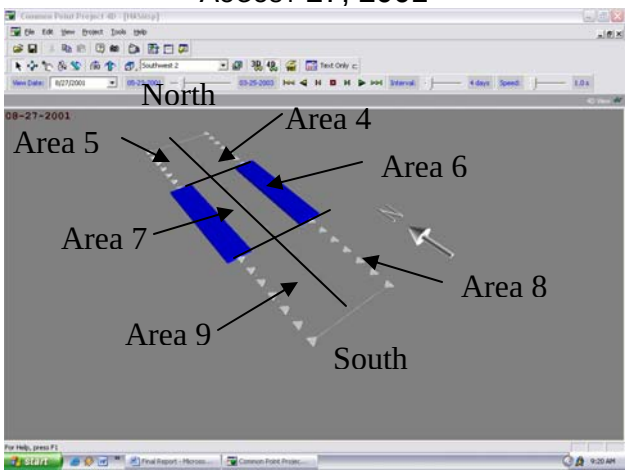
After the 3D model neared completion, it was then time to work on the schedule. This is the areas that took the longest. It needs to be determined when each individual sub is working in each of the areas. As described above, this is not an easy task when the original CPM schedule is over 4700 activities. For this reason, a 4D model schedule can be created with less hassle if it is done in conjunction with the original schedule. Whatever the case, this part of the 4D model might be the most tedious, but it is also the most important.

Just as the steel sequencing plan in Analysis I, the safety plan is put together the same way; by linking each object with a schedule activity. To view a full version of the safety plan, please reference Appendix C.

The 4D Safety Plan works in conjunction with the Safety Plan Legend and the Specific ob Hazard Analysis. The 4D model shows color coded activities in specific areas at a specific time. Then, through the color-coding, the activities are linked to the Legend where the hazards for each activity are listed for both the activity workers and bystanders. Next, the activities are explained in more detail when referring to the Specific Job Hazard Analysis.

Please refer to the next three pages for an example on how to use the Safety Plan. Also refer to Appendix C for a copy of the Legend and Specific Hazard Analysis.

AUGUST 27, 2001



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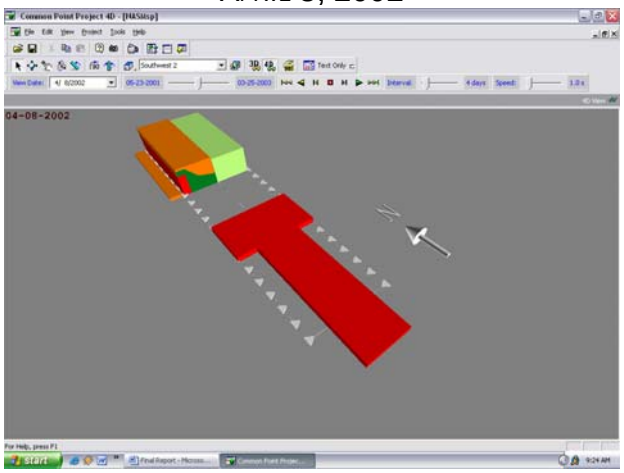
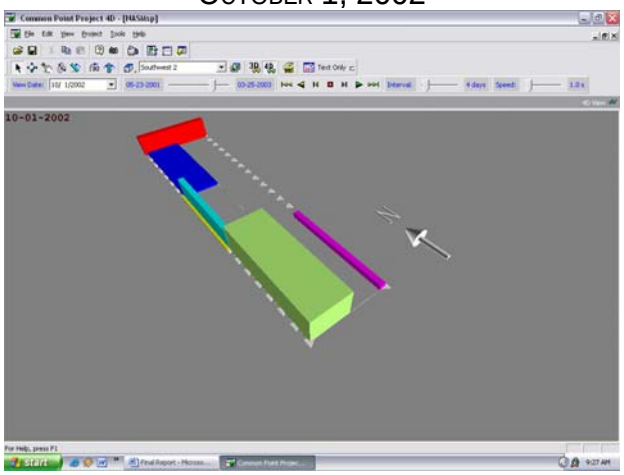


OCTOBER 1, 2002



Safety Hazard Analysis

AUGUST 27, 2001: Area **6 & 7** Concrete workers need to be aware of Excavation hazards, uncovered rebar and nails, any curing compound, as well as silicosis from chipping or drilling of concrete; Bystanders be aware of excavation ditches, metal fillings, drilling or chipping dust.

APRIL 8, 2002: **Area 4** Mechanical workers be aware of falling hazards, metal filling, heavy lifting, and being struck by objects; Bystanders be aware of falling objects, and floor debris

Area 5 Roofing workers need to be aware of falling hazards, cutting metal or wood, hoisting and rigging, and inhaling chemical adhesives. They also need to worry about Fire Protection and Steel below them.
Fire Protection workers need to be aware of falling hazards, cutting metal, welding, heavy lifting, and being struck by objects
They also need to worry about Roofing and Steel around them
Steel workers need to be aware of falling hazards, welding, hoisting and rigging, struck by objects and heavy lifting.
Bystanders be aware of being struck by fallen debris and welding.

Area 6-9 Steel workers need to be aware of falling hazards, welding, hoisting and rigging, struck by objects and heavy lifting; Bystanders be aware of being struck by fallen debris and welding.

OCTOBER 1, 2002: **North 9** Steel workers need to be aware of falling hazards, welding, hoisting and rigging, struck by objects and heavy lifting; Bystanders be aware of being struck by fallen debris and welding.

Area 5 Concrete workers need to be aware of Excavation hazards, uncovered rebar and nails, any curing compound, as well as silicosis from chipping or drilling of concrete; Bystanders be aware of excavation ditches, metal fillings, drilling or chipping dust.

Area 7 Glazing workers need to be aware of falling hazards, cutting metal, hoisting and rigging, struck by objects, and heavy lifting.
They also need to be aware of Electrical work below.
Electrical workers need to be aware of excavation hazards, cutting metal and grounding equipment.
They also need to be aware of Glazing working above.
Bystanders be aware of being struck by falling debris, and cutting metal.

Area 8 Metal Stud workers need to be aware of falling hazards, cutting metal, hoisting and rigging, as well as heavy lifting.
Bystanders be aware of being struck by falling debris, and cutting metal.

Area 9 Mechanical workers be aware of falling hazards, metal filling, heavy lifting, and being struck by objects; Bystanders be aware of falling objects, and floor debris.

ANALYSIS III: SUSTAINABLE REDESIGN OF WATER RETENTION AND MECHANICAL SYSTEMS

What is Sustainability?

When most people think of sustainability, they think of reducing waste such as recycling. This is a great step, however the topic is much more broad that this. Sustainability is actually describes as a process in which individuals realize their potential to have an impact on the Earth's resources (Interface). It translates into the choices we make today and how those choices will affect future generations long after we are gone.

There are three major parts to the sustainable process: Economic, Social, and Environmental sustainability. Environmental is the part that most people associate with; however, the remaining two are just as important. Economical sustainability can be described by a business taking the right steps to create an environment that is environmentally sound. This means to move the industry in the right direction when talking about sustainability (Interface).

Next, Social sustainability is described as taking the steps needed to teach others the value in conserving the Earth's resources. This can be done in a classroom setting, or even teaching by example in a community (Interface). Teaching someone to practice sustainability is just like practicing oneself twice as hard.

Finally, environmental sustainability is the actual idea of minimizing waste into the environment. Also it is important to preserve nature. This is the intention of the first redesign, in which is to eliminate the large retention ponds onsite. Also a large part of environmental sustainability is energy conservation. This will be the main focus of the mechanical redesign. It is important to understand that saving resources like energy and water also means saving money.

Existing Conditions: Water Retention System

The existing water retention system is made up of drain pipes leading to large basins. The basins are made up of a large excavated area around 25 feet deep that is lined with geotextile to eliminate soil erosion. The main drains on the outskirt of the building distribute the roof rain water run-off. Also, the parking lots are equipped with a total of 10 inlets to collect water and drain to the retention ponds.

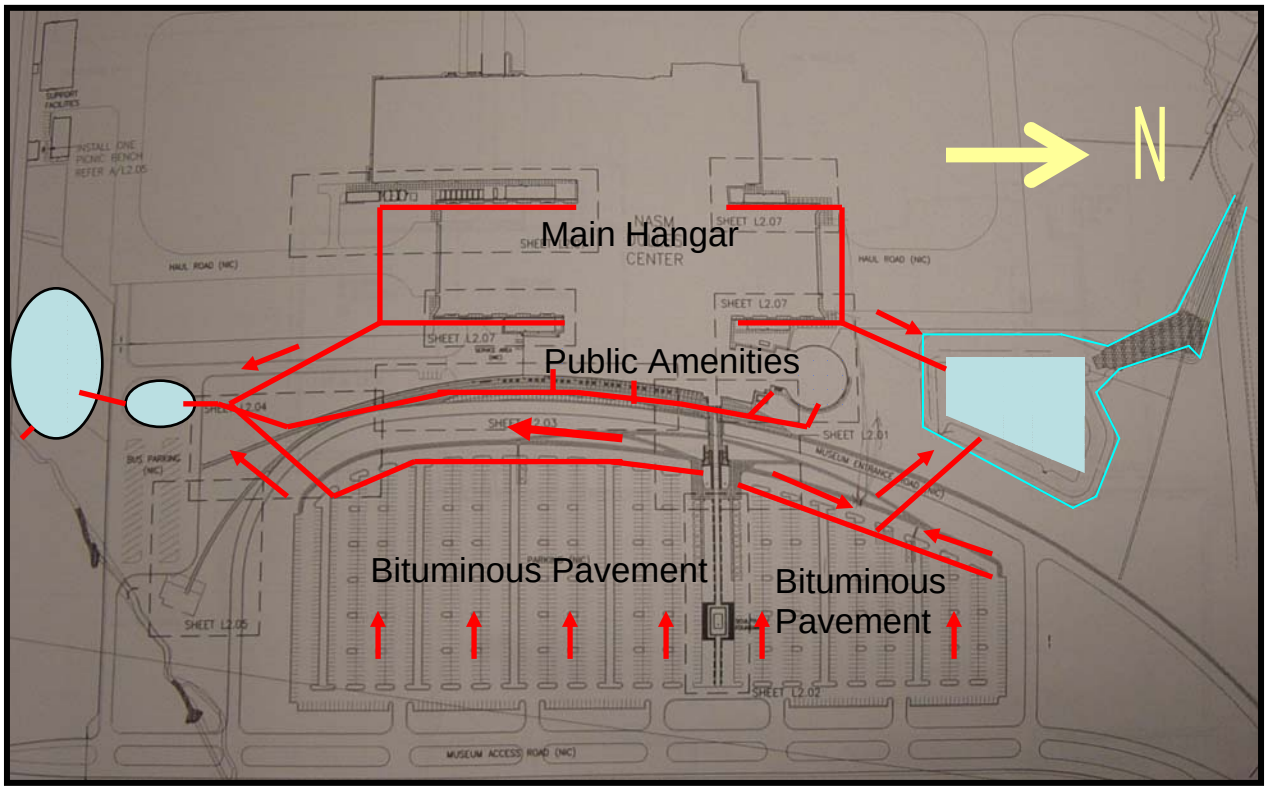


Figure 3: Existing Water Retention System (Smithsonian Institution)

Figure 3 details the drainage plan including the water run-off from the Main Hangar and the Public Amenities. As shown below, the north Water Basin collects the water from the north side of the Main Hangar as well as the north side of the parking lot. The south water basins collect water from the south Main Hangar area, the Public Amenities, and the south parking lot. As a precautionary measure, both basins (north and south) contain an overflow system.

Proposed Solution: Porous Pavement Parking Lots

By proposing the parking lots to be porous pavement rather than regular bituminous pavement, the north basin can be entirely eliminated. This not only allows for a more sustainable system, but also more astatically pleasing. Also, to reduce costs, the far south basin only needs to be half the size because of the Public Amenities draining into the porous pavement. Also, the parking lot inlets can be eliminated. A detailed plan of this is shown below in Figure 4.

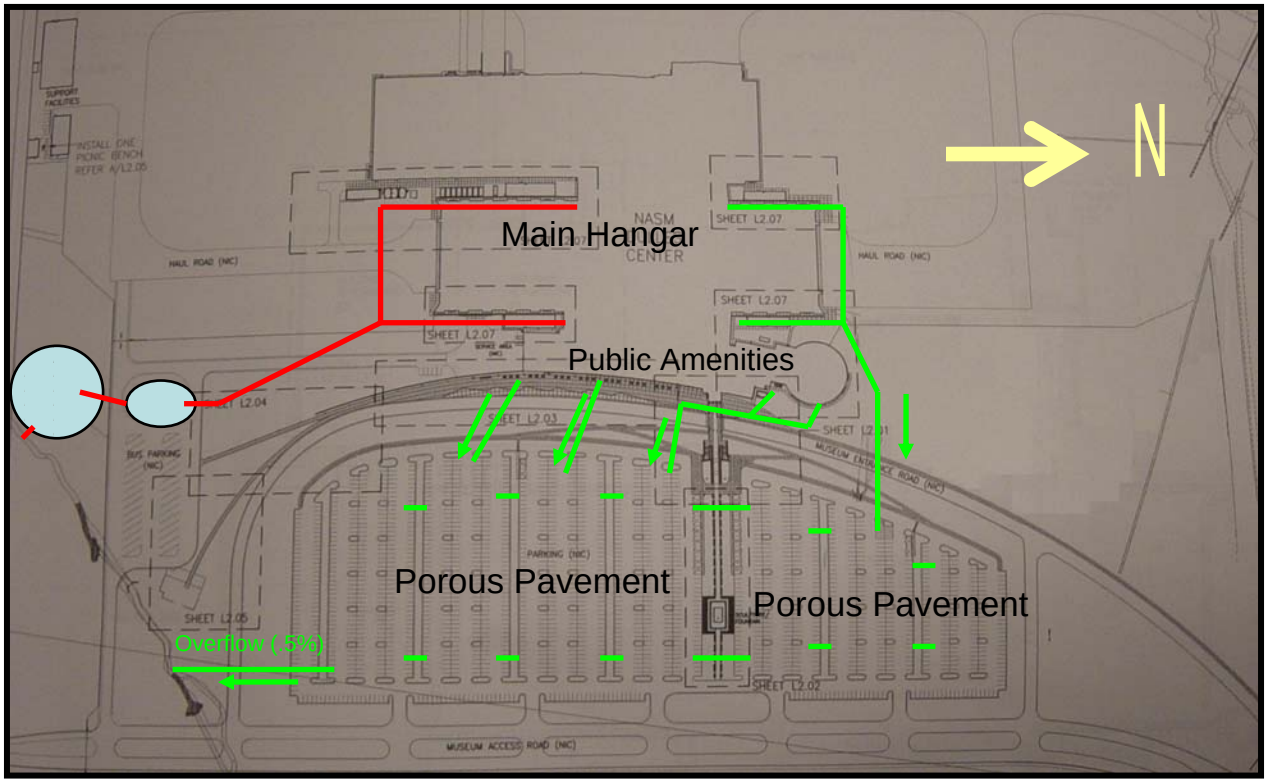


Figure 4: Proposed Water Retention system including porous pavement (Smithsonian Institution)

Elimination of the north retention pond also opens up plenty of room for future expansion. This is an important for the Air and Space Museum knowing that they still only have 80 percent of their exhibits in either museum. Also, this area can also be used for staging during the construction process. This is a great deal, being that staging aver the area in which porous pavement in prohibited. Other facts about porous pavement are listed below as well as in Appendix D.

What is porous pavement?

Porous pavement is a bituminous asphalt mixture similar to conventional asphalt but is an open-graded mix. The aggregate mix is limited in the number of fine aggregates it contains. This allows water to pass through the pavement at a natural infiltrating rate recharging the groundwater rather causing runoff. Since open-graded mixes reduce the amount of water on the surface, splash/spray from tires in wet weather reducing hydroplaning. The surface of also tends to be smoother than the surface of dense-graded Hot Mix Asphalt. Porous pavement can also remove total suspended solids, total phosphorous, and total nitrogen effectively within a life span of 15 to 20 years (Dempsey).

As shown in Figure 5 Porous pavement is made up of least four different layers. The top layer or wearing layer consists of asphalt with greater than normal percentage of voids. Below the wearing layer is a stone reservoir or thick layer of aggregate. This provides the bulk of the water storage capacity. Typically the design consists of two or more transition layers made of 25 to 50 mm diameter stone. One layer is between top wearing layer and the stone reservoir and the other separates the stone reservoir from the undisturbed subgrade soil. Geotextile material can also be added as a layer under the reservoir. The thickness of the different layers depends on the bearing strength and pavement design requirements.

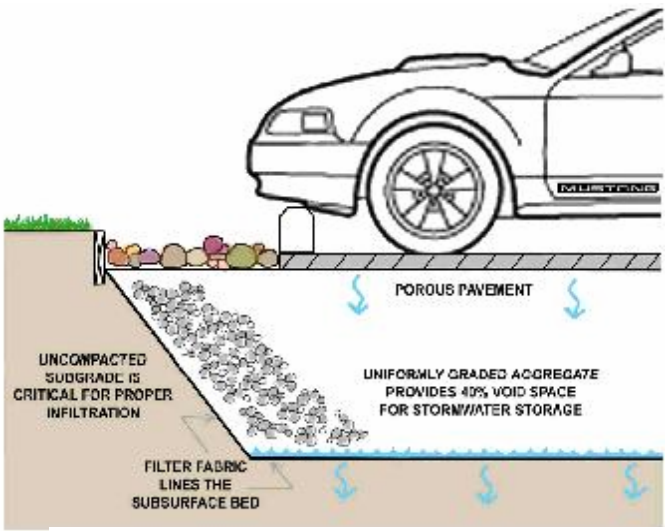


Figure 5: Typical porous pavement section (Adams)

Construction of Porous Pavement

The subsurface in infiltration bed located beneath the porous pavement must be excavated without heavy equipment compacting the bed bottom. Fine grading is done by hand (Adams).

Non-woven geotextile is laid immediately after fine grading is completed. Then clean/washed uniformly graded aggregate is place in the bed as the storage media. This stone provides 40% void space and a stable base for the porous pavement parking surface.

Finally, the porous pavement asphalt layer is then placed, the same way as regular, on top of the stone reservoir.
An unpaved edge is stone often used in the event that the pavement is paved over, forgotten or clogged. This allows the storm water to still reach the stone bed below the pavement.

Photos taken from (Adams)

Construction concerns:

- Excavation must be done with light equipment with tracks or oversized tires in order to prevent soil compaction
- During construction, divert site run-off away from future porous pavement area

Calculations – Water Retention

Table 1: Volume of storage beds

Predominant Soil Type	Silty Clay
Soil Percolation Rate*	35.6 cm/hr = (14 in/hr) = (1.167 ft/hr)
Area of Pervious Parking Lots	23,340 m^2 = (251,230 SF)
% Voids Storage Beds	40% (0.40)
Depth of Storage Beds	1.524 m = (5 ft)
Volume of Storage Beds (Area*Depth*0.40)	**14,228 m^3 = (502,460 ft^3)**

*Percolation rate received from Patton, Harris, & Rust

Table 2: Volume of water to be displaced

North Parking Lot	8820 m^2 = (94,940 SF)
South Parking Lot	14520 m^2 = (156,290 SF)
Main Hangar	12600 m^2 = (135,630 SF)
Public Amenities	7500 m^2 = (80,730 SF)
Total Surface Area	43440 m^2 467590 SF
Maximum Rainfall (10 Year Storm)* **(Total Surface Area * Rainfall)**	**7723 m^3 = (272,757 ft^3)**

*Rainfall Rate taken from www.weather.com = 7.0 in/hour

Since **7723 m^3 is less than 14228 m^3** then the soil will have no problem handling all of the run-off water from the areas detailed above.

Disadvantages of porous pavement (Dempsey):

- Heavy equipment and materials is not allowed on porous soil
  - No staging in future porous pavement areas
  - Compacts soil and greatly lessens permeability
- Facilities must be maintained on a regular basis
  - Leaf Removal
  - Vacuum Sweeping
- Restricted Snow Removal
  - Plastic plow blades – does not damage surface
  - No sand or anti-skid – clogs pores
- Vehicle Restrictions
  - Passenger Cars and Trucks Only – does not compact pavement
  - Rutting may occur

Cost Comparison: Existing vs. Proposed

Cost Incurred

Porous Pavement

Description	Quantity	Unit	Unit Price*	Total
Excavation	46524	CY	$5.00	$232,620.00
Filter Aggregate	46524	CY	$20.00	$930,480.00
Filter Fabric	27915	SY	$3.00	$83,745.00
Porous Pavement	27915	SY	$13.00	$362,895.00
Overflow Pipe	50	ft	$12.00	$600.00
Observation well	2	each	$200.00	$400.00
Erosion control	2	each	$1,000.00	$2,000.00
Subtotal				**$1,612,740.00**

Seeding Old Pond

Description	Quantity	Unit	Unit Price	Total
Seeding	135	mSF	$40.00	$5,400.00
Subtotal				**$5,400.00**
Total Incurred				**-$1,618,140.00**

* Unit prices taken from R.S. Means and Porous Data Sheet in Appendix D

Cost Deducted

North Retention Pond

Description	Quantity	Unit	Unit Price*	Total
Excavation	110024	CY	$5.00	$550,120.00
Geotextile	17575	SY	$3.00	$52,725.00
Stone	15695	CY	$25.00	$392,375.00
Subtotal				**$995,220.00**

South Retention Pond

Description	Quantity	Unit	Unit Price	Total
Excavation	55890	CY	$5.00	$279,450.00
Geotextile	6565	SY	$3.00	$19,695.00
Subtotal				**$299,145.00**

Parking Lot

Description	Quantity	Unit	Unit Price	Total
Paving	251235	SF	$1.73	$434,636.55
Inlets	10	each	$1,100.00	$11,000.00
Manholes	4	each	$1,375.00	$5,500.00
Subtotal				**$451,136.55**
Total Deducted				**$1,745,501.55**

* Unit prices taken from R.S. Means and Porous Data Sheet in Appendix D

The porous pavement saves a total of $127,361.55!

Existing Conditions: Mechanical System – Public Amenities

The mechanical system in the Public Amenities Area is made up of a reheat forced air system with return. This means that interior air handling units (AHU's) receive the heated or cooled air, depending on winter or summer, then mixes it with outdoor air to get to the supply air temperature. Then the air is distributed to variable air volume (VAV) boxes, which are scattered throughout the building. The VAV boxes then control the volume of air that is forced into a given room. This allows for total comfort level in each room. After the air is distributed, it is then collected by a return system and returned to the air handling unit, where it is used to heat up or cool down outdoor air. This can be shown in more detail in Figure 6 below.

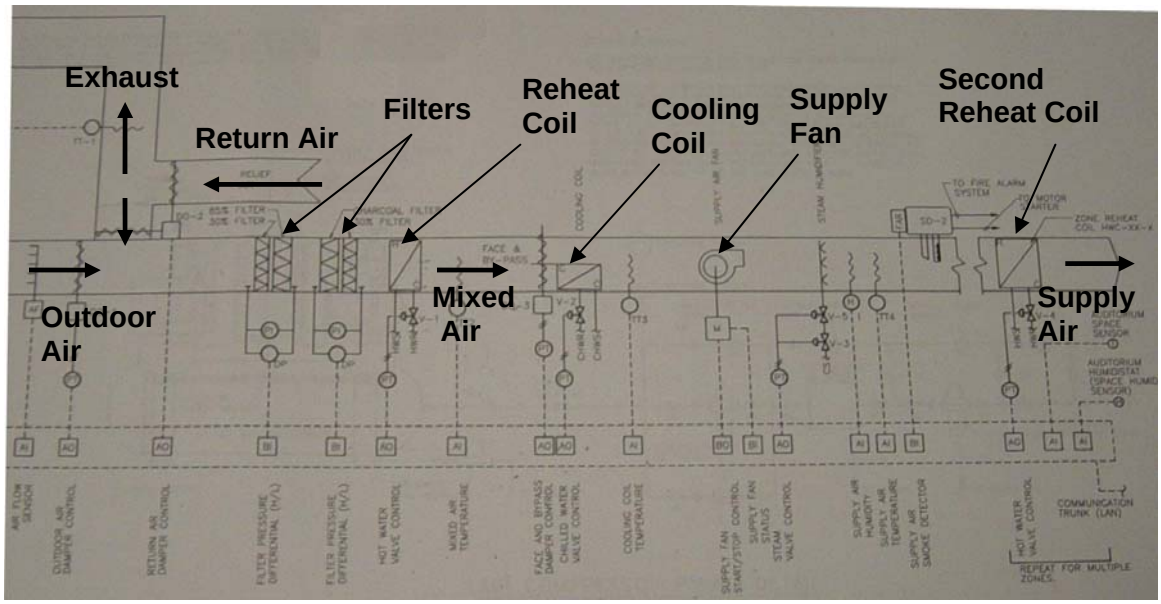


Figure 6: Typical Air Handling Unit Detail (Smithsonian Institution)

The drawing above is a detail of AHU A-07, which is the air handling unit that supplies air to the IMAX theater auditorium. This is the largest space in the Public Amenities area, as well as the focus for the redesign. In addition the air is distributed into the Auditorium through ceiling diffusers that sit around 40 feet in the air.

Proposed Solution: Enthalpy Wheel

As described above, the air in the IMAX auditorium is pumped into the space through ceiling diffusers that sit around 40 feet in the air. The first attempt to reduce energy costs was to look at using floor mounted diffusers, in opposed to what is described above. This would condition the space in which people actually sat, rather than the entire room. This has been known to save a large amount of energy in auditoriums. However, a few things came to mind when the new diffusers were introduced. First, in order to use floor mounted diffusers, the supply duct would have to run through concrete, which would be a construction nightmare. Secondly, and most importantly, the IMAX theatre contains a vast amount of lights and equipment that are hung from the ceiling. This equipment is both expensive, and sensitive to change in temperature.

Next in order to save energy, it was proposed that an enthalpy wheel was introduced into the system as depicted below in Figure 7. An enthalpy wheel transfers heat and humidity between the exhaust and supply air. Their net effect is to bring the supply (incoming) air closer in temperature and humidity to the exhaust air and reduce the load on the heating and cooling systems.

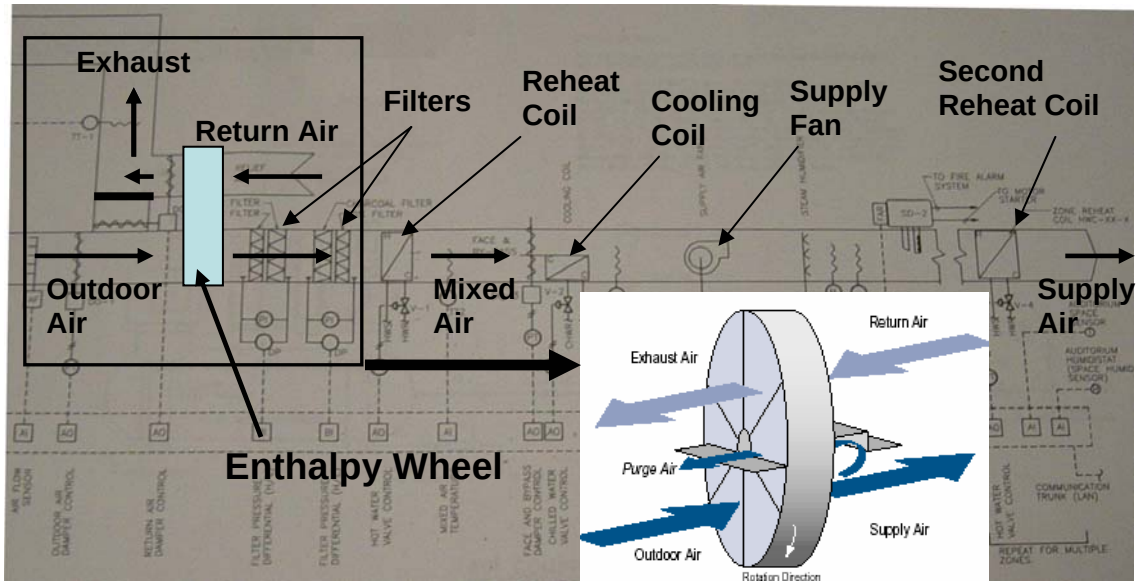


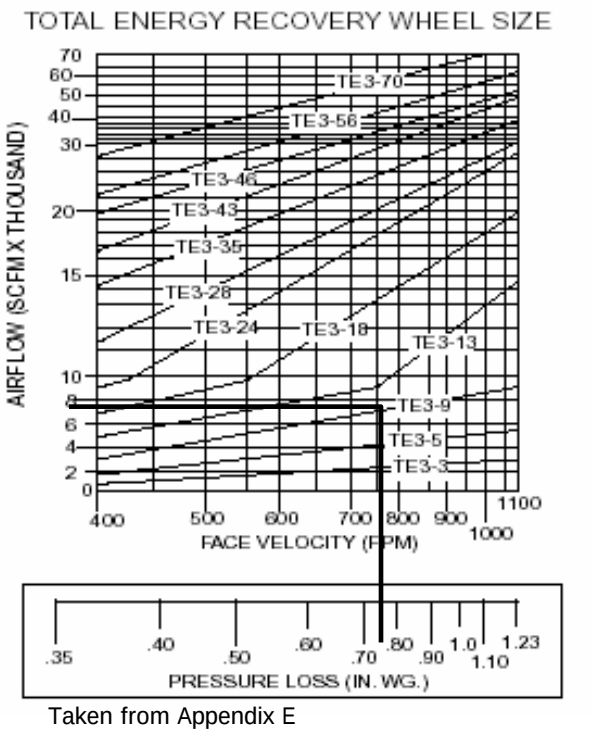
Figure 7: Proposed Enthalpy Wheel Detail (Smithsonian Institution)

A well-designed enthalpy wheel will recover 60% to 80% of the energy that would otherwise be needed to heat or cool outside air (Mumma). It lowers building operating costs and the capital cost of cooling and heating equipment as smaller devices can be installed. The typical payback period of an enthalpy wheel is five years. Some more advantages of an enthalpy wheel are: reliable operation, low maintenance, long life expectancy, and increased indoor air quality.

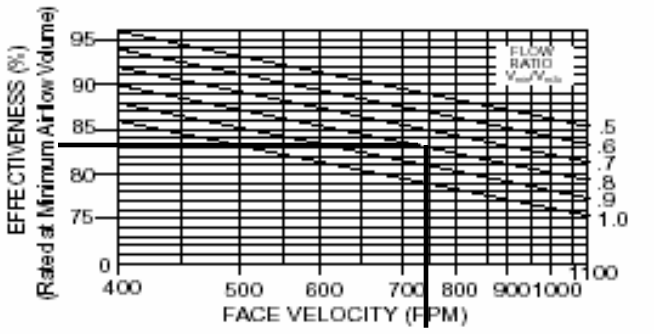
Calculations: Size and Energy Saved

Return air flow = 7314 cfm
Supply air flow = 9200 cfm

Vmin/Vmax = 0.80



Taken from Appendix E



Taken from Appendix E

Unit effectiveness = 0.825

Using a TE 3-9, the face velocity is 760 FPM,
the pressure loss is 0.76 in. wg.

Estimated cost of system = $33,000 (from Semco Inc.)

Estimated Energy Saved

Location	Enthalpy Hours (000)	
	Cooling	Heating
Atlanta	14	16
Boston	5	48
Buffalo	4	59
Chicago	5	50
Detroit	4	56
Houston	34	10
Indianapolis	6	50
Los Angeles	3	6
Miami	55	2
Minneapolis	4	70
Pittsburgh	4	54
St. Louis	8	45
San Juan	80	0
Seattle	3	48
Washington, D.C.	9	41

<u>Washington D.C</u>

Enthalpy Hrs. Cooling = 9,000

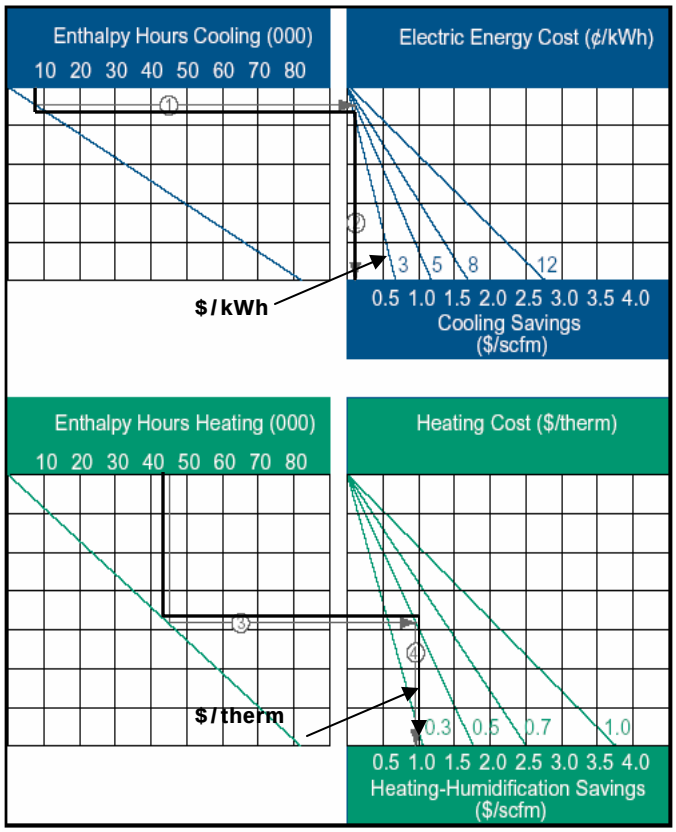
Enthalpy Hrs. Heating= 41,000

<u>Heating and Cooling cost*</u>

Cooling = $0.055/kWh

Heating = $0.55/therm

*gathered from MSN living index



Tables taken from Appendix E

<u>Annual Cost savings</u>

Cooling costs = $0.1/cfm

Heating costs = $1.0/cfm

Total saved = $1.1/cfm of outdoor air

Total OA = 7314 cfm

Total Annual Savings =

7314 cfm * $1.1/cfm

= <u>$8,045 per year</u>

Rate of return =

$33,000 / $8,045

= <u>4.1 Years</u>

RESEARCH: FEASIBILITY OF 4-D CAD SAFETY PLAN

In order to develop a useful safety plan, it is important to answer the following questions:

- What is the primary cause of accidents on a construction site?
- What can be done to eliminate construction accidents?

After these questions are researched and answered, the next step is to look at what is needed to develop an effective safety plan. This will help determine the feasibility of using 4-D CAD in a safety program.

What is the primary cause of accidents on a construction site?

Due to the fact that construction work is so dangerous, there are many answers to the question above. However, I decided to focus on the root causes of construction accidents. According to T. Michael Toole, a professor at Bucknell University, there is a total of eight root causes listed and explained below:

1. **Lack of proper training**
    a. An employee may not be able to recognize all potential hazards associated with the tasks they are to perform.
2. **Deficient enforcement of safety**
    a. For a number of reasons, workers do not always follow proper procedures
3. **Safe equipment not provided**
    a. Safety equipment in order to perform a task is not present at the location of the work.
4. **Unsafe methods or sequencing**
    a. Accidents are associated with a task being performed in sequence with another task that is not safe.
5. **Unsafe site conditions**

a. Working under improper site conditions dramatically increases the chances of an accident occurring.

6. **Not using provided safety equipment**
    a. Accidents occasionally result from workers not effectively using safety equipment that was provided for their use.
7. **Poor attitude toward safety**
    a. Attitudes such as:
        i. "only wimps use equipment like that"
        ii. "If I do it that way I won't finish the job in time"
8. **Isolated, sudden deviation from prescribed behavior "freak accidents"**
    a. Accidents with no individual or organization at fault

After reviewing these eight root causes, it was noticed that some aspects of accidents were over looked. The following is a list of root causes developed by Enno Koehn, a professor at Lamar University, in addition to the eight listed above:

Lack of Safety Budget

- Not enough money is put away for developing a good safety plan

Design too complicated to build

- Safety is not always the number on priority of the design group

Overemphasis on speed of construction rather than safety conditions

- Sometimes safety is put on the back burner when there is a schedule to keep

Lack of communication between contractor and design team

- This causes mixed opinions out in the field

Another root cause of construction accidents are **language barriers between workers and management**. Language barriers are prevalent on construction projects with a Hispanic workforce. The number of Hispanic construction workers killed on the job every year has more than doubled in five years, jumping from 137 deaths in

1996 to 281 deaths in 2001. The increase occurred while the overall number of construction industry deaths climbed only 15 percent, from 1,095 in 1996 to 1,264 in 2001, according to the federal Bureau of Labor Statistics (Hopkins).

Another problem occurs when paramedics arrive on site to treat injuries of Hispanic workers. When the Hispanics speak little or no English, it is very difficult to relay to the paramedics what all the injury entails. This was the case in Springfield, Florida when a clinic roof, of which five Hispanic men were working on, collapsed. Paramedics had difficulty communicating with the workers to treat their injuries (Pittman). This shows that communication is important in all aspects of safety.

Having discussed the root causes of construction accidents, it is now important to look at ways to eliminate them.

What can be done to eliminate construction accidents?

In order to eliminate construction accidents, it is important to eliminate the factors that cause accidents:

Lack of proper training

- Conduct site specific safety training for all workers

Deficient enforcement of safety

- Monitor work on a frequent basis
- Know safety standards for tasks being performed

Safe equipment not provided

- Know what safety equipment is required for each specific task
- Be able to provide safety equipment and enforce its use
- Ensure equipment is in sound operating condition

Unsafe methods or sequencing

- Know safety methods and sequencing for a task
- Determine whether actual sequence is safe for all workers
- If sequence is not safe, resequence with individual subcontractors

Unsafe site conditions

- Know what conditions are appropriate for each individual task
- Monitor site conditions while task is being performed for hidden hazards

Not using provided safety equipment

- Observe workers as often as possible
- Influence behavior through positive praise or awards, or written warnings

Poor attitude toward safety

- Interact with workers, and improve attitude by positive or negative influence

Isolated, “freak” accidents

- Unfortunately, these types of accidents can not be predicted or prevented

Lack of Safety Budget

- Provide adequate funds to improve safety conditions onsite

Design too complicated to build

- Take safety conditions into account during design stage

Overemphasis on speed of construction rather than safety conditions

- Maintain constant speed – use proper scheduling technique
- Make sure schedule is updated regularly

Lack of communication between contractor and design team

- This causes mixed opinions out in the field

In order to eliminate the problems existing because of **language barriers**, great efforts must be made by both managerial and Hispanic employees. Some ways to eliminate these problems are by: setting up a detailed bilingual safety plan, providing on-site English/Spanish classes, and even introducing a 3rd party expert onsite.

When setting up a detailed safety plan, it is important to translate as much as possible from English to Spanish (Pittman). This allows workers to understand policies followed by the jobsite. The most important aspect of the bi-lingual safety plan is the ability of the jobsite to implement and manage it throughout the entire project.

Providing on-site English of Spanish classes can work well with the jobsite safety plan. A local college or educational facility can set up the classes. These classes should be held at lunchtime, and go over terms that are commonly used in construction. If the classes were held at night, it would be very difficult to get a good attendance due commitments after work. The only problem with classes is that each worker will have to start at the same level and work up. English and Spanish classes are a good way of eliminating language barriers, however they are very time consuming.

The final solution that will be discussed is to bring in a 3rd party language specialist. A specialist works with each project's individual situation, and comes up with the best solution (Morris). However, when a specialist comes on site, productivity tends to decrease. This is a result of meetings and case studies that are held to find critical issues on the jobsite.

In addition to specialists, software can be used to resolve language barriers. A CD Rom can be made to provide a video introduction to new employees from the company president, which can be heard in Spanish or English with just a mouse click. Translations for safety items like boots, gloves, eye goggles and ear protection can be heard by passing the cursor over the word next to a picture. The CD ends with a short quiz on information presented. The price tag on the software is around $15,000 and of course computers are needed for the software to run (Proctor).

Developing a Safety plan

When setting up a detailed safety plan, it is a good idea to start with a jobsite orientation (Pittman). This allows workers to understand policies followed by the jobsite. If there is a population of for Hispanics that have trouble comprehending English the orientation should also be given in Spanish. Not comprehending one sentence or phrase could be the determining factor in a life-threatening situation. The jobsite orientation should include training on confined space, fall protection and hazard communication (Pittman).

According to OSHA, the major elements that make up an effective safety plan are: Management Leadership and Commitment, Employee Involvement, Worksite Analysis, Hazard Prevention and Control, and Safety Training.

It is important that the management team develop a policy that clearly states the safety responsibility of organizations involved with the project. It is important that each organization have the authority and resources to meet their expectations. Also, the management team needs to set goals and develop a way to ensure the goals of the program are met. Finally, mangers need to indicate how workers are held accountable for their safety and health actions (OSHA).

Employee involvement is an important part of the safety plan. Most workers with experience have a great understanding of how accidents occur and prevention of these occurrences. This is why it is important for employees to be involved when deciding safety policies. Also, they should have a say in what training needs to take place in order for workers to be ready for their tasks. This can be done through the Job Hazard Analysis (JHA) process which is explained in the following paragraph.

Worksite analysis is identifying the hazards that are present during each activity on a jobsite. It is very important that this is done so that the hazards can be eliminated. A good way to identify these hazards is though Job Hazard Analysis surveys that are written by each major subcontractor. JHA's describe in detail job description, what tools are being used, what hazards are involved, and what can be done to mitigate these hazards. Another important worksite analysis is the emergency plan. This is set up to educate workers what needs to be done when there is an emergency onsite. It is extremely important that the worksite analysis is planned and monitored throughout the project duration.

After the hazards are identified, it is important that there is a way to prevent these hazards from occurring. In order to do this, workers need to be educated on tools and techniques of their trades. An effective safety plan sets up the necessary training needed for each employee to be safe and productive. Some examples of specific training are: forklift operation, basic hand tool training, hoist and rigging training, etc. If the workers are not trained for the job, accidents are more likely to occur.

Creating an effective safety plan is a huge step in managing a successful project. However, in order to make the plan a success, it must be understood and enforced. In order to accomplish this, great efforts must be made to ensure employees understand the task at hand, as well as the hazards that are associated with that task. This is very important when there is a language barrier on the jobsite. When this occurs, steps need to be taken to translate the safety plan, and train the workforce how it works. The most important aspect of the bi-lingual safety plan is the ability of the jobsite to implement and manage it throughout the entire project. As explained by Dave Webb, safety director for Hensel Phelps Construction Company, "If an individual is not trained for the job, or does not understand, it is like setting them up for failure. This is when accidents start to occur."

Feasibility of implementing a 4-D CAD Safety Plan

Some information below was taken from an interview that took place with Dave Webb, safety director, and Nick Trammer, project manager, both employees of Hensel Phelps Construction Company.

After reviewing the root causes of accidents and the guide to an effective safety plan, it has been determined that a 4-D safety plan can be effective in visualization and elimination of jobsite hazards. The key to the safety plan is making sure that it is understood by all workers and enforced at the start of a project. If these two constraints are met, then the simulated 3D safety plan will help in mitigating accidents. This plan can be effectively used during pre-construction meetings, jobsite orientation, and weekly safety meetings (toolbox talks).

A preconstruction meeting is to ensure that new subcontractor understands their role onsite. The meeting is conducted with the management of the subcontractor, the general contractor, and owner's representative. In this meeting the subcontractor informs them of their task at hand, such as delivery date, and equipment used. Also, an important part of this meeting is for the general contractor to inform the subcontractor of hazards that need to be considered (Trammer). This is where the 4D safety plan could be very effective in showing subcontractors hazards from other contractors in their workspace. It would be a great advantage to be able to visualize this before the subcontractor even gets to the site.

The next step is to use the model in a jobsite orientation. This is where employees would be trained on how the safety model works, as well as specific hazards they have to worry about. If a language barrier exists, it is extremely important that every step is taken to ensure the workers understand. This might entail using a translator to go over the model with employees, as well as translating the specific hazards. If a worker does

not understand the safety plan, it is not only ineffective, but confusing. This may actually cause accidents rather than eliminating them (Webb).

The most important aspect of implementing the 4D safety model is training the foreman. "(They) are the key to communication on a jobsite." (Webb) It is crucial that they understand where activities are, and what hazards are assigned to them. If this is accomplished, they have the ability to relay the message onto their crew.

An effective way for the foreman to relay the message of prominent hazards in the work space is through a weekly meeting or toolbox talk. The phrase toolbox talk has been coined because that is precisely what it is; a meeting with a crew in front of the tool box. For the 4D model to be effective in this meeting, a printout of the weekly hazards would be handed out. It would be the responsibility of the general contractor to do this. However, it is the responsibility of the foreman to ensure their crew understands the associated hazards with their work, as well as the work around them. Most accidents occur not because of workers concentrating on their task, but because of careless individuals working around that task (Trammer).

In conclusion, a 4D model can be an effective way of spotting and eliminating hazards. However, if the workers are not trained to notice hazards, the model will be useless. In the words of Dave Webb "it takes every person on the project working together to ensure something like this works".

CONCLUSIONS

A 4D CAD model is a very beneficial way of showing the steel erection process on the Steven F. Udvar-Hazy Center. First, it allows the steel contractor to explain their erection plan to the owner. At times, this can be challenging because some owners are inexperienced and have a tough time understanding a construction process. Next the simulated erection plan keeps all contractors as the same page. They are aware of where the steel is to be erected and what time. Most importantly, it lets the steel contractor know, in order to keep with the schedule, what percentage of the structure has to be completed at what time. Finally it forces the steel erector to ask questions about the erection sequence. Workers can imagine themselves putting the structure together when they see the model. This causes them to think about erecting the steel before they are put into that situation.

Another way of benefiting from a 4D CAD model is in a simulated safety plan as shown in Appendix C. A 4-D safety plan can be effective in visualization and elimination of jobsite hazards. The key to the safety plan is making sure that it is understood by all workers and enforced at the start of a project. If these two constraints are met, then the simulated 3D safety plan will help in spotting and eliminating hazards. However, if the workers are not trained to notice hazards, the model will be useless. In the words of Dave Webb, the safety director of Hensel Phelps Construction Company: "it takes every person on the project working together to ensure (the 4D Safety Plan) is successful."

By improving sustainability, and adopting the proposal to include porous pavement in the large parking lots, Smithsonian Institution can actually save approximately $130,000 in materials cost. This is mostly due to the elimination of the large water retention pond located on the north end of the site as well as the existing parking lot inlets. A detailed estimate summary is located on page 33. However, there will be construction

costs incurred in order to fine grade the bottom of the water storage bed. Also, there will be regular maintenance costs that include sweeping and vacuuming the pavement to unclog pores.

Finally, the National Air and Space museum can also improve sustainability by installing an enthalpy wheel for air handling unit A-07. According to the enthalpy wheel technical guide in Appendix E, around $8,000 can be saved each year in energy costs. This gives the enthalpy wheel a rate of return of about 4.1 years. Calculations of this are located on page 36. Other advantages of the energy wheel are reliable operation, low maintenance, long life expectancy, and increased indoor air quality. In addition to saving energy costs, the enthalpy wheel also creates a more enjoyable public atmosphere.

ACKNOWLEDGEMENTS

I would like to thank the following for their help and support throughout my senior thesis experience:

PSU Architectural Engineering Faculty: Dr. Messner, Dr. Horman, Dr. Riley, Dr. Bahnfleth, and Dr. Ling.

Smithsonian Institution: Lin Ezel

Hensel Phelps Construction Company: Mike Mattivi, Chad Mease, Jason Hammond, John Lougue, and Dave Webb

Pattee Library Reserve Reading Room: Donna Connelly, and fellow co-workers

Family and Friends: Mom, Dad, Amy, Kelly, Jess, Gram, and the list goes on....

REFERENCES

4-D CAD Modeling

Koo, Bonsang & Fischer, Martin. "Feasibility Study of 4D CAD in Commercial Construction." Journal of Construction Engineering and Management. July/August 2000, pp. 251–260.

Safety

Toole, T. Michael. "*Construction Safety Roles*." Journal of Construction Engineering and Management. May/June 2002 p. 203-210

Kohehn, Enno; Datta, Nirmal. "*Quality, Environmental and Health and Safety Management Systems for Construction Engineering*." Journal of Construction Engineering and Management. September/October 2003 p. 562-568

Hopkins, Jim. "Death of Hispanics soar 53%" USA Today. March 24, 2002. http://www.usatoday.com/money/general/2002/03/25/workplace-deaths-hispanics.htm

Pittman, Jennifer & Gonzales, Anne. "*Safety worries spark push to undo language barriers."* Sacramento Business Journal. April 28, 2003.

Morris, Carroll. *Cultural and Language Barriers in the Workplace.* Charlotte-Mecklenburg Workforce Development Board. February 2003.

Proctor, Cathy. *"Software Film Aims at Safer Worksites."* Denver Business Journal. March 10, 2003.

OSHA: "How to develop and implement and effective, comprehensive Safety & Health Program" Occupational Safety and Health Administration (OSHA) http://www.osha.gov/Region7/fallprotection/safety_health_prog.html

Webb, Dave. Interview on 4D safety Model. April 1, 2004

Trammer, Nick. Interview on 4D safety Model. March 31, 2004

Sustainability

Interface Sustainability. "*What is sustainability?"* http://www.interfacesustainability.com/whatis.html

Porous Pavement

Dempsey, B.A., and D.M. Swisher. 2002. Evaluation of Porous Pavement and Infiltration in Centre County.

Adams, Michele C. 2003. Porous Asphalt Pavement with Recharge Beds: 20 years & still working. *Stormwater Magazine.* May/June 2003, 24-32.

Enthalpy Wheel

Mumma, Stanley A. "Dedicated Outdoor Air-Dual Wheel System Control Requirements" ASHRAE TRANSACTIONS 2001, V. 107, Pt. 1.

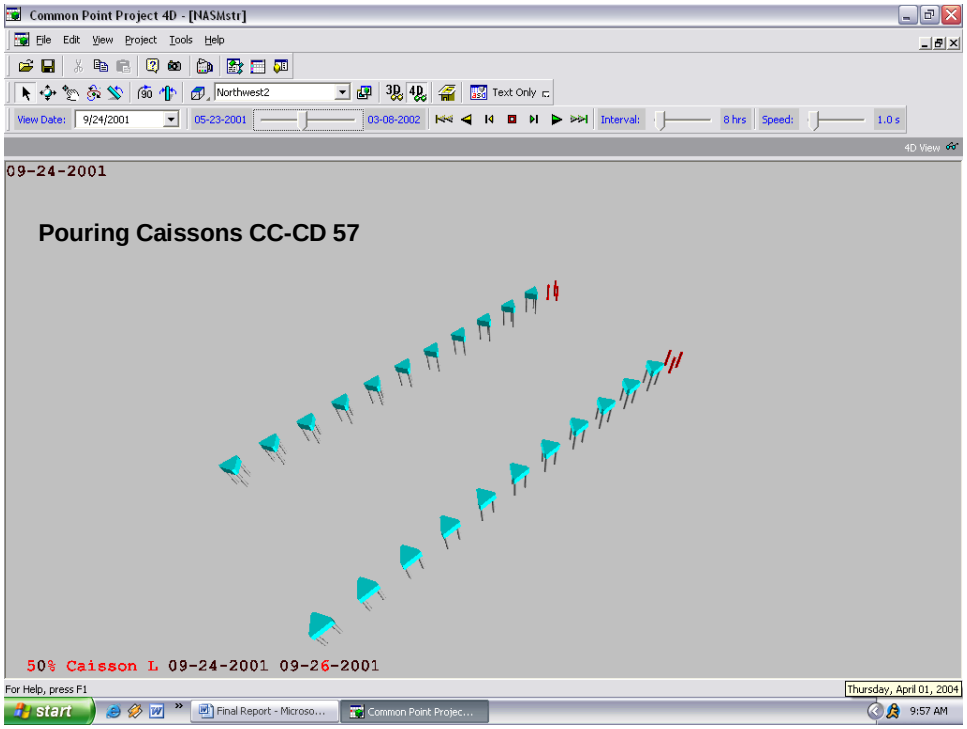
MSN: Compare Cities Index - http://houseandhome.msn.com/pickaplace/comparecities.aspx

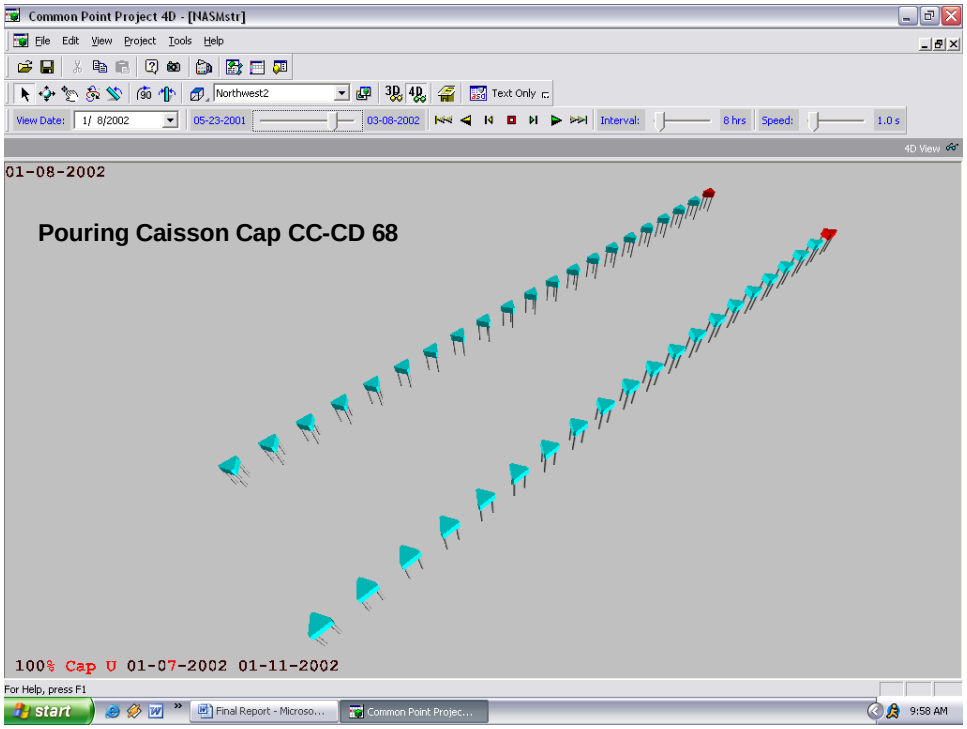
APPENDIX A

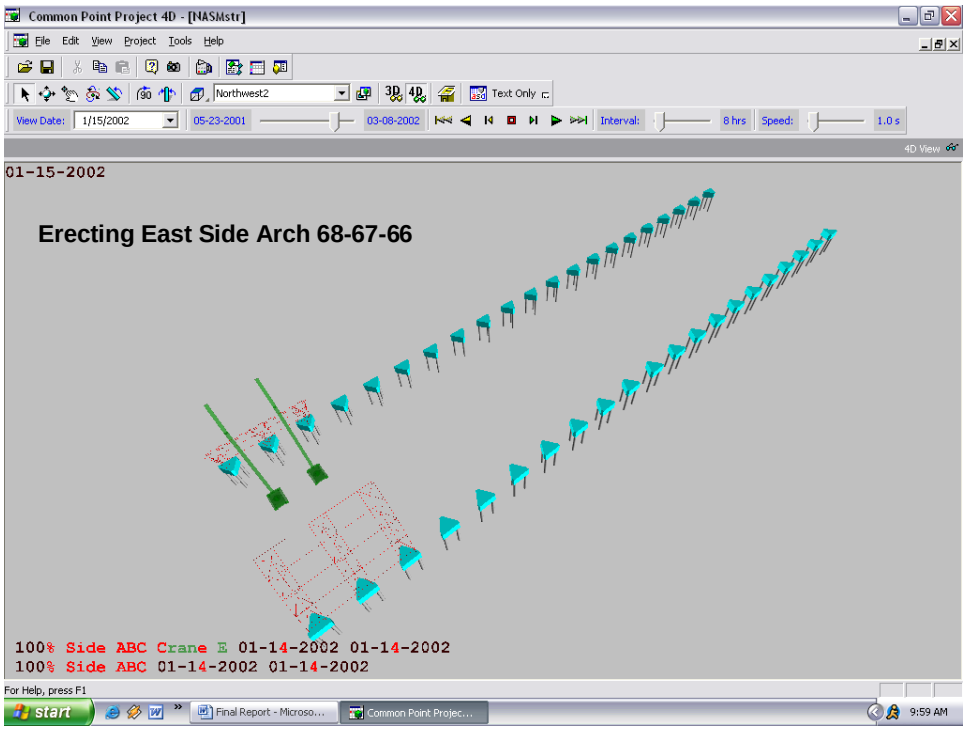
4D SIMULATION

MAIN HANGAR STEEL SEQUENCING SCHEDULE

STEEL SEQUENCING SIMULATION



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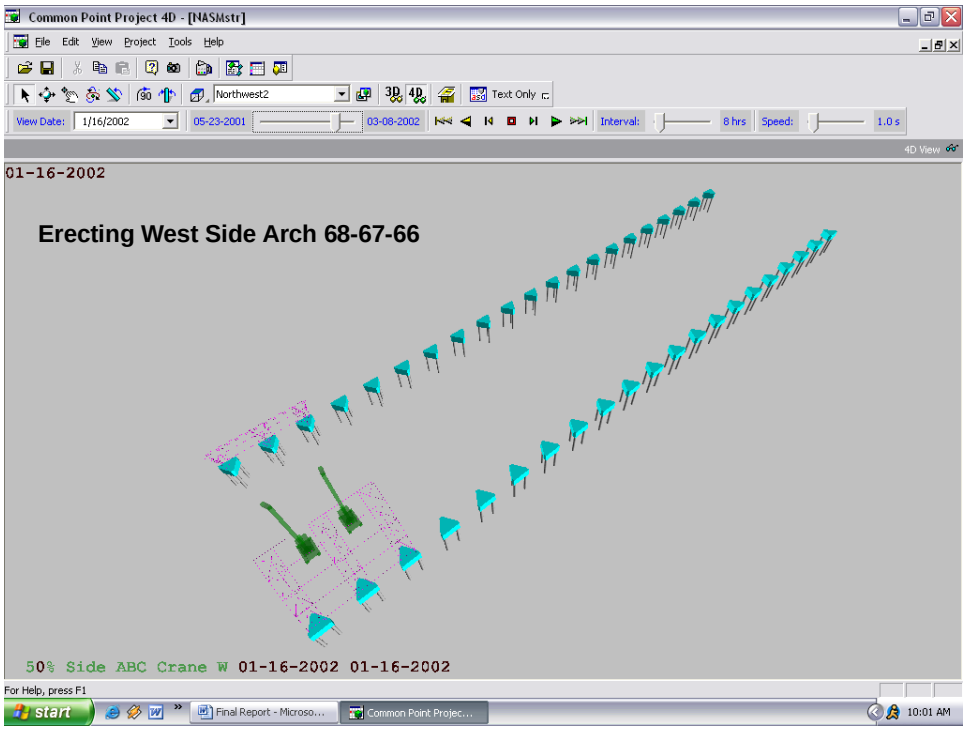
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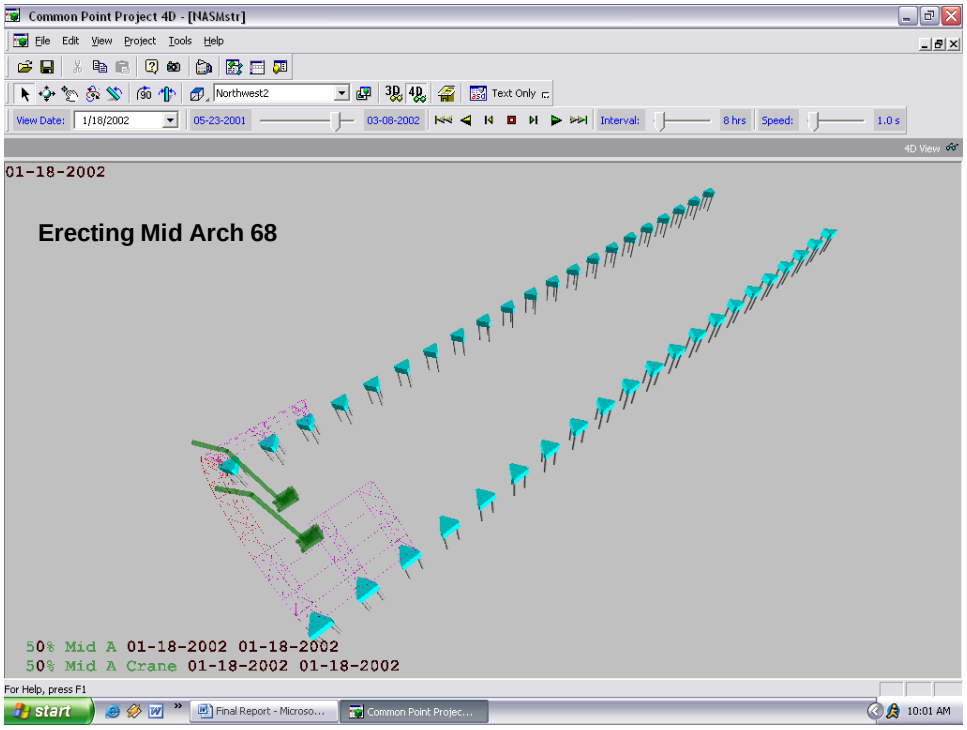
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Interval:
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4D View
01-18-2002
Erecting Mid Arch 68
50% Mid A 01-18-2002 01-18-2002
50% Mid A Crane 01-18-2002 01-18-2002
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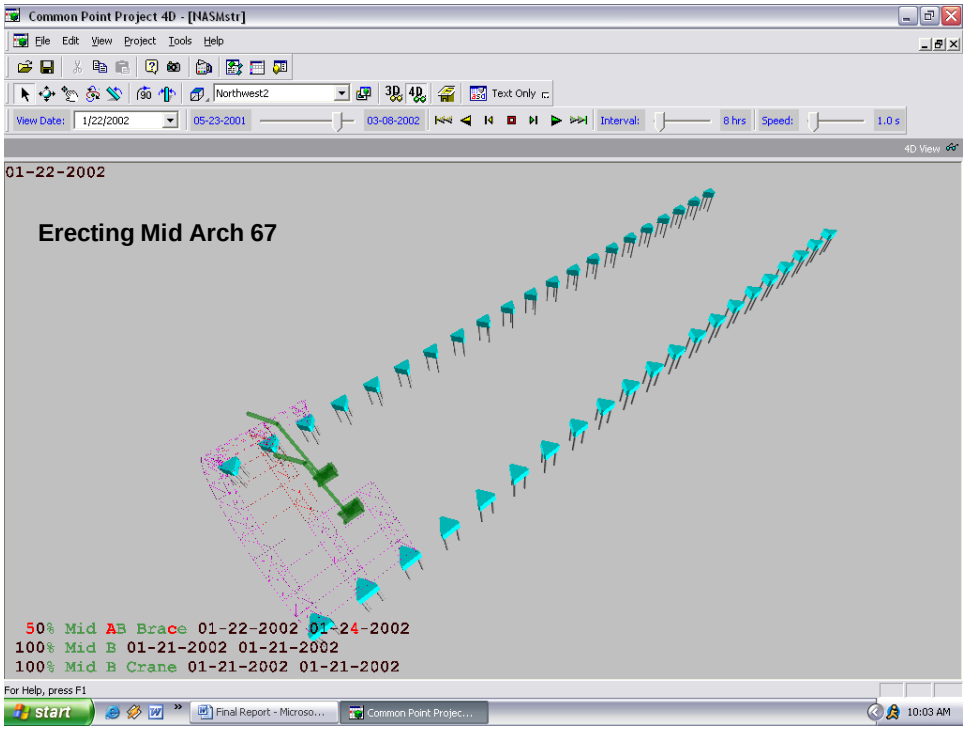
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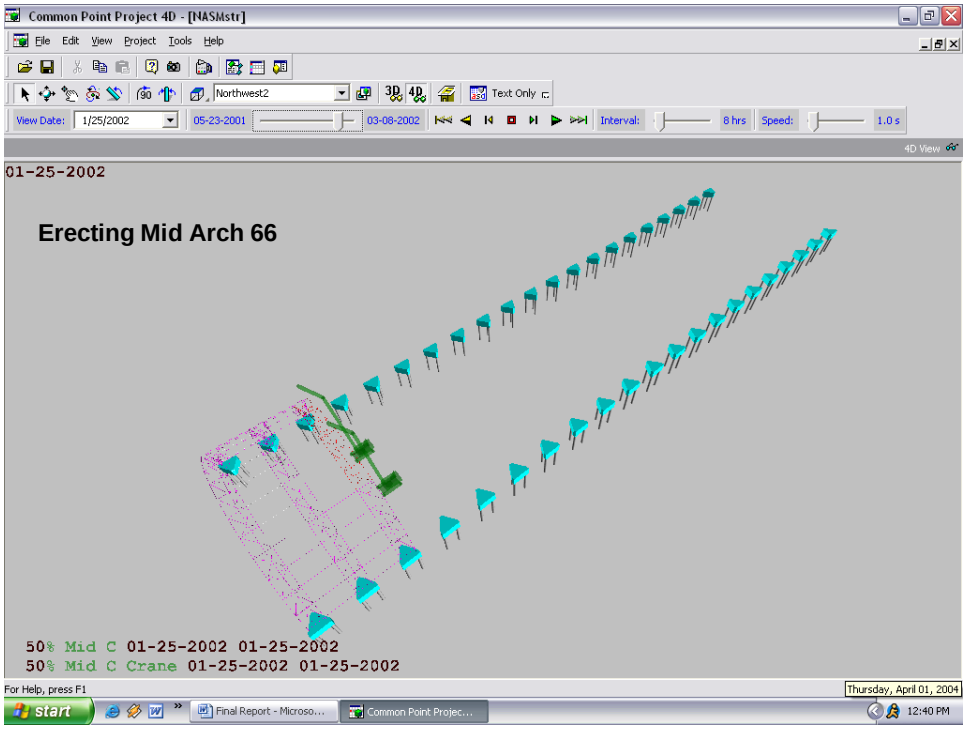
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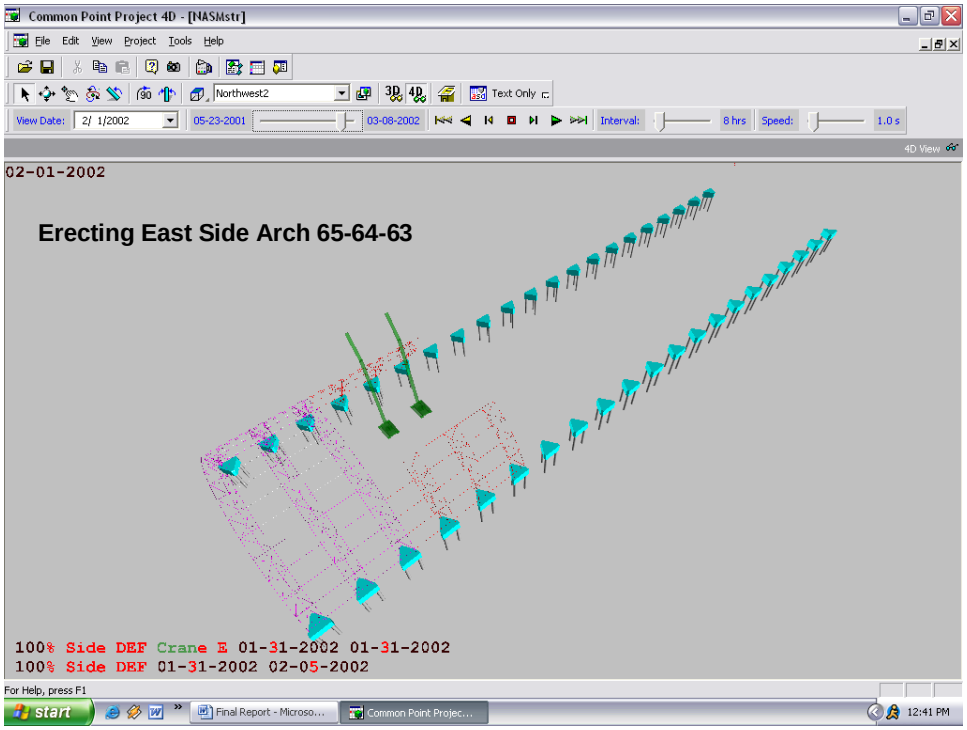
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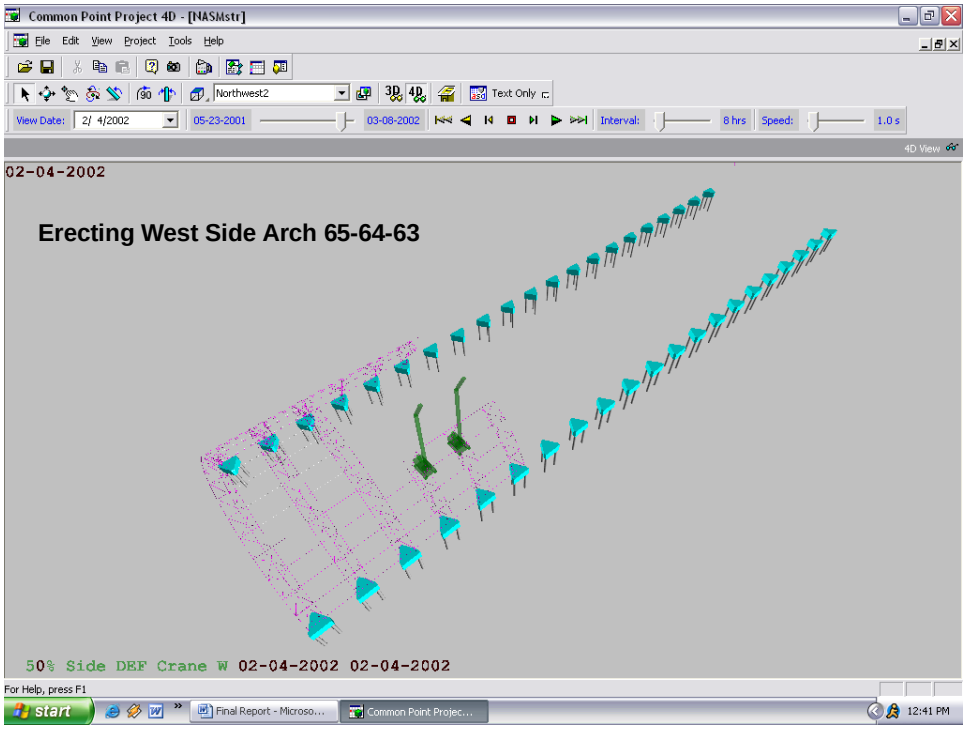
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4D View
02-04-2002
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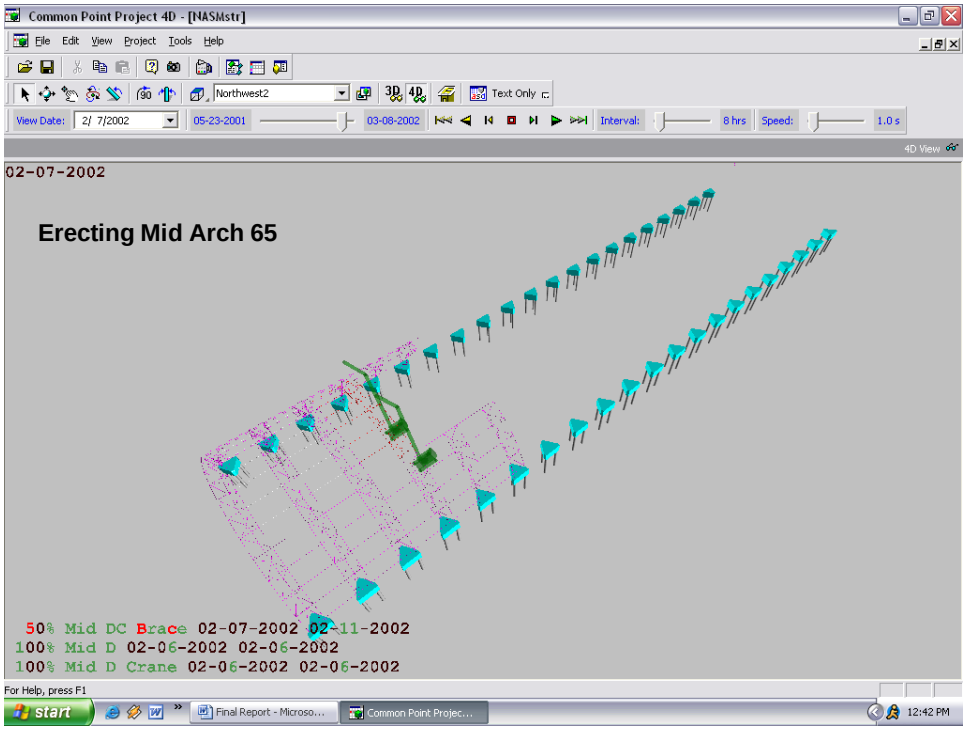
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Speed:
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4D View
02-07-2002
Erecting Mid Arch 65
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100% Mid D 02-06-2002 02-06-2002
100% Mid D Crane 02-06-2002 02-06-2002
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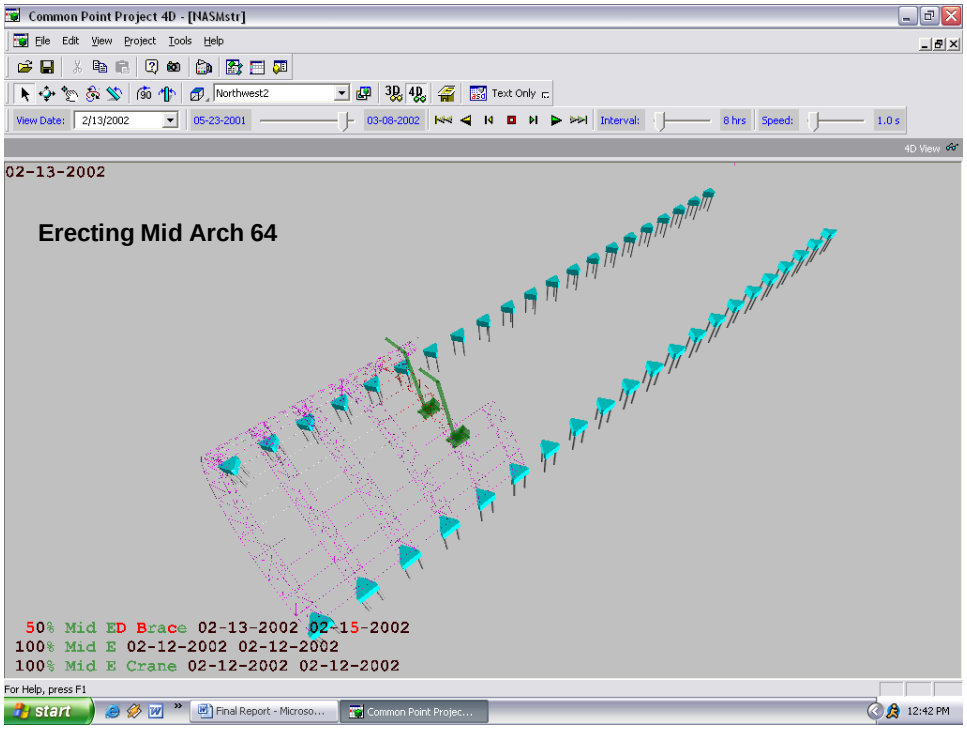
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100% Mid E 02-12-2002 02-12-2002
100% Mid E Crane 02-12-2002 02-12-2002
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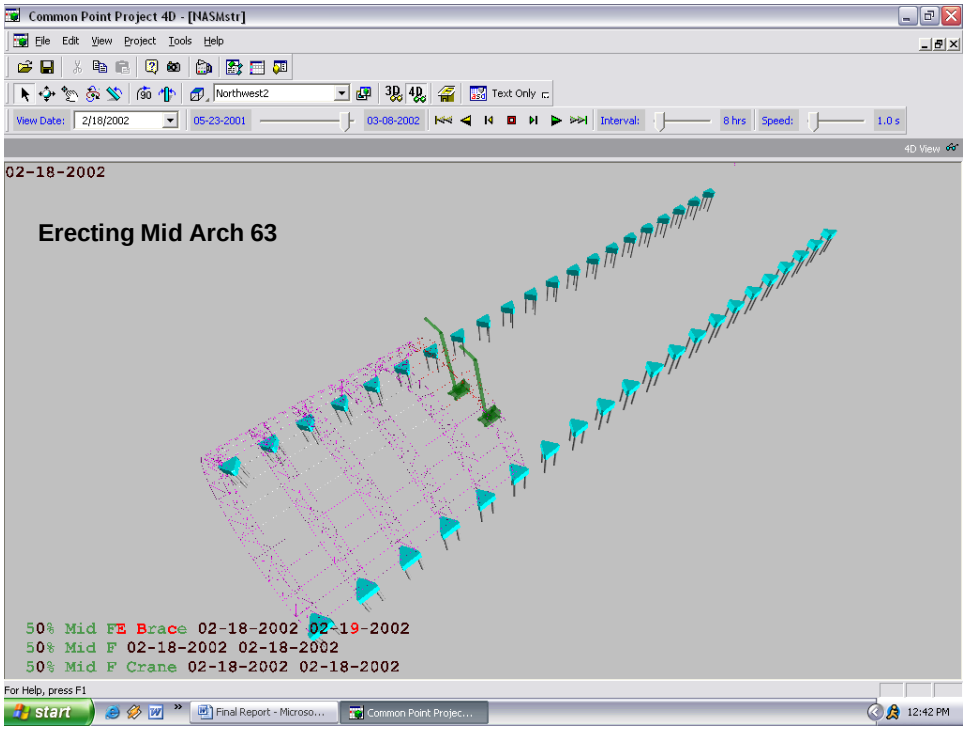
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50% Mid F Crane 02-18-2002 02-18-2002
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STEEL SEQUENCING SCHEDULE

ACTIVITY	ES	EF	TYPE	CODE
Caisson A	07-18-2001	07-20-2001	CONSTRUCT	
Caisson B	07-06-2001	07-10-2001	CONSTRUCT	
Caisson C	06-26-2001	06-28-2001	CONSTRUCT	
Caisson D	05-23-2001	05-25-2001	CONSTRUCT	
Caisson E	06-04-2001	06-06-2001	CONSTRUCT	
Caisson F	06-14-2001	06-18-2001	CONSTRUCT	
Caisson G	07-30-2001	08-01-2001	CONSTRUCT	
Caisson H	08-09-2001	08-13-2001	CONSTRUCT	
Caisson I	08-21-2001	08-23-2001	CONSTRUCT	
Caisson J	08-31-2001	09-04-2001	CONSTRUCT	
Caisson K	09-12-2001	09-14-2001	CONSTRUCT	
Caisson L	09-24-2001	09-26-2001	CONSTRUCT	
Caisson M	10-04-2001	10-08-2001	CONSTRUCT	
Caisson N	10-16-2001	10-18-2001	CONSTRUCT	
Caisson O	10-26-2001	10-30-2001	CONSTRUCT	
Caisson P	11-07-2001	11-09-2001	CONSTRUCT	
Caisson Q	11-19-2001	11-21-2001	CONSTRUCT	
Caisson R	11-29-2001	12-03-2001	CONSTRUCT	
Caisson S	12-11-2001	12-13-2001	CONSTRUCT	
Caisson T	12-21-2001	12-25-2001	CONSTRUCT	
Caisson U	01-02-2002	01-04-2002	CONSTRUCT	
Cap A	07-23-2001	07-27-2001	CONSTRUCT	
Cap B	07-11-2001	07-17-2001	CONSTRUCT	
Cap C	06-29-2001	07-05-2001	CONSTRUCT	
Cap D	05-28-2001	06-01-2001	CONSTRUCT	
Cap E	06-07-2001	06-13-2001	CONSTRUCT	
Cap F	06-19-2001	06-25-2001	CONSTRUCT	
Cap G	08-02-2001	08-08-2001	CONSTRUCT	
Cap H	08-14-2001	08-20-2001	CONSTRUCT	
Cap I	08-24-2001	08-30-2001	CONSTRUCT	
Cap J	09-05-2001	09-11-2001	CONSTRUCT	
Cap K	09-17-2001	09-21-2001	CONSTRUCT	
Cap L	09-27-2001	10-03-2001	CONSTRUCT	
Cap M	10-09-2001	10-15-2001	CONSTRUCT	
Cap N	10-19-2001	10-25-2001	CONSTRUCT	
Cap O	10-31-2001	11-06-2001	CONSTRUCT	
Cap P	11-12-2001	11-16-2001	CONSTRUCT	
Cap Q	11-22-2001	11-28-2001	CONSTRUCT	
Cap R	12-04-2001	12-10-2001	CONSTRUCT	
Cap S	12-14-2001	12-20-2001	CONSTRUCT	
Cap T	12-26-2001	01-01-2002	CONSTRUCT	
Cap U	01-07-2002	01-11-2002	CONSTRUCT	

ACTIVITY	ES	EF	TYPE	CODE
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Mid A Crane	01-18-2002	01-18-2002	TEMPORARY	49
Mid AB Brace	01-22-2002	01-24-2002	CONSTRUCT	52
Mid B	01-21-2002	01-21-2002	CONSTRUCT	47
Mid B Crane	01-28-2002	01-31-2002	CONSTRUCT	53
Mid C	01-25-2002	01-25-2002	CONSTRUCT	48
Mid C Crane	01-25-2002	01-25-2002	TEMPORARY	51
Mid D	02-06-2002	02-06-2002	CONSTRUCT	55
Mid D Crane	02-06-2002	02-06-2002	TEMPORARY	56
Mid DC Brace	02-07-2002	02-11-2002	CONSTRUCT	57
Mid E	02-12-2002	02-12-2002	CONSTRUCT	61
Mid E Crane	02-12-2002	02-12-2002	TEMPORARY	62
Mid ED Brace	02-13-2002	02-15-2002	CONSTRUCT	63
Mid F	02-18-2002	02-18-2002	CONSTRUCT	64
Mid F Crane	02-18-2002	02-18-2002	TEMPORARY	65
Mid FE Brace	02-18-2002	02-19-2002	CONSTRUCT	66
Mid G	02-26-2002	02-26-2002	CONSTRUCT	70
Mid G Crane	02-26-2002	02-26-2002	TEMPORARY	71
Mid GF Brace	02-27-2002	02-28-2002	CONSTRUCT	72
Mid H	03-01-2002	03-01-2002	CONSTRUCT	73
Mid H Crane	03-01-2002	03-01-2002	TEMPORARY	74
Mid HG Brace	03-04-2002	03-05-2002	CONSTRUCT	75
Mid I	03-06-2002	03-06-2002	CONSTRUCT	76
Mid I Crane	03-06-2002	03-06-2002	TEMPORARY	77
Mid IH Brace	03-07-2002	03-08-2002	CONSTRUCT	78
Side ABC	01-14-2002	01-14-2002	CONSTRUCT	
Side ABC Crane E	01-14-2002	01-14-2002	TEMPORARY	44
Side ABC Crane W	01-16-2002	01-16-2002	TEMPORARY	45
Side DEF	01-31-2002	02-05-2002	CONSTRUCT	58
Side DEF Crane E	01-31-2002	01-31-2002	TEMPORARY	59
Side DEF Crane W	02-04-2002	02-04-2002	TEMPORARY	60
Side GHI	02-19-2002	02-25-2002	CONSTRUCT	67
Side GHI Crane E	02-19-2002	02-19-2002	TEMPORARY	68
Side GHI Crane W	02-22-2002	02-22-2002	TEMPORARY	69
Steel Crane Stage	12-11-2001	01-13-2002	TEMPORARY	54

APPENDIX B

SUBCONTRACTOR JOB HAZARD ANALYSIS

STEEL CONTRACTOR (8)

ROOFING CONTRACTOR (2)

MECHANICAL CONTRACTOR (3)

ELECTRICAL CONTRACTOR (3)

GLAZING CONTRACTOR (4)

CONCRETE CONTRACTOR (2)

JOB HAZARD ANALYSIS

STEEL CONTRACTOR

JOB HAZARD ANALYSIS	Date: daily	Truss Erection
Contra. NASM 2001-016	Phase: Sector	Drawing #

Identify non-routine task; Activity Operation	Identify Potential Hazards Involved Unsafe conditions, actions, or other hazard	Preventive or Corrective Action to be taken
a) Examine the specific job task, break it down into a series of steps. b) Planning each step will help discover potential hazards c) Identify the equipment needed d) Respect hoisting and rigging load charts e) Respect the hoisting and rigging stress factor charts	a) Identify both hazards, environmental conditions and those connected with the job procedures b) Danger exposed to employee c) Can employee be caught in between d) Identify tripping, slipping and falling potentials e) Possible strains the employee could suffer from pushing, pulling, lifting, bending, or twisting. f) Hazardous to safety and or health (toxic gas, vapor, mist, fumes, dust, heat, or radiation) g) Examine each step carefully identify all hazards and its actions, conditions, and possibilities that could lead to a serious accident. h) Compile an accurate list of potential hazards and develop an effective procedure to and complete the task safely.	a. Using the procedures from 1a-e and 2a-h, as a guide will decide what actions or procedures are necessary to minimize and or eliminate accident injury or occupational illness b. Engineer the hazard out…say exactly what needs to be done to correct the hazard c. Provide guards, safety devices, additional personal protection equipment d. Provide job instruction training e. Maintain Good Housekeeping f. Position personnel at key areas to assure safety g. All serious hazards should be corrected immediately as they occur to avoid serious loss or injury. h. Review all information and input for accuracy and determine if the corrective actions and procedures are in place. Re-evaluate the JHA if necessary.
Set-up Crane	Surface must be a level hard firm surface free of debris 1. Determine the weight load before rigging it. 2. Know the safe working load of the rigging equipment and never exceed the charted limits. 3. Wear gloves when handling wire rope. 4. Inspect all hardware, equipment, tackle and slings before using them. 5. *Destroy* defective components. 6. Never use kinked or damaged slings 7. Sharp bends, pinching and crushing must be avoided. Use softeners or pads to prevent slings from cuts and bent 8. Never allow wire rope to lie on the ground for any length of time. 9. Keep all wire rope away from flame cutting and electric welding. 10. When using two or more slings on a load all slings must be made of the same material. 11. Avoid bending the eye section of wire rope slings around corners, as the bend will weaken the splice.	Clear area for set-up, grade if necessary. 1. Improper rigging could cause the load to drop causing serious injury and or damage. 2. Know the exact load route overloading could cause the crane to tip over 3. To prevent cuts and wire pricks 4. To prevent load loss and or serious injury and damage 5. Get rid of defective hoisting equipment destroy it and throw it away. 6. Slings could malfunction by breakage. 7. Slings could break once loaded 8. Rusting lowers the charted limit of the sling 9. Heat could weaken the wire rope, causing breakage 10. Wire rope could seriously damage nylon slings 11. Properly rig slings avoid damaging rigging eyes 12. Rope damage is invariable 13. Wire rope eyes should not cross over each other on the hook any binding warrants the installation of a shackle as described. 14. Ensure that designated work area is defined wider than the

JOB HAZARD ANALYSIS	Date: daily	Truss Erection
Contract: NASM 2001-016	Phase: Sector	Drawing #

	There must be no bending near any attached fitting. 12. When using choker hitches, do not force the eye towards the load once tension is applied. 13. Whenever more than two wire rope eyes must be placed over a hook, install a shackle on the hook with the shackle pin resting in the hook and hook the wire rope eyes to the shackle. Or use a collection ring.	crane swing radius and the height of the tallest column does not become a factor. • Beware of swinging loads at all times as they may spin into your area. • Always use tag lines, lines should not be less than 10 feet long. 15 Provide adequate fall protection and perimeter barriers as needed to signify the crane work area. Clearly define the work zone area as available to"" Authorized Personnel Only" • Clear all lift pieces of debris and tools to eliminate possible falling objects 16 Wear PPE needed to such as gloves, eye protection and any other means required to maintain a safe working environment. Provide adequate fall protection and perimeter barriers as needed to signify the work area. 17 possibility of slipping and tripping hazards, stress the importance of the 100% tie-off rule. 18 Provide necessary barricades to ensure only authorized personnel are permitted in the working area or below the working point.

JOB ZARD ANALYSIS	Date: 1/25/2002	Drawing # ESK-82
Contract: NASM 2001-016	Phase: Truss Erection (EAST 5T-1) + WEST Sector 1	# ESK-40A rev 1 # ESK-39

Preparation	1. Restricted amount of space. 2. Uneven or soft work surface. 3. Unauthorized personnel entering area. 4. Swing route, falling material.	1. Provide advanced coordination with HPCC to ensure an adequate work area. 2. Coordinate with HPCC to ensure work area preparation is performed as required. 3. Provide necessary barricades to ensure only authorized personnel are permitted in the working area. Provide men to watch controlled area. 4. Ensure that controlled area cordon is larger than the crane swing radius and the length of the truss. Remove any and excess rigging and or unwarranted tools and material.
Flagman / Communications	1. Flagman will have total control of the lift and will be in direct contact with the lift manager and the crane(s) operator(s), AT ALL TIMES	1. Flagman and crane operator will discuss the pre-lift and erection route prior to any job task procedure is executed.
Rigging	2. Inspect appropriate Rigging. 3. Rigging substitutes should be of an equivalent value or greater.	2. Install correct rigging as per critical lift procedure. Inspect rigging before use. 3. *A Rigging and Lift Plan has been prepared as a separate document.* 4. Inspect hook and safety latch.
Tighten up on load	1. Make sure the rigging settles accordingly, piece could shift if not settled as specified	1. Ensure equal loading of rigging lines.
Lift Truss	1. Rigging could break. 2. Body parts could get pinched.	1. Ensure equal loading of rigging lines. Ensure rigging is as per plan. 2. Ensure body parts are always clear.
Remove Truss from jig. N/A	1. Truss swing. 2. Truss could fall. 3. Truss could catch on jig.	1. Use two tag lines per end to control movement. 2. Ensure men are NEVER under the load. 3. Remove truss slowly. Men on jig to stand back from truss and watch for snagging. Non-participants to stand well clear of operation.
Swing boom and truss.	1. Truss could get away from men.	1. Swing slowly. Control load with tag lines. Ensure tag lines are long enough.
Crawl truss to hanger. N/A	1. Truss could fall off. 2. Unauthorized personnel entering area.	1. Keep truss as close to the ground as possible. Ensure that no one is under the truss at any time. Move slowly. Utilize attached warning procedure. Men to keep hold of tag lines.

JOB ZARD ANALYSIS	Date:1/25/2002	Drawing # ESK-82
Contract: NASM 2001-016	Phase: Truss Erection (EAST 5T-1) Sector 1	# ESK-40A rev 1 # ESK-39

		attached warning procedure. Men to keep hold of tag lines at all times. 2. A designated man is to precede the operation at all times. A designated man is to walk to each side and behind of the operation to ensure area under operation is secure
Cross bridge. N/A	1. Loss of control of the load.	1. Men must retain control of the load at all times. One man and one tag line on each end will precede the truss across the bridge. One man and one tag line on each end will follow the truss across the bridge. Mark utility trench at the truss ends to allow the future installation of a footbridge r optimal points.
Swing truss into position	1. Truss could get away from men.	1. Swing slowly. Control load with tag lines. Ensure tag lines are long enough.
Truss Erection / Connecting into position.	1. Compare actual dimension of erection piece to actual spacing of erection point. 2. Anticipate the tools needed to connect the piece and have the tools readily available. 3. Suspended Truss, beware of binding once loose truss could cause serious injury. 4. Crane Operator will not respond until he is satisfied the safety of the crane is not in jeopardy. 5. Pinch body parts.	1. Avoid unnecessary work while truss is suspended. 2. Do not prolong the suspended mode of the connecting truss. Preplanning should eliminate any and all delaying factors. 3. Connectors must identify and evaluate all known binding points and all involved personnel will work towards that common goal. 4. Crane is not to release load unless authorized by the lift foreman 5. Watch body parts.
Disconnect Truss Rigging.	1. Rigging could swing. 2. Fall hazards.	1. Release rigging cautiously. Hold rigging until it comes to center if possible, when rigging is over sized and difficult to handle connectors will watch for each other before releasing any rigging which could cause injury to another. 2. 100% tie off when over 6'. Use JLG to release rigging when possible.

JOB HA[redacted]RD ANALYSIS	Date: January 7, 2002	Ref; Erection Scheme Drawings
Contract: [redacted]SM 2001-016	Phase: Sector 45, Main Hanger metal decking	ER-10A rev 2
	Laying Deck	

Identify non-routine task; Activities	Identify Potential Hazards Involved Related Task	Preventive or Corrective Action to be taken Hazards related to task
Rigging Deck	1. Determine the weight load before rigging it. 2. Know the safe working load of the rigging equipment and never exceed the charted limits. 3. Wear gloves when handling wire rope. 4. Inspect all hardware, equipment, tackle and slings before using them. 5. *Destroy* defective components. 6. Never use kinked or damaged slings 7. Sharp bends, pinching and crushing must be avoided. Use softeners or pads to prevent slings from cuts and bent 8. Never allow wire rope to lie on the ground for any length of time. 9. Keep all wire rope away from flame cutting and electric welding. 10. When using two or more slings on a load all slings must be made of the same material. 11. Avoid bending the eye section of wire rope slings around corners, as the bend will weaken the splice. There must be no bending near any attached fitting. 12. When using choker hitches, do not force the eye towards the load once tension is applied. 13. Whenever more than two wire rope eyes must be placed over a hook, install a shackle on the hook with the shackle pin resting in the hook and hook the wire rope eyes to the shackle.	1. Improper rigging could cause the load to drop causing serious injury and or damage. 2. Know the exact load route overloading could cause the crane to tip over 3. To prevent cuts and wire pricks 4. To prevent load loss and or serious injury and damage 5. Get rid of defective hoisting equipment destroy it and throw it away. 6. Slings could malfunction by breakage. 7. Slings could break once loaded 8. Rusting lowers the charted limit of the sling 9. Heat could weaken the wire rope, causing breakage 10. Wire rope could seriously damage nylon slings 11. Properly rig slings avoid damaging rigging eyes 12. Rope damage is invariable 13. Wire rope eyes should not cross over each other on the hook any binding warrants the installation of a shackle as described.
Flying Deck Landing Deck Shake-out metal Decking, CDZ	1. Pre-plan a load route; wherever decking is to be located assure crane will be working within its load limit. 2. Bundled decking should be laid as close as possible to the load bearing point. 3. Unauthorized personnel are restricted from entering the Controlled Decking Zone. Loose decking, openings and uneven work level could cause slipping or falling. 4. Uneven work surface, radius roof surface. 5. Falling material. 6. Cut metal band straps on deck bundle, loose end	1. Ensure that designated work area is defined wider than the crane swing radius and the height of the tallest column does not become a factor. • Beware of swinging loads at all times as they may spin into your area. • Always use tag lines, lines should not be less than 10 feet long 2. Mid-span of joist are not engineered to maintain bundled decking. 3. Authorized personnel only, clearly define work area. Provide 4. Adequate fall protection and perimeter barriers as needed to signify the work area.

Drawing

JOB HA[redacted]RD ANALYSIS	Date: January 7, 2002	Ref; Erection Scheme Drawings
Contract: [redacted]SM 2001-016	Phase: Sector 45, Main Hang[redacted] metal decking	ER-10A rev 2
	Laying Deck	

	were to backlash it could cause serious eye injury and or cut to unprotected exposed skin areas.	5. Radius roof presents a higher possibility of slipping and tripping hazards, stress the importance of the 100% tie-off rule. 6. Provide necessary barricades to ensure only authorized personnel are permitted in the working area or below the decking area, workers working below the CDZ should be advised of the possible falling objects. • Clear all area of debris and tools to eliminate possible falling objects • Gloves required whenever handling deck to protect hands from sharp edge. 7. Apply pressure to longest side of metal strap while cutting bundled decking. Metal strap could fall to the lower level if worker does not support strap.
Cutting Deck Welding Deck	1. Safety equipment and protective devices functioning properly, when cutting with an acetylene torch or using steel saw. 2. Personal Protective Equipment is required 3. Cutting deck could cause burning by hot slag, open flame / fire. 4. Compressed / flammable gasses. 5. Fumes. 6. Electric shock, Hot materials or surfaces and UV/IR radiation	1. Ensure all cutting equipment (gas cylinders, torches, hoses, regulators, flash-back arrestors) are inspected and are in good condition. 2. Ensure proper cutting gloves, goggles, and PPE are worn. 3. Remove combustible materials from area. Provide fire extinguishers and fire as needed. 4. Maintain 20' separation of ox/act bottles unless in an approved cart. 5. Provide appropriate respirator as required. 6. Ensure all welding machines, cables and connections are inspected and in good condition. • Ensure welding gloves and other welding PPE are worn. • Ensure proper welding lens/hood is worn.
Decking Installation complete	1. Keep deck area clean and free of tools and debris.	1. Cover or cable any exposed opening and clear area of any slip or tripping hazards. 2. Ensure area directly below CDZ is restricted for authorized personnel use only.

JOB HAZARD ANALYSIS	Date:	**Wall Line Truss Erection**
Contract: NASM 2001-016	Phase: Main Hangar	Refer to Erection Drawings
	Truss 49-67 trusses	**ER 12 arrangement #2**
	Truss 48 & 68 end truss	**ER 12 arrangement #3**
	Release rigging off man-basket	

Identify non-routine task;	Identify Potential Hazards Involved	Preventive or Corrective Action to be taken
a) Examine the specific job task, break it down into a series of steps, b) Planning each step will help discover potential hazards c) Identify the equipment needed d) Respect hoisting and rigging load charts e) Respect the hoisting and rigging stress factor charts	a) Identify both hazards, environmental conditions and those connected with the job procedures b) Danger exposed to employee c) Can employee be caught in between d) Identify tripping, slipping and falling potentials e) Possible strains the employee could suffer from pushing, pulling, lifting, bending, or twisting. f) Hazardous to safety and or health (toxic gas, vapor, mist, fumes, dust, heat, or radiation) g) Examine each step carefully identify all hazards and its actions, conditions, and possibilities that could lead to a serious accident. h) Compile an accurate list of potential hazards and develop an effective procedure to and complete the task safely.	a. Using the procedures from 1a-e and 2a-h, as a guide will decide what actions or procedures are necessary to minimize and or eliminate accident injury or occupational illness b. Engineer the hazard out…say exactly what needs to be done to correct the hazard c. Provide guards, safety devices, additional personal protection equipment d. Provide job instruction training e. Maintain Good Housekeeping f. Position personnel at key areas to assure safety g. All serious hazards should be corrected immediately as they occur to avoid serious loss or injury. h. Review all information and input for accuracy and determine if the corrective actions and procedures are in place. Re-evaluate the JHA if necessary.
Identify the Truss and its known weight	All rigging used should be capable of sustaining the actual Truss Weight without relying on the 5 to 1 safety factor.	To assure the rigging is capable of performing the task to prevent serious injury and or property damage.
Tandem Lifting spreader beam pyramid lifting procedures requires: 2-two cranes 4-point lifting beam 8-pick points on the actual truss.	Assure lifting beam is capable of supporting the known weight. Assure the cranes are within their charted capacities to complete the pick. Assure all rigging; shackles and pins are properly attached.	Tandem spreader beam will spanned _____' and will be supported by two cranes one on either side. Spreader beam will pick the truss at four pre-determined pick points Each pick point consists of two spreader connections at the truss, one spreader connected on either side of the top two cords.
Crane Communications	Crane operators will be under the direction of the erection Forman with radio communication	Use of radios and separate channel to eliminate miscommunication and constant control
Tilt Wall Truss from laying position to upright position	Identify and fix any rigging kinks and pinch points	All employees should be aware of any and all rigging pinch points, employees should keep there hands and bodies away from a potential pinch point, it could cause serious injury
Temporary, Shoring Tower	The wall line truss erection progress will allow the attached shoring tower to pivot into its upright	When moving dunnage coordinate movements with the forklift operators and the men involved in the shoring tower installation.

JOB HAZARD ANALYSIS	Date:	Wall Line Truss Erection
Contract: NASM 2001-016	Phase: Main Hangar	Refer to Erection Drawings
	Truss 49-67 trusses	ER 12 arrangement #2
	Truss 48 & 68 end truss	ER 12 arrangement #3
	Release rigging off man-basket	

	anchorage position. The tower will be positioned at its designed point to support the wall line truss awaiting the center truss connection.	
Transfer load from crane to shoring jacks	Make sure the load of the truss is let off equally between the two cranes.	Make sure all the anchor bolts are installed and tight. That the shoring towers are secure and plum. Evaluate the truss position and any conditional issues which may affect the erected trust before the cranes are cut loose.
MAN-BASKET	**Disconnect rigging**	**Minimal fall exposure**
Pre-load test	Prior to hoist personnel on the platform, and after any modification, the platform and rigging shall be proof tested to 125 percent of the platform rated capacity by holding it in a suspended position for five minutes with the test load evenly distributed on the platform. The total weight of the loaded personnel platform and related rigging shall not exceed 50% of the rated capacity for the radius and configuration of the crane.	After the proof testing, a competent person shall inspect the platform and rigging. Any deficiencies found shall be corrected and another proof test shall be conducted. Personnel hoisting shall not be conducted until the proof testing requirements are satisfied ATB, anti tool block shall be used to prevent contact between the load block and boom point or a system shall be used which deactivates the hoisting action before damage occurs in the event of a two-blocking situation (two-block damage prevention feature). ***Free Fall is prohibited***
Hoisting Personnel	The crane operator shall remain at the controls at all times when the crane is running and the platform is occupied.	Hoisting of employees shall be immediately discontinued upon any indication of any dangerous weather condition or other impending danger. Employees shall remain in constant sight of the operator; direct communication such as radio may use.

JOB HAZARD ANALYSIS

ROOFING CONTRACTOR

Form C4.1

JOB HAZARD ANALYSIS Date: August 30, 2001

Contract: Phase: 10 Roof Areas

Contractor: Pioneer Roofing Systems, Inc. Location: NASM - Dulles Airport

ACTIVITY OPERATION	UNSAFE CONDITION, ACTION, OR OTHER HAZARD	PREVENTATIVE OR CORRECTIVE ACTION THAT WILL BE TAKEN
1) Main Hangar Area	Fall Hazard / Slippery Condition	Scaffolding will be used. Safety Harnesses and Safety Lines will
		also be used
2) Theater Area & Tower Area	Fall Hazard / Higher Elevations are	Safety monitor at all times, and anyone within 6' of edge will be tie
	rounded roof areas	off.
3) Public Amenities Areas One & Two		
		All areas will have a 6' Warning Line erected, with a monitor (w/vest)
4) Building Management Area	Areas 3, 4, 5, 6, 7	at all times.
	Fall Hazard and Openings in	
5) Side Gallery Area	Roof Areas	Any openings in roof will need to be properly covered to prevent
		anyone falling through openings. If Hensel-Phelps does not cover
6) Central Plant (2 Areas)		openings, Pioneer will properly cover openings.
7) Gate House		
		Note: All Power Equipment have GFI Circuit Breakers.

Form C4.1

JOB HAZARD ANALYSIS

Date: 5-13-02

Contract: Hpco, NASM

Phase: N/ASM hanger

Contractor: Pioneer Coating systems

Location: ~~East~~ and west side OF hanger

ACTIVITY OPERATION	UNSAFE CONDITION, ACTION, OR OTHER HAZARD	PREVENTATIVE OR CORRECTIVE ACTION THAT WILL BE TAKEN
Loading of wood on to man lift to be put on hunger.	Working over-head, 2x6 could Fall.	1. C-Clamps attached To wood. 2. Rope attached To C-clamps and wood 3. Rope attached To basket of man lift 4. Controlled access zone around area of work.
Cutting of wood.	Eye's, burns, irritation To eye's. Pressure Treated lumber will be used. Chemical contacts with skin, eye's, Dust/particle's To eye's	PPE will be used. Face shield, gloves, hard-hats, and Face dust Mask.

JOB HAZARD ANALYSIS

MECHANICAL CONTRACTOR

JOB HAZARD ANALYSIS - LIFT PLAN HANGER **Date:** 4/15/02

Contract: NAT'AIR + SPACE MUSEUM **Phase:**

Contractor: UNITED SHEET METAL **Location:** HANGER

ACTIVITY OPERATION	UNSAFE CONDITION, ACTION, OR OTHER HAZARD	PREVENTATIVE OR CORRECTIVE ACTION THAT WILL BE TAKEN
DUCTWORK RIGGING	DUCT FALLING	FOREMEN WILL CALCULATE DUCT WEIGHT, CONFIRM CHOKERS + CHAINFALLS WEIGHT RATINGS BEFORE LIFTING
		MAX DUCT WGT 2200 lbs
		EQUIPMENT; 2 TON CHAIN FALLS,
		NYLON SLINGS; 6400 lbs VERT,
		5000 lbs CHOKER, 12800 lbs BASKET
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Date: March 4, 2002

UNITED SHEET METAL, INC.
JOB HAZARD ANALYSIS

PROJECT NAME: National Air & Space Museum

PHASE: Hanging HVAC Ductwork

CONTRACTOR: UNITED SHEET METAL, INC.

LOCATION: Chantilly, VA

ACTIVITY / OPERATION	UNSAFE CONDITION, ACTION OR HAZARD	PREVENTIVE OR CORRECTIVE ACTION
Hanging duct work for HVAC	Ladders	Inspect ladders on a regular basis and train employees on ladder safety
	Electrical	Tools are inspected quarterly and a ground fault system is used
	Material Used	MSDS Program is used to inform employees of materials used
	Truck Deliveries	All trucks are equipped with back up beepers and seat belts which all employees are instructed to use
	Metal-sharp Edges	All employees are instructed to use caution when handling metals

Mike Breen

4-17-02

Form 160F 01/94

Dave Spears 4/17/02

Date: March 4, 2002 — OF 3

UNITED SHEET METAL, INC.
JOB HAZARD ANALYSIS

PROJECT NAME: National Air & Space Museum

PHASE: Hanging HVAC Ductwork

CONTRACTOR: UNITED SHEET METAL, INC.

LOCATION: Chantilly, VA

ACTIVITY / OPERATION	UNSAFE CONDITION, ACTION OR HAZARD	PREVENTIVE OR CORRECTIVE ACTION
Drilling and Hanging Sheetmetal	Getting Objects in Eye	All employees are required to wear safety glasses while drilling or chiseling, which are supplied by USM
	Objects Falling From Upper Levels	All employees are required to wear hard hats at all times on all jobs
Working in Riser	Falling in Riser	To have employees wear fall protection which is supplied by USM
Working on Aerial Platform	Running Off Edge, Falling Off, and Hitting Power Lines	All employees will take the Operator's Training Program before they use them

Form 160F 01/98

Dave Spear 4/17/02

JOB HAZARD ANALYSIS

ELECTRICAL CONTRACTOR

JOB HAZARD ANALYSIS

Page 1 of 1

Date: May 17, 2001

PROJECT NAME National Air and Space Museum
CONTRACTOR Hensel Phelps Construction Company
SUBCONTRACTOR M. C. Dean, Inc.

PHASE
LOCATION 14420 Lee Jackson Memorial Highway

ACTIVITY/OPERATION	UNSAFE CONDITION, ACTION OR HAZARD	PREVENTIVE OR CORRECTIVE ACTION
Use of Ladders	Falls	Employees shall inspect ladder before each use
		Defective ladders shall be immediately tagged with a label that reads, "DO NOT USE" and removed from the job site. Ladders shall be maintained free of grease, oil, and other slipping hazards. Ladders shall not be place in location where they can be displaced by workplace activities. Portable ladders shall extend at least three (3) feet above the landing surface. No standing or setting on the top two- (2) rungs of a step ladders. Non-self supporting ladders shall be used at an angle such that the horizontal distance from the top support to the foot of the ladders is approximately one-quarter of the working length of the ladder. EXTENSION LADDERS WILL BE TIED OFF AT TOP. Also secured at bottom.
Use of Ladders	Falling overhead Objects	No tools or equipment shall be left on top of ladders. No TOOLS OR EQUIPMENT SHALL BE BROUGHT DOWN LADDE
Use of Ladders	Electrical Shock	Only wood or fiberglass ladders shall be used. **No Metal Ladders**

JOB HAZARD ANALYSIS

Page 1 of 1

Date: May 17, 2001

PROJECT NAME National Air and Space Museum
CONTRACTOR Hensel Phelps Construction Company
SUBCONTRACTOR M.C. Dean Inc.

PHASE
LOCATION 14420 Lee Jackson Memorial Highway

ACTIVITY/OPERATION	UNSAFE CONDITION, ACTION OR HAZARD	PREVENTIVE OR CORRECTIVE ACTION
Trenching and Excavation	Surface Encumbrances	Remove or support as necessary to safeguard workers
Trenching and Excavation	Underground Installations	Prior to the start of excavation, Miss Utility shall be notified and all underground installation marked. When the excavation operation approaches the estimated location of underground installation, the exact location shall be determine by hand excavation in a safe manner. Underground installation shall be protected, supported or removed as necessary to protect workers.
Trenching and Excavation	Access and Egress	A ladder or ramp shall be located in trench excavation that are 4 feet or more in depth so as to require no more than 25 feet of lateral travel to egress.
Trenching and Excavation	Open Trench	Barricading and warning system shall be used
Trenching and Excavation	Water in Trench	Water shall be remove from trench prior to anyone entering.
Trenching and Excavation	Cave-in	Daily inspection, use trench box, or trench shield/shoring system SLOPE BACK 1½:1 FROM 4 FOOT DEEP
Trenching and Excavation	Confined Space (Engulfment; Hazardous Atmosphere)	Follow M.C. Dean Confined Space Procedure
Trenching and Excavation	Exposure to vehicle traffic	Employees shall wear reflectorized or highly visible vest.
Trenching and Excavation	General	Daily inspection and when condition change
		SOIL IS CLASS 'C'
		SPOILS MUST HAVE A MINIMUM OF 2' OF CLEARANCE FROM TOP OF SLOPE

JOB HAZAkU ANALYSIS

Page 1 of 1

Date: May 17, 2001

PROJECT NAME National Air and Space Museum
CONTRACTOR Hensel Phelps Construction Company
SUBCONTRACTOR M. C. Dean, Inc.

PHASE
LOCATION 14420 Lee Jackson Memorial Highway

ACTIVITY/OPERATION	UNSAFE CONDITION, ACTION OR HAZARD	PREVENTIVE OR CORRECTIVE ACTION
Temporary Electric	Qualification of Operators	Only qualified and authorized person shall be allowed to install temporary wiring.
Wiring	Worn or torn insulation	All electrical installation shall be suitably insulated with no expose conductors.
	Undersized/under rated conductors	Each size of conductor shall have a safe current carrying capacity and be provided with the required overload protection. All boxes and fitting shall have covers.
Grounding	Equipment becoming unintentional energized	All electrical equipment shall be grounded in accordance with the NEC. ALL GENERATORS SHALL BE GROUNDED INDEPENDENTLY.
Service Panel	Unidentified rating of equipment	All temporary electrical equipment shall be listed and labeled. Electrical equipment shall be marked with the manufacturer's name, trademark, and voltage, current or wattage or other rating as necessary.
Service Panel	Unidentified circuits	All equipment shall be identified with the disconnecting means and circuitry. Each service feeder and branch circuit, at its disconnecting means or over current device, shall be legibly marked to indicate its purpose. Sufficient working space and access shall be maintained to permit ready and safe operation and maintenance of such equipment.
General	Electrical Shock	Sign warning of high voltage will be posted. No employe shall be permitted to work in such proximity to any part electric power such that the employee could come into contact with an energized circuit. All temporary electrica equipment shall be inspected weekly. Worn or frayed electric cords or cable shall not be used.

JOB HAZARD ANALYSIS

GLAZING CONTRACTOR

JOB HAZARD ANALYSIS Harmon Inc.		Date: Through Contract Completion
Contract: NAtional Air and Space Museum		Phase: All
Contractor: Hensel Phelps		Location: Chantilly, Va.
		Date 04/24/02
ACTIVITY OPERATION	**UNSAFE CONDITION, ACTION, OR OTHER HAZARD**	**PREVENTIVE OR CORRECTIVE ACTION THAT WILL BE TAKEN**
Layout and install curtain wall anchors at hanger.	Triping hazard working at ground level. Working around other trades. Working from a ladder. Using a welding machine. Grinding welds	• Have other trades remove any material not need after there compleation. • Use caution signs or tape to zone off work aera. • Set up ladder on a level surface. • Place machine out of traffic and use caution when filling. Ware proper PPE when Burning and Welding (Approved burning Goggles and Welding shield) • Have a fire extinguisher with in 25' of welding and burning. • Grinding welds waer a full face shield with proper lens.
Installing curtain wall at end of hanger.	Hazardes fall condition, at trusses and boom lift. Personnel working below. Dropping tools. Inadequate rigging for lifting and insulation. Placement of crane.	• When working from lift, use a harness and a double lanyard (DBI/Sala) at all times. All employees to be train to operate lifts. • Caution tape area off. • Use tool lanyards on all hand tools, power cords to be tied together. • Use tag lines when neccessary. (Any suspended loads) • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.
Public Amenities, layout, anchors, preglazed units.	Hazardes fall condition, working from roof, ladder, scaffold, boom and or scissor lift. Personnel working below. Using a welding machine. Dropping tools. Inadequate rigging for lifting and insulation. Placement of crane.	• When working from lift, use a harness and a double lanyard (DBI/Sala) at all times. • Set up ladder on a level surface. • Build scaffold in accordance to OSHA standards. (Scaffold to be supervised by a competent person) • Caution tape area off. • Place machine out of traffic and use caution when filling. • Use tag lines when neccessary. • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.

Light shelf windows:	Hazardes fall condition, working from , boom lift and or walk way.	• When working from lift, use a harness and lanyard(DBI/Sala)at all times.
	Personnel working below. Dropping tools. Inadequate rigging for lifting and insulation. Placement of crane.	• If working off of walk way all hand rail to be in place. • Caution tape area off. • Use tool lanyards on all hand tools, power cords to be tied together. • Use tag lines when neccessary.(Any suspended loads) • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.
Fuslage windows: layout, ...el, anchors and preglazed units	Hazardes fall condition working from roof, ladder, scaffold, boom and or scissor lift. Personnel working below. Using a welding machine. Grinding welds Dropping tools. Inadequate rigging for lifting and insulation. Placement of crane.	• When working from lift, harness and a double lanyard (DBI/Sala)at all times. • Set up ladder on a level surface. • Build scaffold in accordance to OSHA standards. • Caution tape area off. • Place machine out of traffic and use caution when filling.Ware proper PPE when Burning and Welding (Approved burning Goggles and Welding shield) • Have a fire extinguisher with in 25' of welding and burning. • Grinding welds ware a full face shield with proper lens. • Use tag lines when neccessary.(Any suspended loads) • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.
Theater roof frames: layout, ...chors and preglazed units	Hazardes fall condition working from roof, ladder, scaffold. Using a welding machine. Grinding welds Inadequate rigging for lifting and insulation. Placement of crane.	• Set up ladder on a level surface. • Build scaffold in accordance to OSHA standards. • Place machine out of traffic and use caution when filling.Ware proper PPE when Burning and Welding (Approved burning Goggles and Welding shield) • Grinding welds ware a full face shield with proper lens. • Use tag lines when neccessary.(Any suspended loads) • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.

Theater Aluminum Trusses	Hazardes fall condition working from boom lift.	• When working from lift, harness and lanyard(DBI/Sala) at all times. • Place machine out of traffic and use caution when filling.
	Personnel working below. Using a welding machine. Grinding welds Dropping tools. Using a welding machine. Inadequate rigging for lifting and insulation. Placement of crane.	• Caution tape area off. • Place machine out of traffic and use caution when filling.Ware proper PPE when Burning and Welding (Approved burning Goggles and Welding shield) • Have a fire extinguisher with in 25' of welding and burning. • Grinding welds ware a full face shield with proper lens. • Use tool lanyards on all hand tools, power cords to be tied together. • Use tag lines when neccessary. • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.
Control tower frames: layout anchors installing units and caulking frames.	Hazardes fall condition, working from roof, ladder, scaffold and boom lift. Personnel working below. Using a welding machine. Grinding welds Dropping tools. Inadequate rigging for lifting and insulation. Placement of crane.	• Working from floor tie off to a structure member and or a life line. • When working from lift, harness and a double lanyard (DBI/Sala)at all times. • Caution tape area off. • Place machine out of traffic and use caution when filling. Ware proper PPE when Burning and Welding (Approved burning Goggles and Welding shield) • Have a fire extinguisher with in 25' of welding and burning. • Grinding welds ware a full face shield with proper lens. • Use tool lanyards on all hand tools, power cords to be tied together. • Use tag lines when neccessary. • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.
Elevator Enclosure:	Hazardes fall condition working from ladder, scaffold and boom lift. Personnel working below. Dropping tools. Inadequate rigging for lifting and insulation. Placement of crane.	• When working from lift, harness and lanyard(DBI/Sala) at all times. • Caution tape area off. • Use tool lanyards on all hand tools, power cords to be tied together. • Use tag lines when necessary. • Check all rigging each day before use. • Check load charts for correct placement and zone off for swing of crane.

Storage of flammable material	Fire, explosion	• Keep flammable away from welding or burning also in an approved container. Any failure to comply with any of the above will result in disciplinary actions.
Drilling, and Screwing	Eye damage, broken wrist or hand, other trades in the area.	• Safety glasses will be worn at all times when operating power tools. • Make sure we have the right tools for the job and persons trained in using the tool • Caution other trades working in the area..
Installing Storefronts and doors	Working off step ladders, Using power equipment.	• Making sure that we have correct footing with the ladders • Have all power equipment in good working order and use a ground fault circuit or a ground fault protector.

JOB HAZARD ANALYSIS

CONCRETE CONTRACTOR

JOB HAZARD ANALYSIS Date: 7-22-02

Contract: NASM Phase: MAIN HANGAR SLABS SOG.

Contractor: Coral Concrete Location: ALL MAIN HANGAR

ACTIVITY OPERATION	UNSAFE CONDITION, ACTION, OR OTHER HAZARD	PREVENTATIVE OR CORRECTIVE ACTION THAT WILL BE TAKEN
PLACING CONCRETE	CONCRETE TRUCKS	ONLY 1 SIGNAL PERSON TO GUIDE TRUCK
SOG	SWINGING CHUTE	CHECK CHUTE CATCH BEFORE MOVING TRUC
	CONCRETE PANNS	WEAR HARD HAT, SAFETY GLASSES, RUBBER
		GLOVES, RUBBER BOOTS (DUCTTAPE TOP)
		TYVEK SUIT MAY BE REQUIRED. FACE
		SHIELD SHOULD BE WORN WHEN USING
		PUMP. WASH SKIN IS CONCRETE GETS
		ON YOU.
	USING VIBRATOR	ALL PPE. - GFCI MUST BE USED ON
		EXT. CORD. GRAND GENERATOR - CHECK CO
	PUMP TRUCK	MUST HAVE EYE CONTACT W/ OPERATOR -
		USE PROPER HAND SIGNALS. KEEP HOSE
		FROM KINKING
	APPLY DRY SHAKE	ALL PPE. - MUST WEAR DUST
	"SURFEX"	MASK @ ALL TIMES

Attachment 1 Form C4.1

PAGE 2

JOB HAZARD ANALYSIS	Date:
Contract:	Phase:
Contractor:	Location:

ACTIVITY OPERATION	UNSAFE CONDITION, ACTION, OR OTHER HAZARD	PREVENTATIVE OR CORRECTIVE ACTION THAT WILL BE TAKEN
		MUST WEAR RUBBER GLOVES. IF VERY FOGGY CONDITIONS ARE PRESENT VENTILATE AREA TO CLEAR DRY SHAKE FOG. USE MIST OF WATER TO CONTAIN. WASH SKIN THOROUGHLY. IF USED IN NON VENTILATED AREA A NIOSH APPROVED RESPIRATOR WILL BE REQUIRED. PROTECT WORKERS IN AREA OF PLACEMENT (DUST MASK OR HAVE CREWS RELOCATE DURING PLACEMENT TIME.

Attachment 1 Form C4.1

APPENDIX C

SAFETY PLAN LEGEND

SPECIFIC JOB HAZARD ANALYSIS

SAFETY PLAN SIMULATION

SAFETY PLAN SCHEDULE

Safety Plan Legend

	Worker	Bystander or Same Space Worker
Steel Erection	•Falling •Welding •Hoisting and Rigging •Struck by objects •Heavy Lifting	•Struck by objects •Welding
Roof Construction	•Falling •Cutting Metal •Hoisting and Rigging •Struck by objects •Chemical Adhesive	•Struck by objects
Fire Protection	•Falling •Welding •Cutting Metal •Heavy objects •Struck by objects	•Struck by objects •Welding •Cutting Metal
Mechanical	•Falling •Cutting Metal •Heavy objects •Struck by objects	•Struck by objects •Cutting Metal

	Worker	Bystander or Same Space Worker
Glazing	•Falling •Cutting Metal •Hoisting and Rigging •Struck by objects •Heavy Lifting	•Struck by objects •Cutting Metal
Painting	•Falling •Struck by objects •Paint in eyes	•Struck by objects •Paint in Eyes
Electrical	•Excavation •Cutting Metal •Grounding Equipment	•Struck by objects
Metal Studs	•Falling •Cutting Metal •Hoisting and Rigging •Heavy Lifting	•Struck by objects •Cutting Metal
Concrete	•Excavation •Struck by objects •Curing Compound •Drilling or Chipping	•Excavation Trench •Struck by objects •Curing Compound •Drilling or Chipping

SPECIFIC JOB HAZARD ANALYSIS

Steel Erection

Worker Hazards

Falling - protect workers from falls of 6 feet of more off unprotected sides or edges
- use proper fall arrest systems for proper heights:
  - 6'-18' : use full body harness with retractable lanyard
  - above 18' : use full body harness with shock-absorbing lanyard

Welding - protect against burns by covering skin (e.g. gloves, long sleeves, face shield)
- Protect eye irritation by wearing proper welding mask
- be aware of what is being welded due to toxic fumes (e.g. galvanized metal)
- mark off area below welding

Hoisting and rigging - be sure to follow proper rigging techniques (test equipment)
- do not stand below martial being hoisted
- mark off area below hoisted material
- never overload crane

Struck by objects – be aware of all activities around and above the working area

Heavy Lifting – let the equipment do the work and guide material

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Bystanders or workers in same space

Struck by objects - be aware of all activities around and above the working area
- watch for tripping hazards

Welding - Do not look directly into the welding
- Do not walk under welding activity

Roof Construction

Worker Hazards

Falling - protect workers from falls of 6 feet of more off unprotected sides or edges
- use proper fall arrest systems for proper heights:
  - 6'-18' : use full body harness with retractable lanyard
  - above 18' : use full body harness with shock-absorbing lanyard

Cutting Metal – Wear proper clothing and eye protection

Hoisting and rigging - be sure to follow proper rigging techniques
- do not stand below martial being hoisted (test equipment)
- mark off area below hoisted material
- never overload crane

Struck by objects – be aware of all activities around and above the working area

Chemical Adhesive – be sure to get fresh air when applying

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Bystanders or workers in same space

Struck by objects - be aware of all activities around and above the working area
- watch for tripping hazards

Fire Protection

Worker Hazards

Falling - protect workers from falls of 6 feet of more off unprotected sides or edges
- use proper fall arrest systems for proper heights:
  - 6'-18' : use full body harness with retractable lanyard
  - above 18' : use full body harness with shock-absorbing lanyard

Cutting Metal – Wear proper clothing and eye protection

Welding - protect against burns by covering skin (e.g. gloves, long sleeves, face shield)
- Protect eye irritation by wearing proper welding mask
- be aware of what is being welded due to toxic fumes (e.g. copper or brass)
- mark off area below welding

Hoisting and rigging - be sure to follow proper rigging techniques
- do not stand below martial being hoisted
- mark off area below hoisted material
- never overload crane or lift

Struck by objects – be aware of all activities around and above the working area

Heavy Lifting – let the equipment do the work and guide material

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Bystanders or workers in same space

Struck by objects - be aware of all activities around and above the working area
- watch for tripping hazards

Welding - Do not look directly into the welding
- Do not walk under welding activity

Mechanical

Worker Hazards

Falling - protect workers from falls of 6 feet of more off unprotected sides or edges
- use proper fall arrest systems for proper heights:
  - 6'-18' : use full body harness with retractable lanyard
  - above 18' : use full body harness with shock-absorbing lanyard

Cutting Metal – Wear proper clothing and eye protection

Hoisting and rigging - be sure to follow proper rigging techniques
- do not stand below martial being hoisted
- mark off area below hoisted material
- never overload crane or lift

Struck by objects – be aware of all activities around and above the working area

Heavy Lifting – let the equipment do the work and guide material

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Bystanders or workers in same space

Struck by objects - be aware of all activities around and above the working area
- watch for tripping hazards

Glazing

Worker Hazards

Falling - protect workers from falls of 6 feet of more off unprotected sides or edges
- use proper fall arrest systems for proper heights:
  - 6'-18' : use full body harness with retractable lanyard
  - above 18' : use full body harness with shock-absorbing lanyard

Cutting Metal – Wear proper clothing and eye protection

Hoisting and rigging - be sure to follow proper rigging techniques
- do not stand below martial being hoisted
- mark off area below hoisted material
- never overload crane or lift

Struck by objects – be aware of all activities around and above the working area

Heavy Lifting – let the equipment do the work and guide material

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Bystanders or workers in same space

Struck by objects - be aware of all activities around and above the working area
- watch for tripping hazards

Cutting Metal – watch for air born filings

Painting

Worker Hazards

Falling - protect workers from falls of 6 feet of more off unprotected sides or edges
- use proper fall arrest systems for proper heights:
  - 6'-18' : use full body harness with retractable lanyard
  - above 18' : use full body harness with shock-absorbing lanyard

Struck by objects – be aware of all activities around and above the working area

Paint in eyes – watch for wind direction

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Bystanders

Struck by objects - be aware of all activities around and above the working area
- watch for tripping hazards (esp. paint on floor)

Paint in eyes – watch for wind direction

Electrical

Worker Hazards

Cutting Metal – Wear proper clothing and eye protection

Excavation – wear bright vests when around equipment

Grounding – make sure all equipment is properly grounded

Bystanders

Struck by objects - watch for tripping hazards (esp. paint on floor)
- watch for excavation trenches

Metal Studs

Worker Hazards

Falling - protect workers from falls of 6 feet of more off unprotected sides or edges
- use proper fall arrest systems for proper heights:
  - 6'-18' : use full body harness with retractable lanyard
  - above 18' : use full body harness with shock-absorbing lanyard

Cutting Metal – Wear proper clothing and eye protection

Hoisting and rigging - be sure to follow proper rigging techniques
- do not stand below martial being hoisted
- mark off area below hoisted material
- never overload crane or lift

Struck by objects – be aware of all activities around and above the working area

Heavy Lifting – let the equipment do the work and guide material

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Bystanders

Struck by objects - watch for tripping hazards (esp. paint on floor)
- watch for excavation trenches

Cutting Metal – watch for air born filings

Concrete

Worker Hazards

Cutting Metal – Wear proper clothing and eye protection

Excavation – wear bright vests when around equipment

Grounding – make sure all equipment is properly grounded

Curing Compound – wear proper mask when applying

Weather – stay hydrated in summer, stay warm and watch for ice in the winter

Drilling or Chipping – Do not breathe in dust, may cause silicosis

Bystanders

Struck by objects - watch for tripping hazards (esp. paint on floor)
- watch for excavation trenches
- watch for exposed nails and protruding rebar

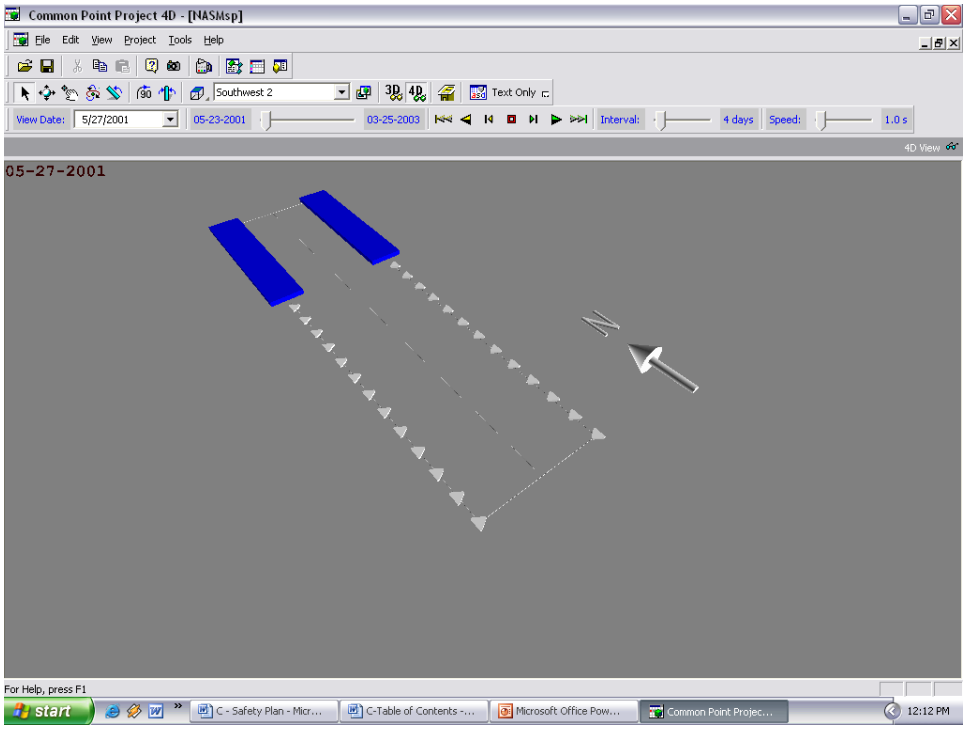
Excavation – watch for holes and trenches

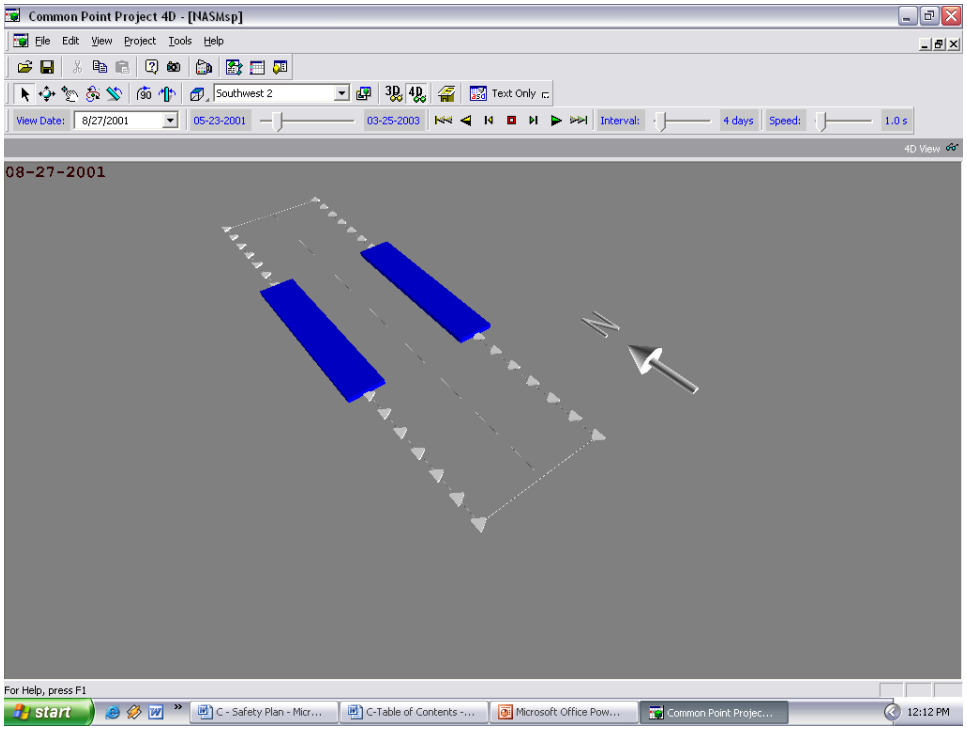
Cutting Metal – watch for air born filings

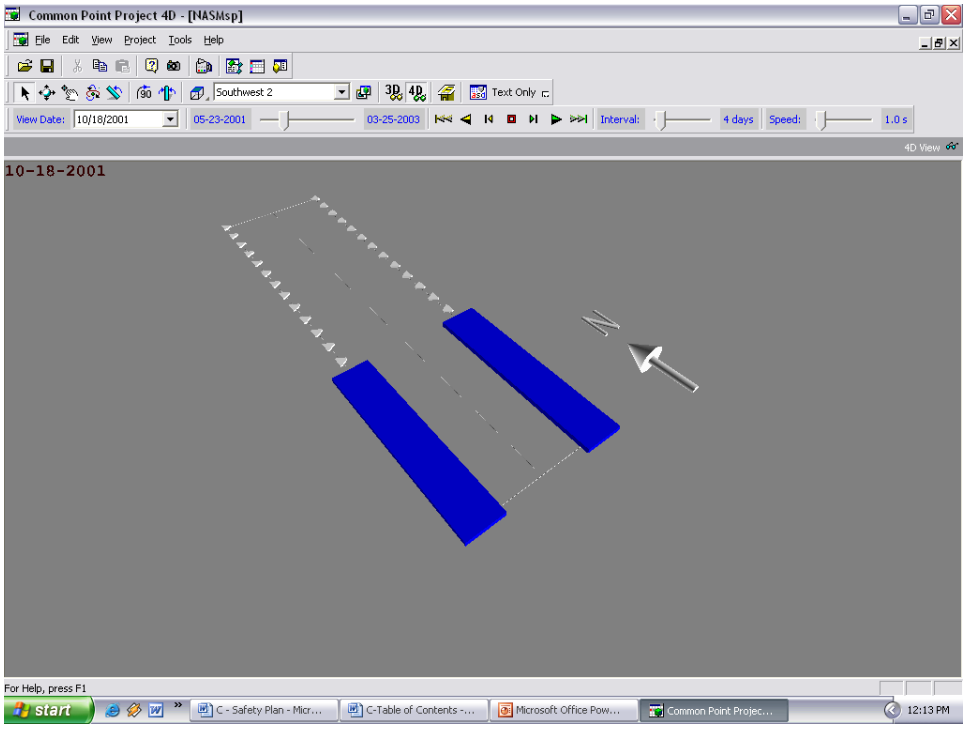
Curing Compound – do not breathe in shake hardener

Drilling or Chipping – Do not breathe in dust, may cause silicosis

SAFETY PLAN SIMULATION



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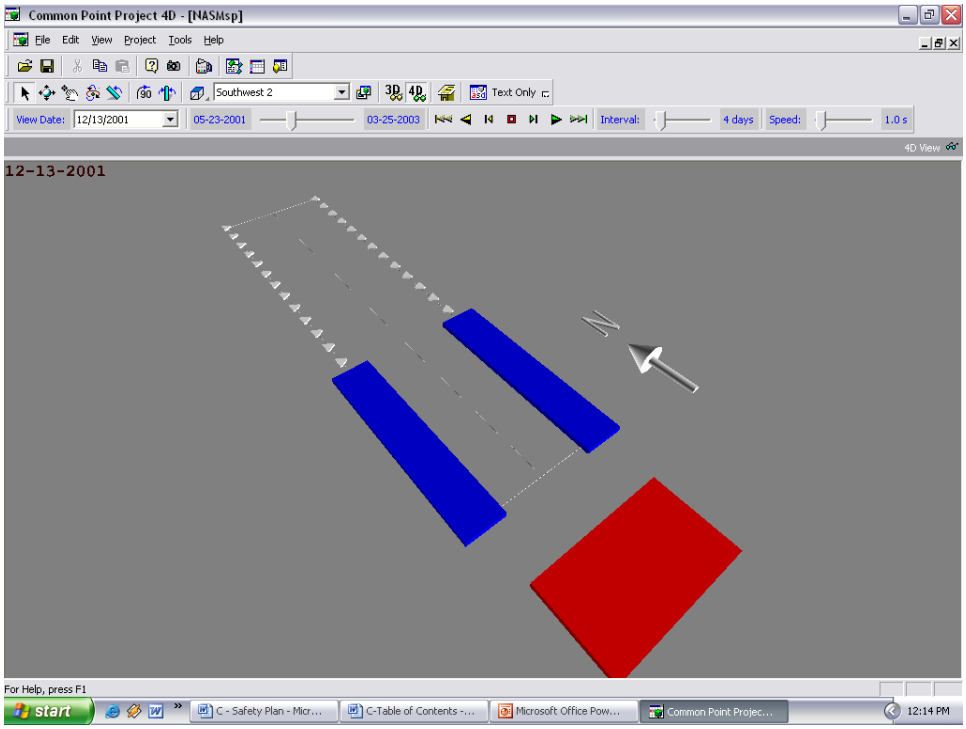
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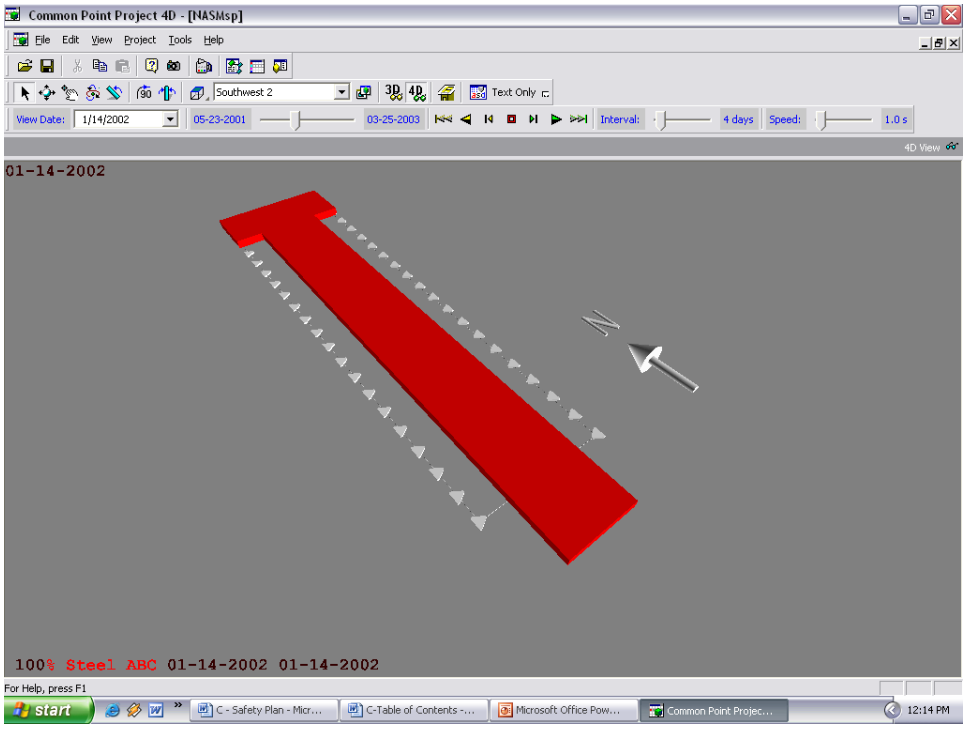
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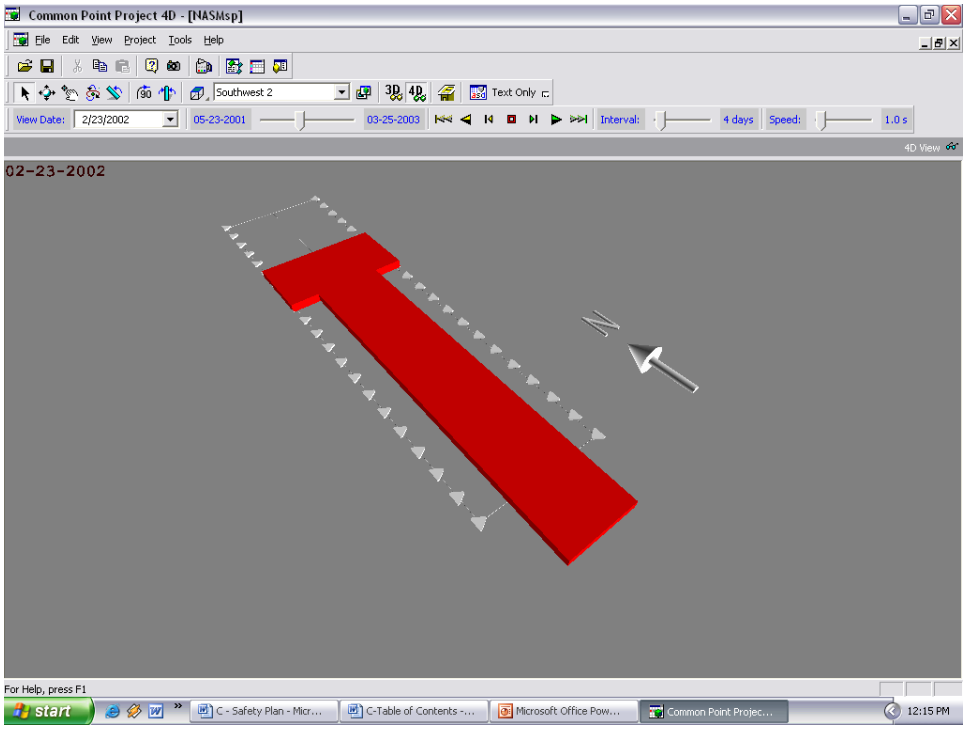
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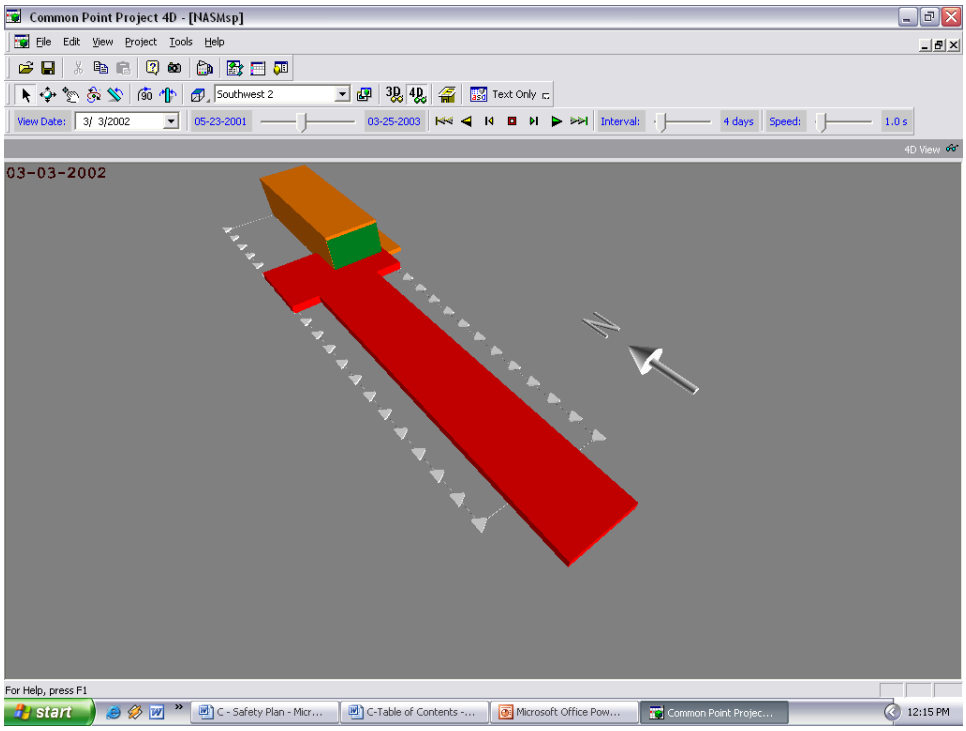
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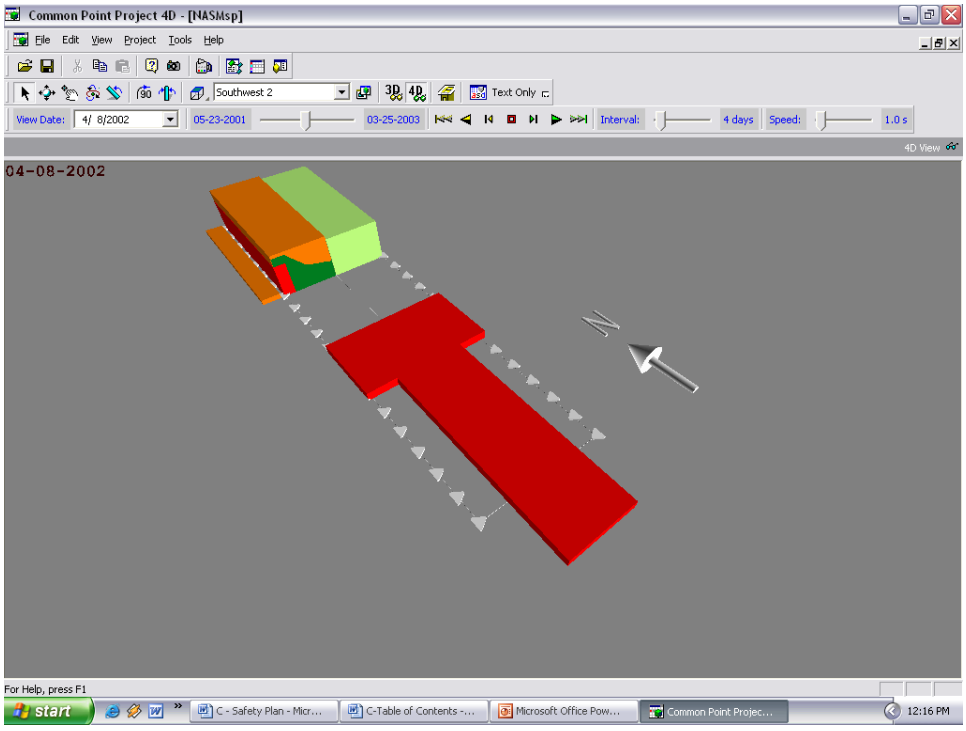
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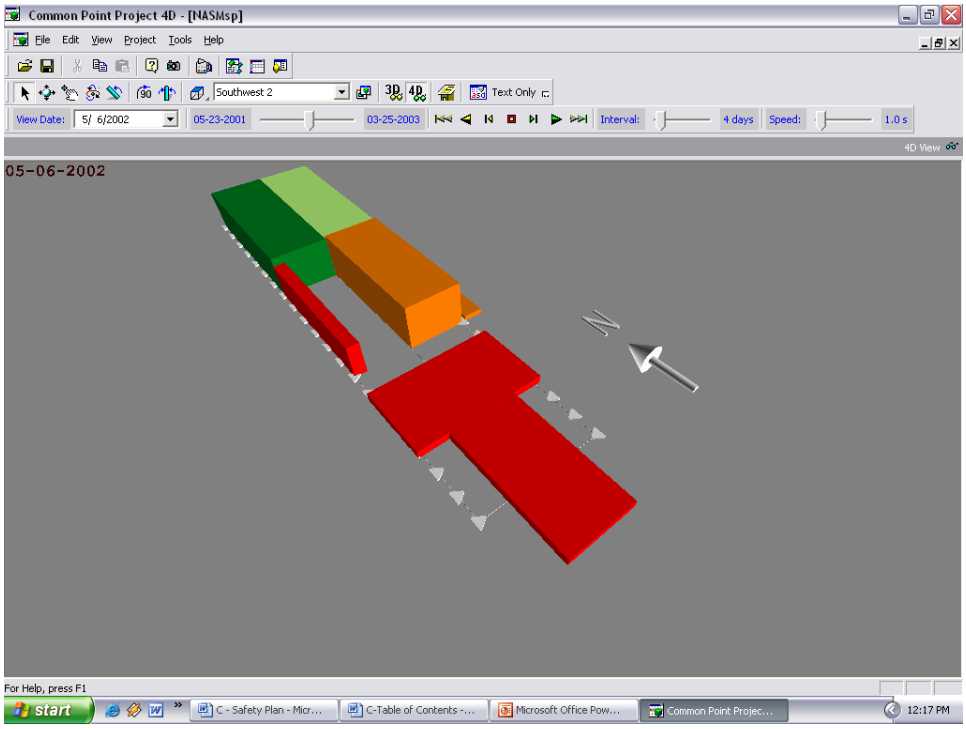
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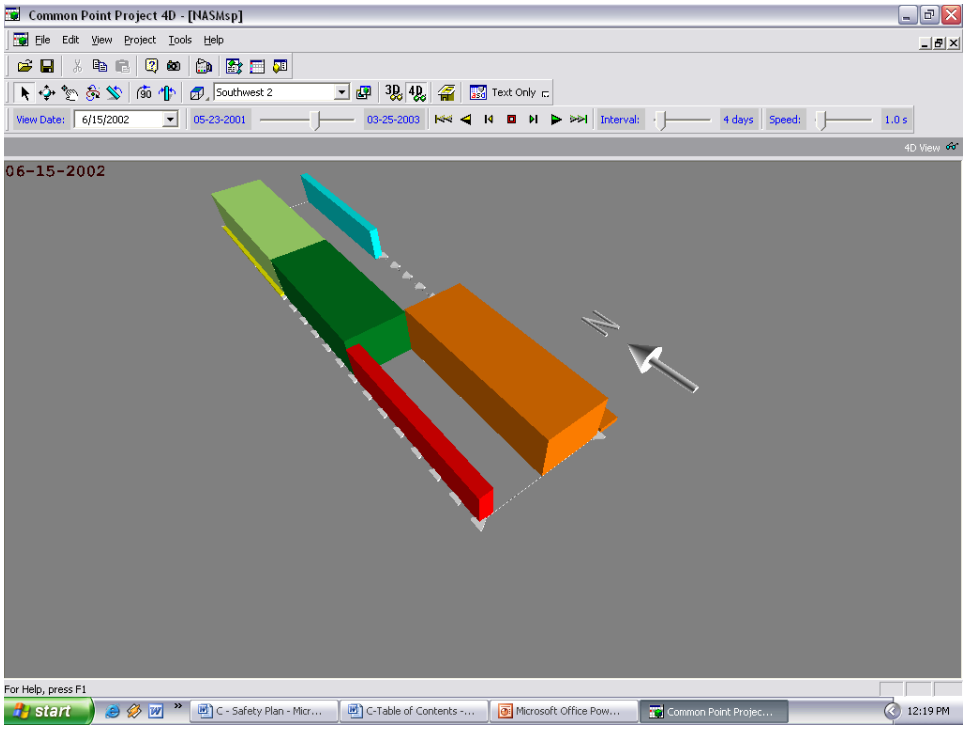
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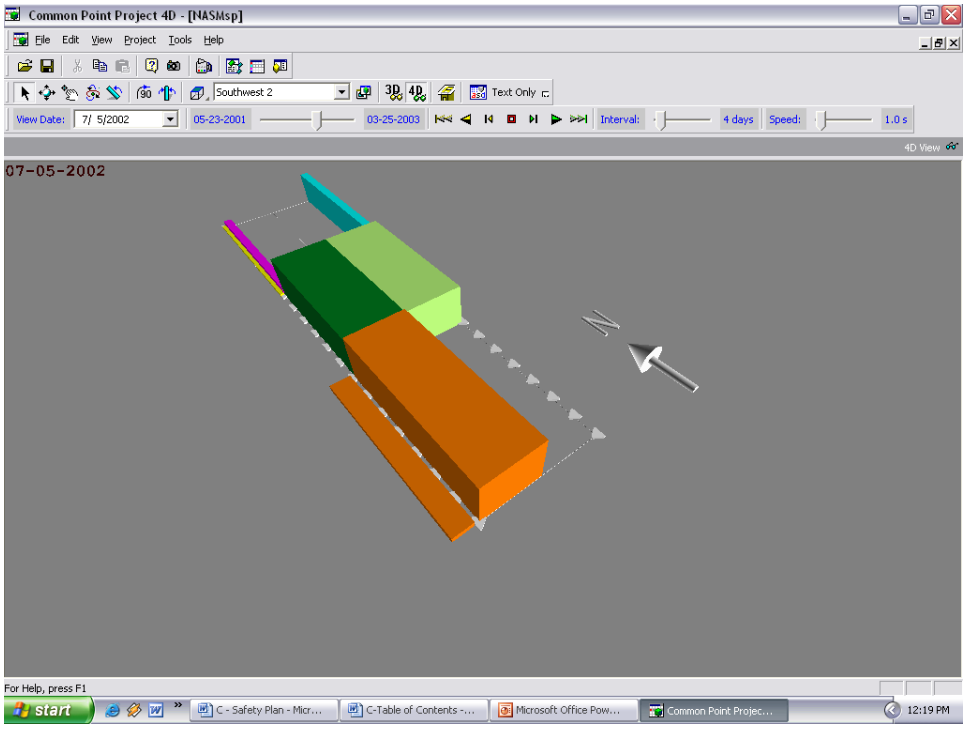
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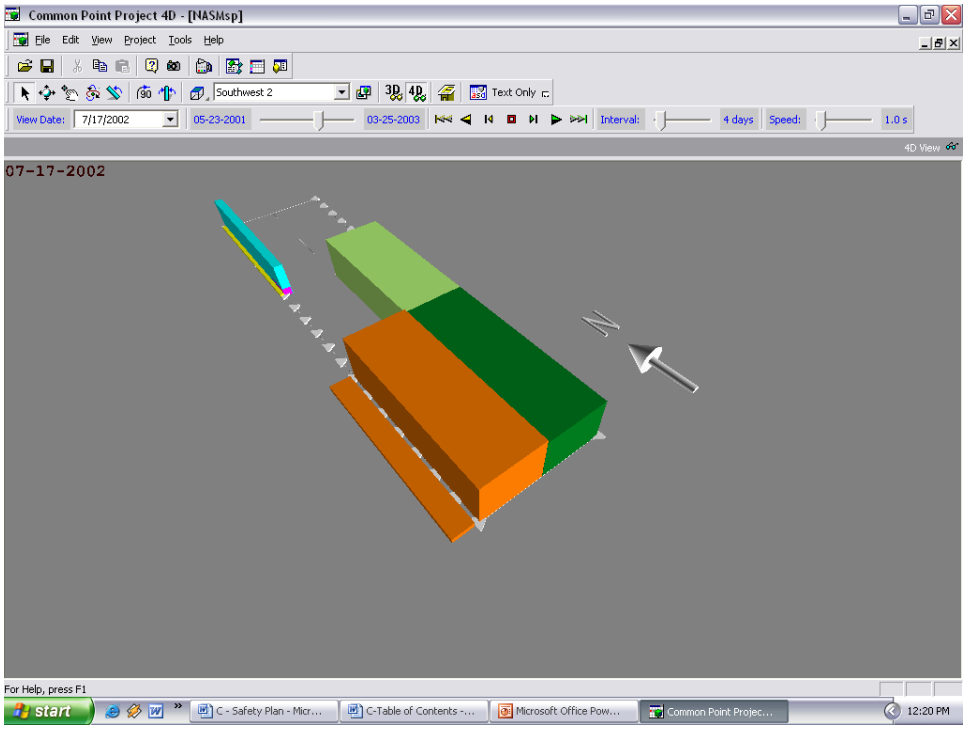
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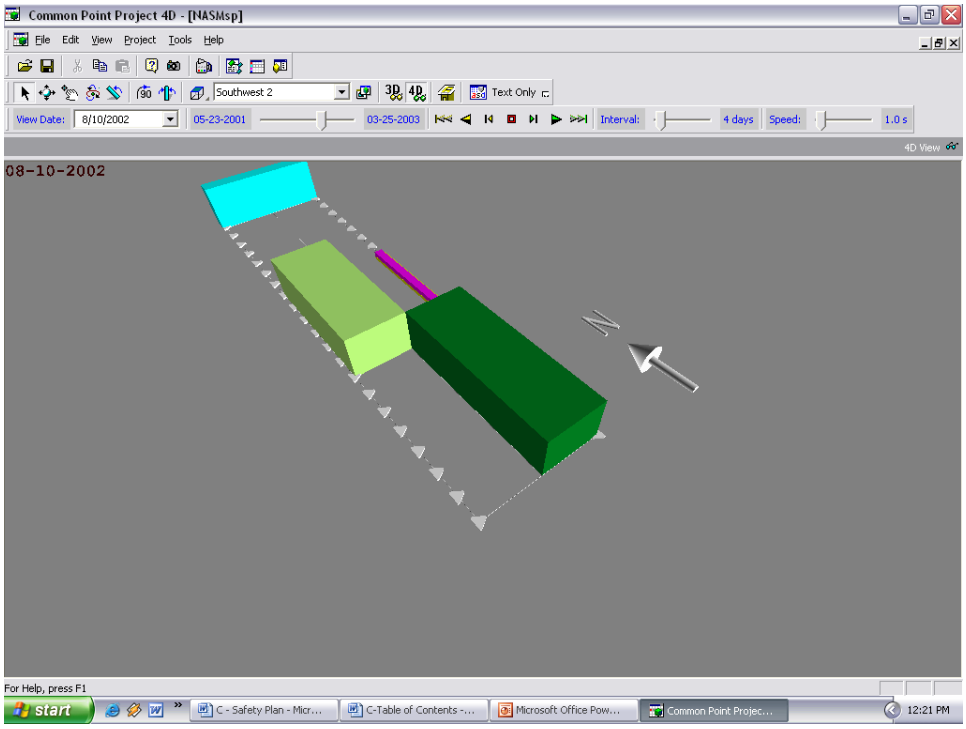
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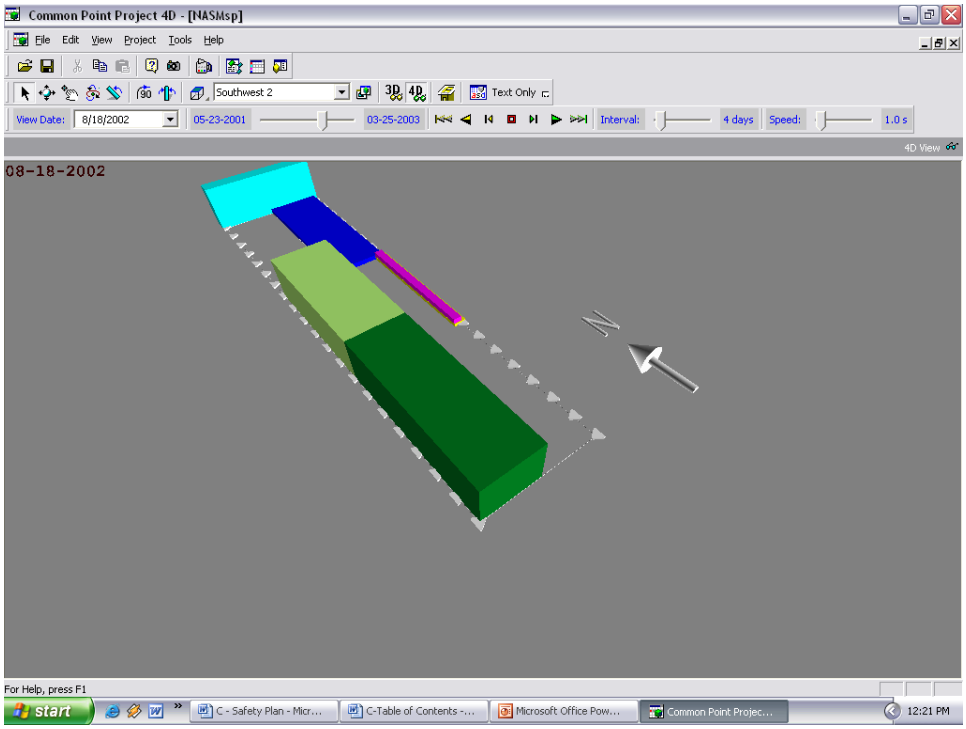
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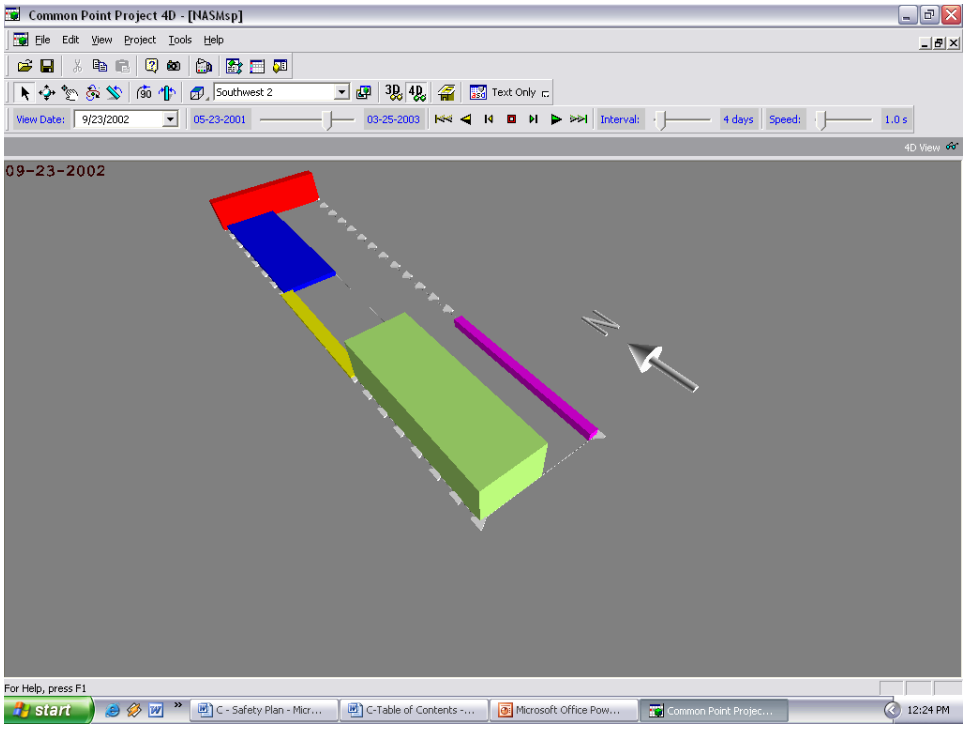
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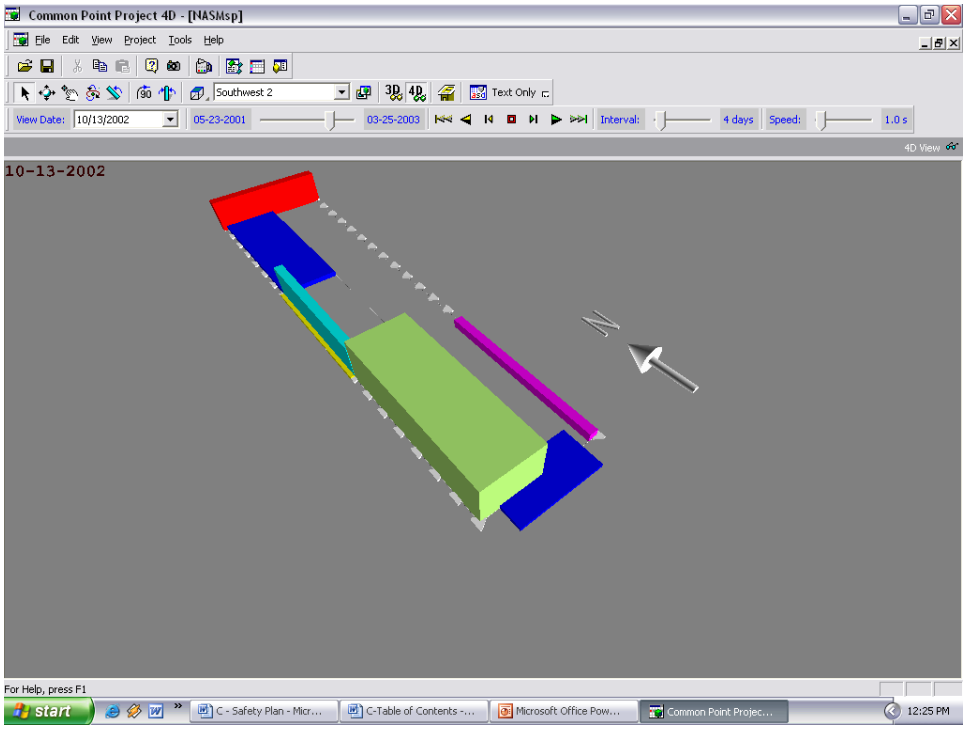
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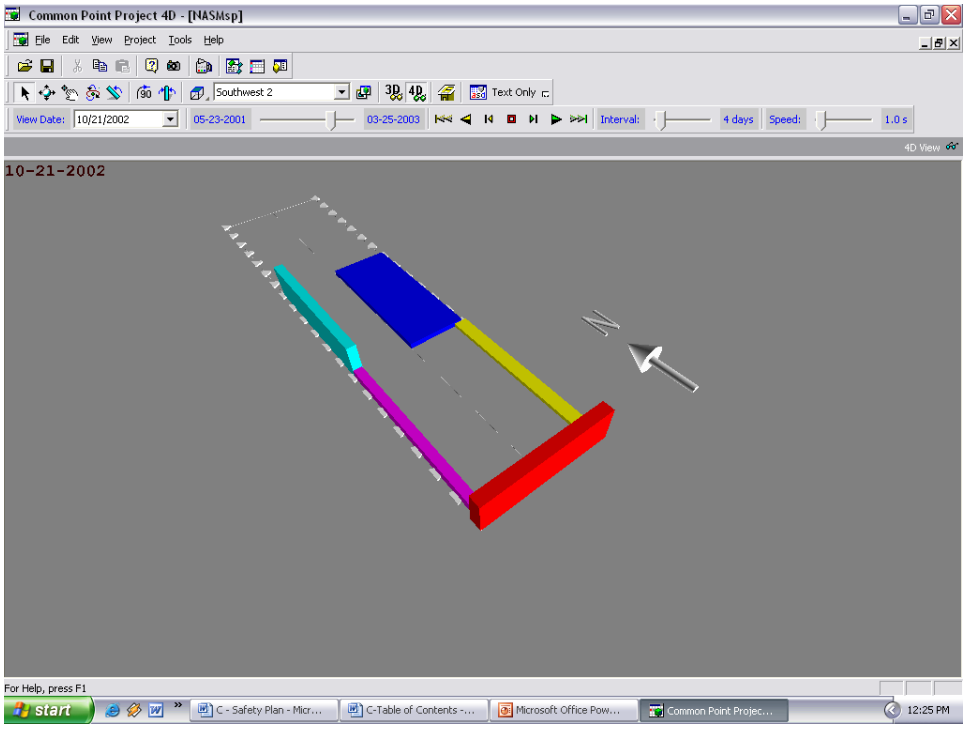
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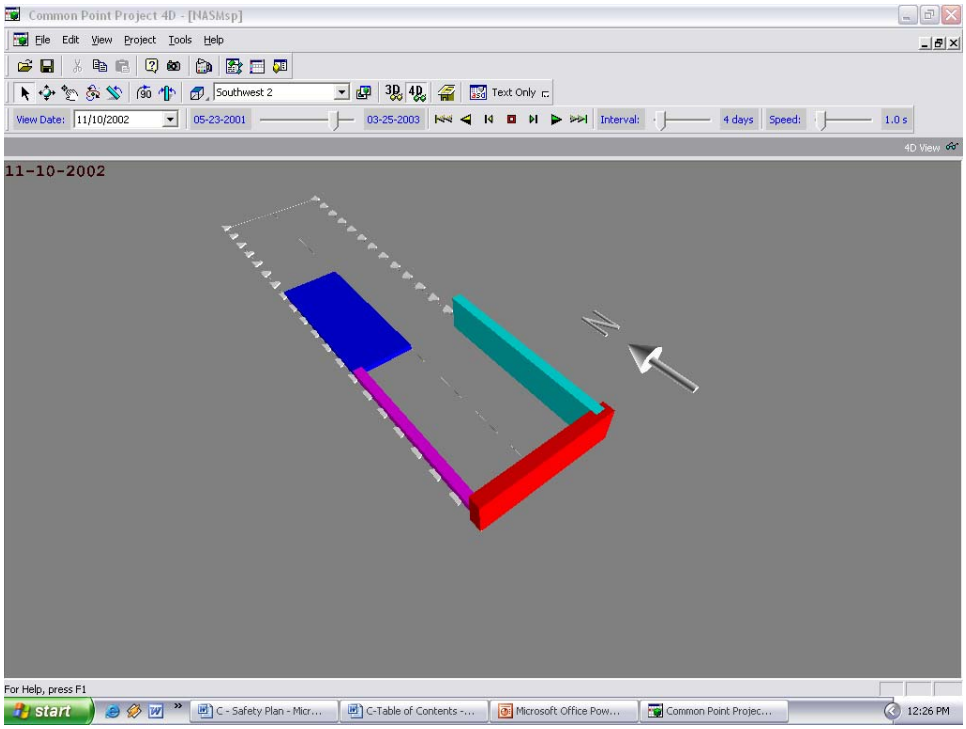
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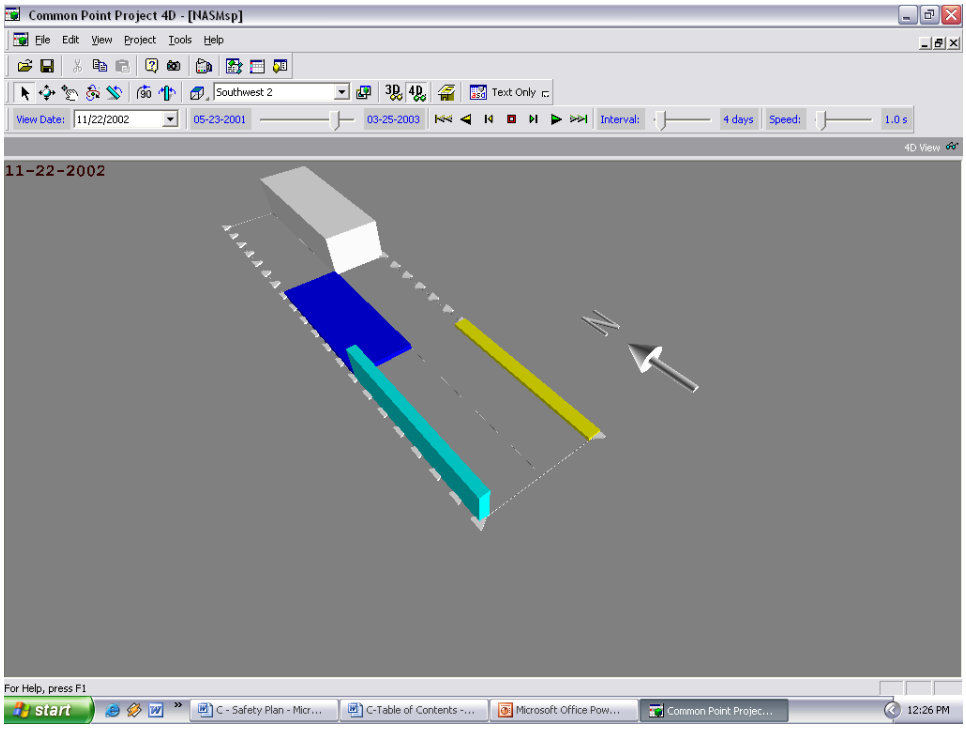
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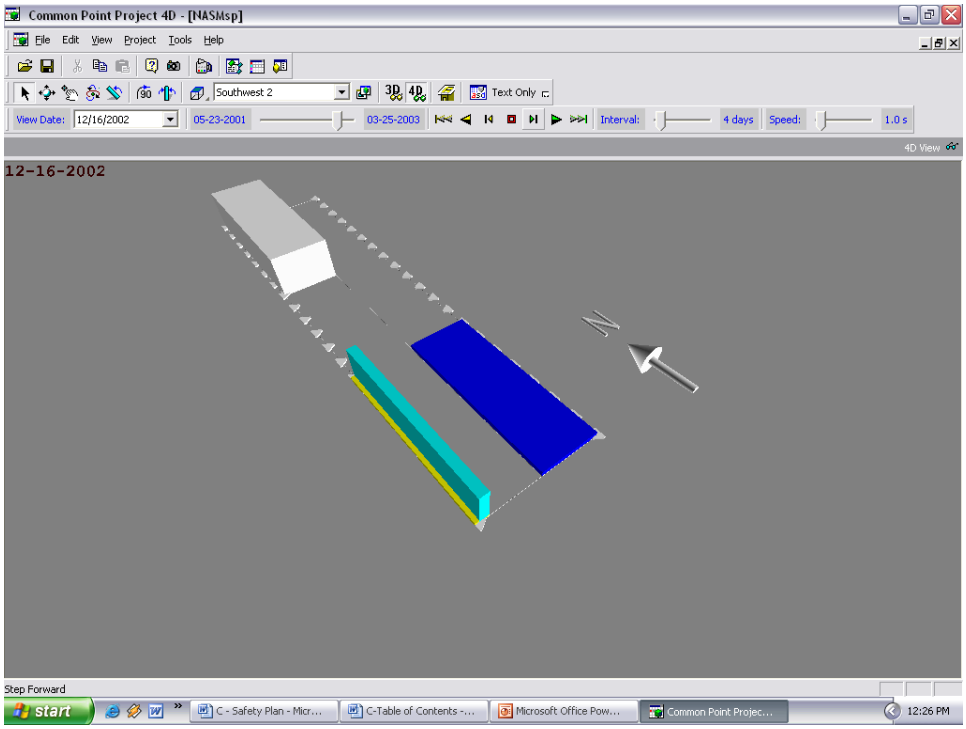
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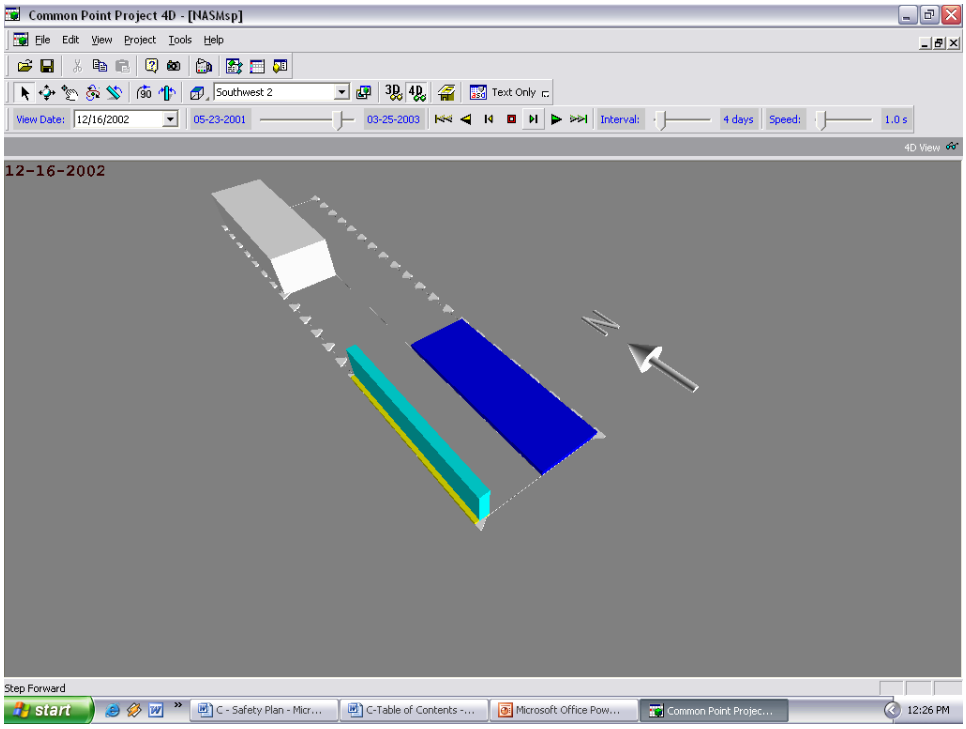
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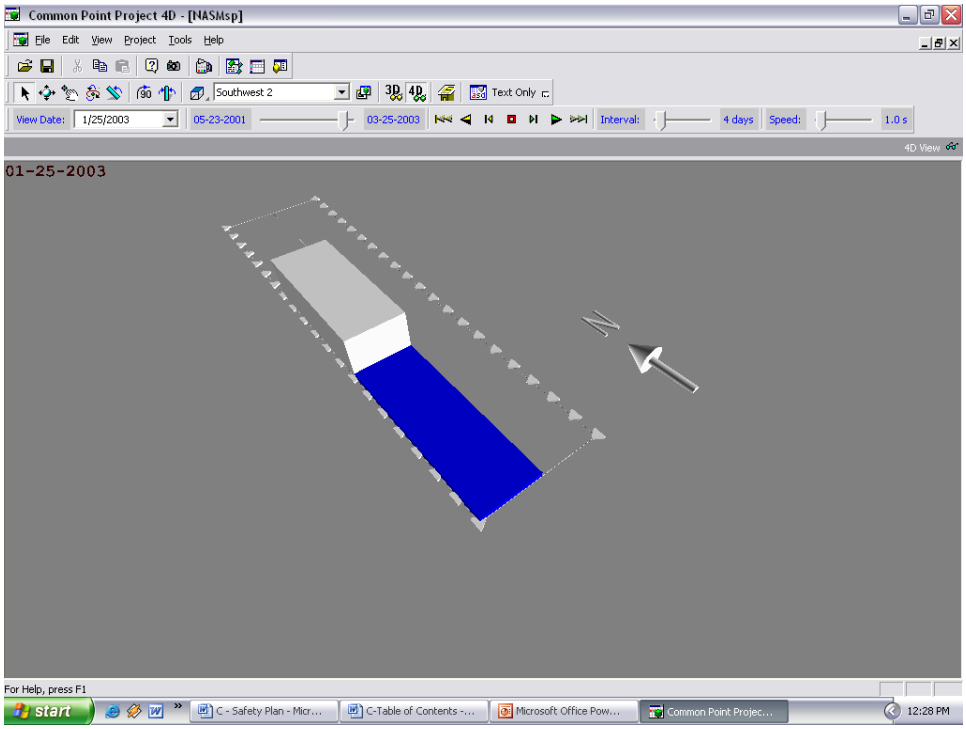
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SAFETY PLAN SCHEDULE

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Concrete B	09-16-2002	09-16-2002	CONSTRUCT	8
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Concrete C	10-15-2002	10-15-2002	CONSTRUCT	9
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Studs 9	11-13-2002	11-13-2002	DEMOLISH	78

United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-023 September 1999

Storm Water Technology Fact Sheet
Porous Pavement

DESCRIPTION

Porous pavement is a special type of pavement that allows rain and snowmelt to pass through it, thereby reducing the runoff from a site and surrounding areas. In addition, porous pavement filters some pollutants from the runoff if maintained.

There are two types of porous pavement: porous asphalt and pervious concrete. Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of specially formulated mixtures of Portland cement, uniform, open-graded coarse aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of liquids through the pavement.

The porous pavement surface is typically placed over a highly permeable layer of open-graded gravel and crushed stone. The void spaces in the aggregate layers act as a storage reservoir for runoff. A filter fabric is placed beneath the gravel and stone layers to screen out fine soil particles. Figure 1 illustrates a common porous asphalt pavement installation.

Two common modifications made in designing porous pavement systems are (1) varying the amount of storage in the stone reservoir beneath the pavement and (2) adding perforated pipes near the top of the reservoir to discharge excess storm water after the reservoir has been filled.

Some municipalities have also added storm water reservoirs (in addition to stone reservoirs) beneath the pavement. These reservoirs should be designed to accommodate runoff from a design storm and should provide for infiltration through the underlying subsoil.

APPLICABILITY

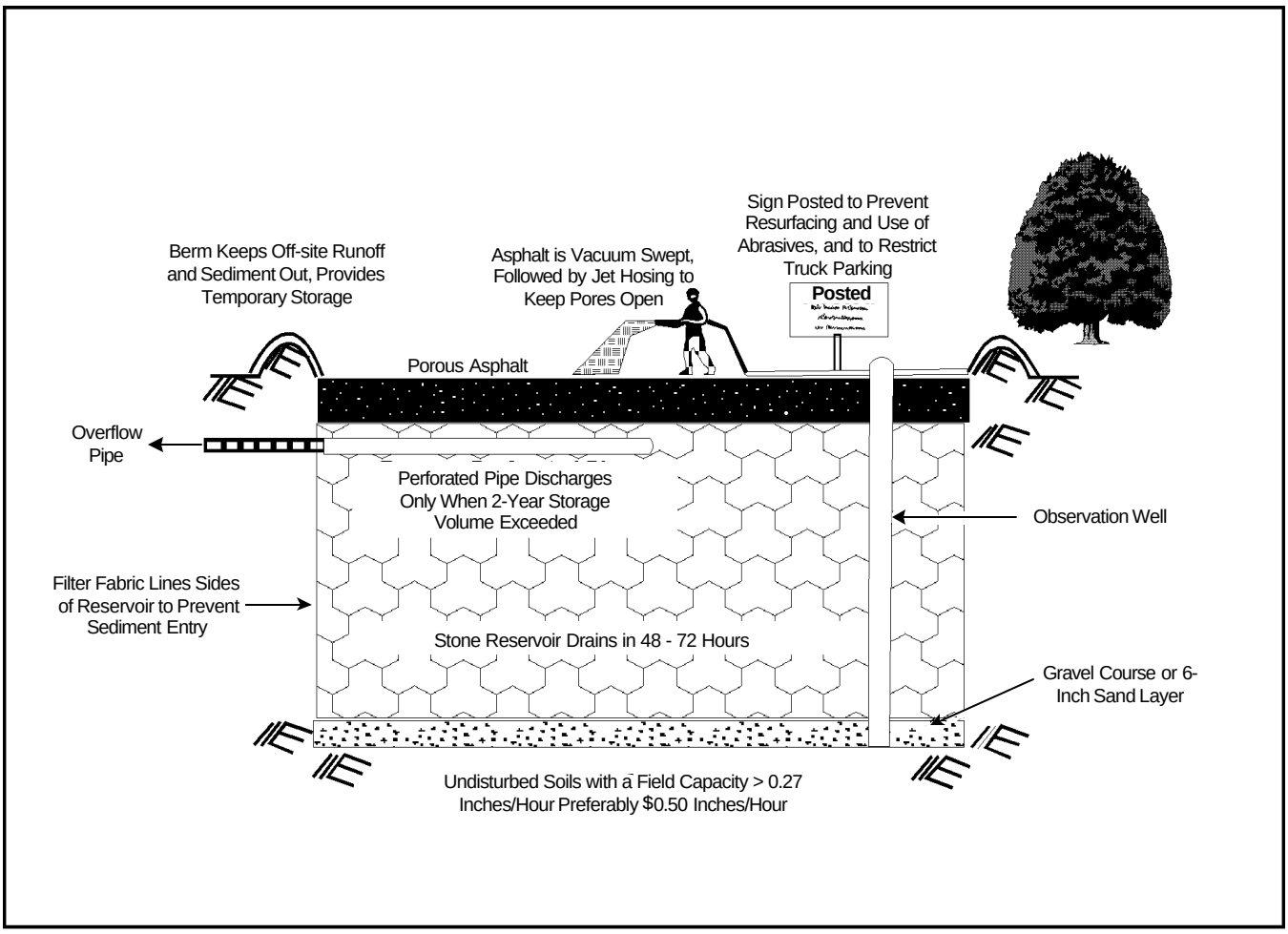
Porous pavement may substitute for conventional pavement on parking areas, areas with light traffic, and the shoulders of airport taxiways a runways, provided that the grades, subsoils, drainage characteristics, and groundwater conditions are suitable. Slopes should be flat or very gentle. Soils should have field-verified permeability rates of greater than 1.3 centimeters (0.5 inches) per hour, and there should be a 1.2 meter (4-foot) minimum clearance from the bottom of the system to bedrock or the water table.

ADVANTAGES AND DISADVANTAGES

The advantages of using porous pavement include:

- Water treatment by pollutant removal.
- Less need for curbing and storm sewers.
- Improved road safety because of better skid resistance.
- Recharge to local aquifers.

The use of porous pavement may be restricted in cold regions, arid regions or regions with high wind erosion rates, and areas of sole-source aquifers. The use of porous pavement is highly constrained, requiring deep permeable soils, restricted traffic, and adjacent land



Source: Modified from MWCOG, 1987.

FIGURE 1 TYPICAL POROUS PAVEMENT INSTALLATION

uses. Some specific disadvantages of porous pavement include the following:

- Many pavement engineers and contractors lack expertise with this technology.
- Porous pavement has a tendency to become clogged if improperly installed or maintained.
- Porous pavement has a high rate of failure.
- There is some risk of contaminating groundwater, depending on soil conditions and aquifer susceptibility.
- Fuel may leak from vehicles and toxic chemicals may leach from asphalt and/or binder surface. Porous pavement systems are not designed to treat these pollutants.
- Some building codes may not allow for its installation.
- Anaerobic conditions may develop in underlying soils if the soils are unable to dry out between storm events. This may impede microbiological decomposition.

As noted above, the use of porous pavement does create risk of groundwater contamination. Pollutants that are not easily trapped, adsorbed, or reduced, such as nitrates and chlorides, may continue to move through the soil profile and into the groundwater, possibly contaminating drinking water supplies. Therefore, until more scientific data is available, it is not advisable to construct porous pavement near groundwater drinking supplies.

In addition to these documented pros and cons of porous pavements, several questions remain regarding their use. These include:

- Whether porous pavement can maintain its porosity over a long period of time, particularly with resurfacing needs and snow removal.
- Whether porous pavement remains capable of removing pollutants after subfreezing weather and snow removal.
- The cost of maintenance and rehabilitation options for restoration of porosity.

DESIGN CRITERIA

Porous pavement - along with other infiltration technologies like infiltration basins and trenches - have demonstrated a short life span. Failures generally have been attributed to poor design, poor construction techniques, subsoils with low permeability, and lack of adequate preventive maintenance. Key design factors that can increase the performance and reduce the risk of failure of porous pavements (and other infiltration technologies) include:

- Site conditions;
- Construction materials; and
- Installation methods.

These factors are discussed further in Table 1.

PERFORMANCE

Porous pavement pollutant removal mechanisms include absorption, straining, and microbiological decomposition in the soil. An estimate of porous pavement pollutant removal efficiency is provided by two long-term monitoring studies conducted in Rockville, MD, and Prince William, VA. These studies indicate removal efficiencies of between 82 and 95 percent for sediment, 65 percent for total phosphorus, and between 80 and 85 percent of total nitrogen. The Rockville, MD, site also indicated high removal rates for zinc, lead, and chemical oxygen demand. Some key factors to increase pollutant removal include:

- Routine vacuum sweeping and high pressure washing (with proper disposal of removed material).
- Drainage time of at least 24 hours.
- Highly permeable soils.
- Pretreatment of runoff from site.
- Organic matter in subsoils.
- Clean-washed aggregate.

Traditionally, porous pavement sites have had a high failure rate - approximately 75 percent. Failure has been attributed to poor design, inadequate construction techniques, soils with low permeability, heavy vehicular traffic, and resurfacing with nonporous pavement materials. Factors enhancing longevity include:

- Vacuum sweeping and high-pressure washing.
- Use in low-intensity parking areas.
- Restrictions on use by heavy vehicles.
- Limited use of de-icing chemicals and sand.
- Resurfacing.
- Inspection and enforcement of specifications during construction.
- Pretreatment of runoff from offsite.
- Implementation of a stringent sediment control plan.

OPERATION AND MAINTENANCE

Porous pavements need to be maintained. Maintenance should include vacuum sweeping at least four times a year (with proper disposal of

TABLE 1 DESIGN CRITERIA FOR POROUS PAVEMENTS

Design Criterion	Guidelines
Site Evaluation	• Take soil boring to a depth of at least 1.2 meters (4 feet) below bottom of stone reservoir to check for soil permeability, porosity, depth of seasonally high water table, and depth to bedrock.
	• Not recommended on slopes greater than 5 percent and best with slopes as flat as possible.
	• Minimum infiltration rate 0.9 meters (3 feet) below bottom of stone reservoir: 1.3 centimeters (0.5 inches) per hour.
	• Minimum depth to bedrock and seasonally high water table: 1.2 meters (4 feet).
	• Minimum setback from water supply wells: 30 meters (100 feet).
	• Minimum setback from building foundations: 3 meters (10 feet) downgradient, 30 meters (100 feet) upgradient.
	• Not recommended in areas where wind erosion supplies significant amounts of windblown sediment.
	• Drainage area should be less than 6.1 hectares (15 acres).
Traffic conditions	• Use for low-volume automobile parking areas and lightly used access roads.
	• Avoid moderate to high traffic areas and significant truck traffic.
	• Avoid snow removal operations; post with signs to restrict the use of sand, salt, and other deicing chemicals typically associated with snow cleaning activities.
Design Storm Storage Volume	• Highly variable; depends upon regulatory requirements. Typically design for storm water runoff volume produced in the tributary watershed by the 6-month, 24-hour duration storm event.
Drainage Time for Design Storm	• Minimum: 12 hours.
	• Maximum: 72 hours.
	• Recommended: 24 hours.
Construction	• Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction.
	• As needed, divert storm water runoff away from planned pavement area before and during construction.
	• A typical porous pavement cross-section consists of the following layers: 1) porous asphalt course, 5-10 centimeters (2-4 inches) thick; 2) filter aggregate course; 3) reservoir course of 4-8 centimeters (1.5-3-inch) diameter stone; and 4) filter fabric.
Porous Pavement Placement	• Paving temperature: 240° - 260° F.
	• Minimum air temperature: 50° F.
	• Compact with one or two passes of a 10,000-kilogram (10-ton) roller.
	• Prevent any vehicular traffic on pavement for at least two days.
Pretreatment	• Pretreatment recommended to treat runoff from off-site areas. For example, place a 7.6-meter (25-foot) wide vegetative filter strip around the perimeter of the porous pavement where drainage flows onto the pavement surface.

removed material), followed by high-pressure hosing to free pores in the top layer from clogging. Potholes and cracks can be filled with patching mixes unless more than 10 percent of the surface area needs repair. Spot-clogging may be fixed by drilling 1.3 centimeter (half-inch) holes through the porous pavement layer every few feet.

The pavement should be inspected several times during the first few months following installation and annually thereafter. Annual inspections should take place after large storms, when puddles will make any clogging obvious. The condition of adjacent pretreatment devices should also be inspected.

COSTS

The costs associated with developing a porous pavement system are illustrated in Table 2.

Estimated costs for an average annual maintenance program of a porous pavement parking lot are approximately $4,942 per hectare per year ($200 per acre per year). This cost assumes four inspections each year with appropriate jet hosing and vacuum sweeping treatments.

REFERENCES

1. Field, R., et al., 1982. "An Overview of Porous Pavement Research." *Water Resources Bulletin*, Volume 18, No. 2, pp. 265-267.

2. Metropolitan Washington Council of Governments, 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*.

3. Metropolitan Washington Council of Governments, 1992. *A Current Assessment of Best Management Practices: Techniques for Reducing Nonpoint Source Pollution in a Coastal Zone*.

4. Southeastern Wisconsin Regional Planning Commission, 1991. *Costs of Urban Nonpoint Source Water Pollution Control Measures*, Technical Report No. 31.

5. U.S. EPA, 1981. *Best Management Practices Implementation Manual*.

TABLE 2 ESTIMATED COSTS FOR A POROUS PAVEMENT SYSTEM

Component	Unit Cost	Total
Excavation Costs	740 cy X $5.00/cy	$3,700
Filter Aggregate/Stone Fill	740 cy X $20.00/cy	$14,800
Filter Fabric	760 sy X $3.00/cy	$2,280
Porous Pavement	556 sy X $13.00/sy	$7,228
Overflow Pipes	200 ft X $12.00/ft	$2,400
Observation Well	1 at $200 each	$200
Grass Buffer	822 sy X $1.50/sy	$1,250
Erosion Control	$1000	$1,000
Subtotal		$32,858
Contingencies (Engineering, Administration, etc.)	25%	$8,215
Total		$41,073

6. U.S. EPA, 1992. *Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices*. EPA 833-R-92-006.

7. Washington State Department of Ecology, 1992. *Stormwater Management Manual for the Puget Sound Basin*.

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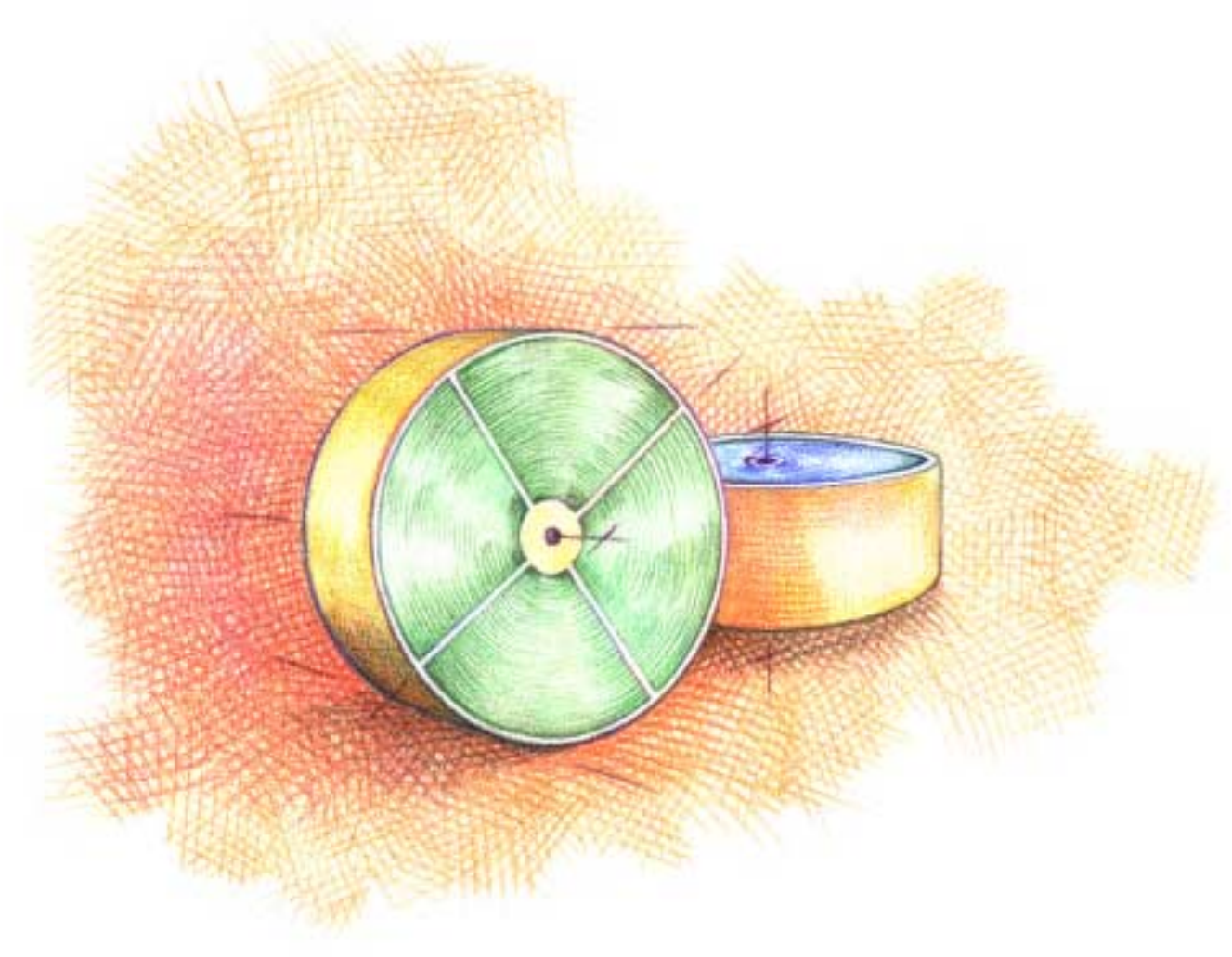
Energy Recovery Wheel



Technical Guide

Table of Contents

Introduction

This design manual presents the SEMCO EXCLU-SIEVE® total energy (TE3) and sensible only (TS) recovery wheels. It explains features and benefits provided by this technology, provides a detailed selection procedure and reviews specific guidelines to assure an effective system design. This material should be reviewed carefully before beginning the design process.

Please contact your local SEMCO sales representative for additional design support or to answer any technical questions which go beyond the scope of this brochure. You will find a listing of SEMCO sales representatives on our website. Please point your browser to www.semcoinc.com. You can reach SEMCO Incorportaed on our toll free line at 888-473-6264.

The Ventilation Mandate

ASHRAE Standard 62-1999, Ventilation for Acceptable Indoor Air Quality, defines the minimum outdoor air ventilation rates required to achieve acceptable indoor air quality. This standard, which is referenced in part or whole by all building codes in the United States, recommends that outdoor air quantities be increased from 5 cfm per person to 20 cfm per person (in an office environment) to avoid adverse health effects. Although most owners, architects and engineers recognize the benefits of bringing in more outdoor air, many are concerned about the impact on equipment and operating costs.

EXCLU-SIEVE® provides the solution to the ASHRAE 62-1999 mandate. It precools and dehumidifies the outdoor air during the cooling season and preheats and humidifies the outdoor air during the heating season. As a result, the outdoor air quantity can be increased from 5 to 20 cfm per person without increasing energy costs.

As importantly, the first cost savings associated with the reduction in chiller and heating/humidification capacity typically pay for the added cost associated with the installation of the total energy recovery equipment.

As shown in Figure 1, significant reductions in the heating/cooling plant capacity can be recognized through the application of total energy recovery.

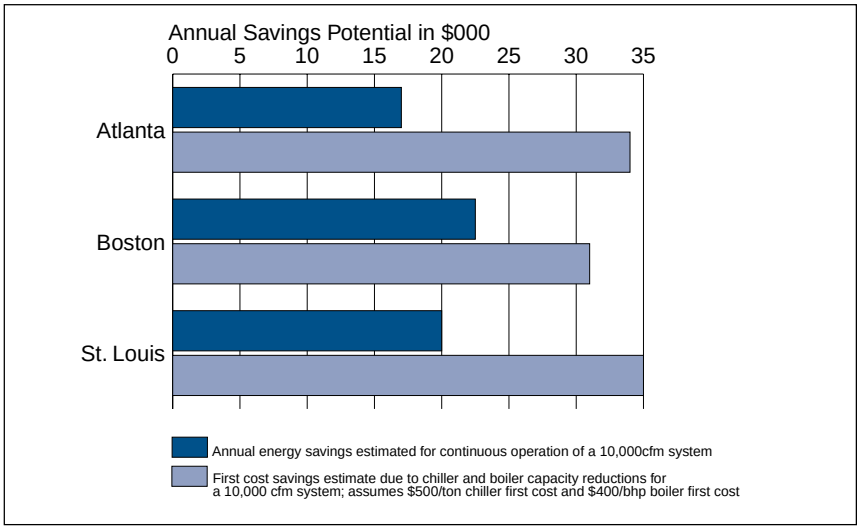


Figure 1. *Savings potential with EXCLU-SIEVE® technology when increasing the ventilation air amount from 5 cfm/person to 20 cfm/person.*

Typical Applications

Energy recovery equipment can be applied to a wide variety of applications:

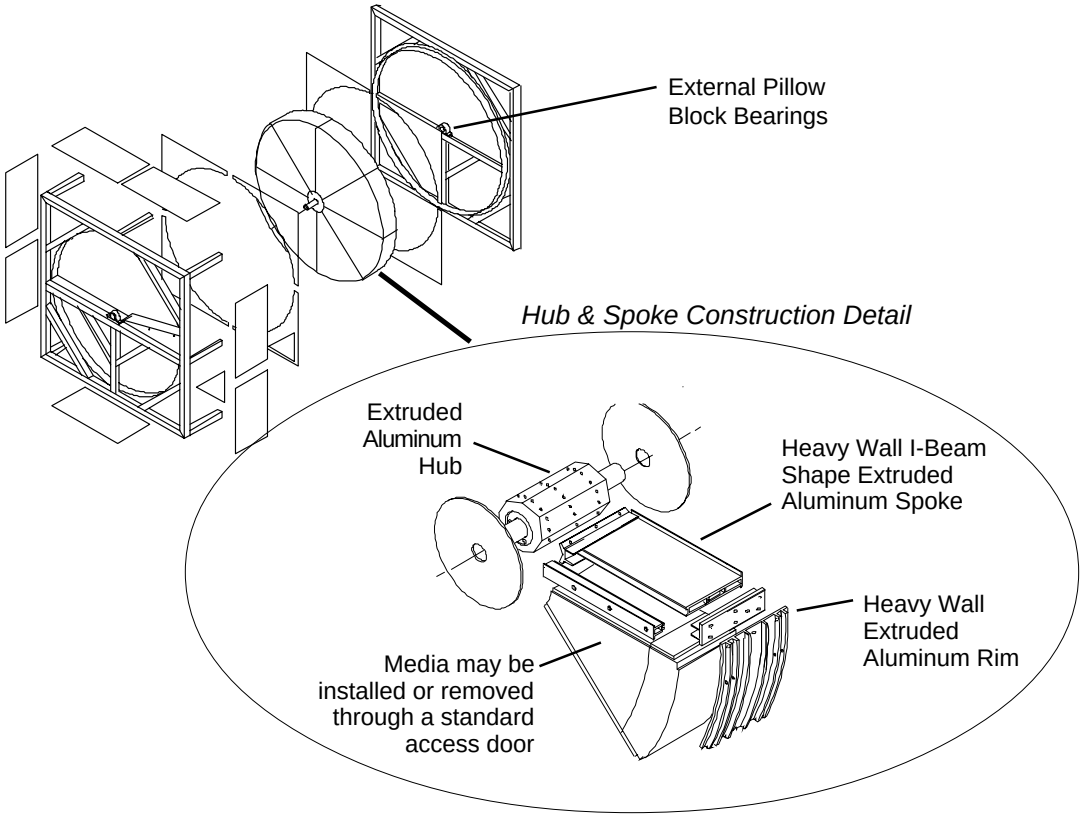
- Schools, universities, dormitories;
- offices, condominiums, apartments;
- smoking lounges, casinos;
- hospitals, nursing homes, day care centers;
- hotels, motels, department stores;
- clean rooms, circuit board, chip manufacturing;
- breweries;
- swimming pools, sports arenas;
- convention centers, airports, prisons;
- bus and train maintenance facilities;
- welding, foundry, casting areas;
- printing operations;
- all humidity controlled spaces; and
- product drying operations.

Benefits

The SEMCO EXCLU-SIEVE® technology affords a number of benefits:

- Independently certified wheel performance.
- Equal latent and sensible heat transfer.
- Highest effectiveness for given size equipment.
- Virtually no cross-contamination (independently certified to be less than 0.04 percent).
- Field adjustable purge section.
- Wheel independently certified to pass NFPA 90A requirements for flame spread and smoke generation based upon ASTM E84 fire test method.
- Reliable operation.
- Low maintenance.
- Low operating costs.
- Long life expectancy.
- Can be applied where stationary heat exchangers cannot.

Design Features



Recovery Effectiveness (in %)		
Velocity (fpm)	EXCLU-SIEVE®	Competition
400	86.0	81.0
600	80.5	75.5
800	77.0	70.5
1000	74.5	66.0
Pressure Loss (in in. w.g.)		
Velocity (fpm)	EXCLU-SIEVE®	Competition
400	0.37	0.45
600	0.56	0.66
800	0.79	0.89
1000	1.05	1.15

Table 1. Comparison of SEMCO's EXCLU-SIEVE® wheel performance with published data by competitors.

Superior Certified Performance Allows Compact Design

The performance data published for the EXCLU-SIEVE® Energy Wheel is independently certified in accordance with ASHRAE 84-78P and is far superior to all other air-to-air energy recovery systems.

A unique flute design, coupled with numerous other design innovations, provides for the highest possible heat transfer characteristics while simultaneously reducing pressure loss parameters. These combined features optimize the "sensible" (temperature) recovery portion of the performance.

Providing "latent" (moisture) recovery efficiencies that match the improved sensible values is made possible by EXCLU-SIEVE®'s 3Å molecular sieve desiccant coating. The "rate of adsorption" by this transfer surface is more than twice that of other desiccants. This allows for effective moisture transfer from the high velocity airstreams inherent in energy recovery applications.

EXCLU-SIEVE®'s performance advantage is best shown by the comparison chart in Table 1. Notice that EXCLU-SIEVE® has a better performance than the competition for a given face velocity. The higher effectiveness at a lower pressure drop maximizes savings.

3Å Molecular Sieve Desiccant Coating

The EXCLU-SIEVE® wheel utilizes a 3Å molecular sieve desiccant coating to limit the risk of desiccant cross-contamination which would otherwise cause a portion of the exhaust air pollutants to be transferred, along with the water vapor, to the fresh airstream.

The 3Å molecular sieve material utilized by SEMCO was developed specifically for "selective adsorption" and has been successfully used for decades by the petrochemical industry. Other desiccants like silica gel and oxidized aluminum cannot provide selective adsorption.

Molecular sieves are structurally stable, chemically inert and have a strong affinity for water vapor. This strong affinity for water vapor produces the high rate of adsorption which provides superior latent transfer performance.

Non-oxidized Coated Media Construction

The EXCLU-SIEVE® media is made from aluminum which is evenly coated, prior to being formed into its honeycomb configuration, with a dense layer of corrosion resistant desiccant. This extends the life of the aluminum media substrate and enhances its structural integrity. This is in sharp contrast to most other total energy wheels which are produced by oxidizing the surface of the aluminum substrate to form a crude desiccant which leaves the product susceptible to further oxidation and diminishes its structural integrity.

Modular Media Sections with Aluminum Spoke Support System

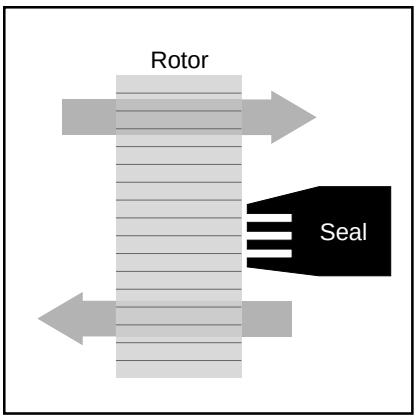
The media support system is made from aluminum extrusions. This provides the substantial structural backbone required to withstand the forces encountered during a wheel's 10,000,000 annual revolutions (assuming continuous operation).

The use of aluminum drastically reduces the weight of the rotor when compared to a steel support system. The result is a more evenly balanced rotor which reduces wear and tear on the drive system and bearings.

The tolerances obtainable from an extruded media support structure allow for the flattest possible sealing surface. This adds significantly to the integrity of the total sealing system.

Service Free Drive and Control System

A responsive and maintenance-free drive system is an integral part of any rotary heat exchanger. The drive system standard with any EXCLU-SIEVE® unit is an AC constant or variable speed system with drive belts.



Air flowing between the rotor and labyrinth seal expands repeatedly, creating a pressure loss that forms an effective seal and prevents air from bypassing the rotor. The labyrinth seal never touches the rotor.

Non-wearing Extruded Labyrinth Seals

EXCLU-SIEVE® utilizes a four pass labyrinth seal which has been designed to give optimum performance under the pressure conditions encountered in this application. Since the seals never actually touch the rotating surface, their life is indefinite. All seals are easily field adjustable. This efficient sealing system increases performance and virtually eliminates carryover of contaminants from the return airstream to the supply airstream.

Tubular Steel Casing Construction

To avoid deflection of the energy wheel casing due to the significant torque imposed by the air pressure on the energy wheel surface, a tubular steel framework is used. Casing deflection is undesired since it increases the gap between the seals and the wheel surface causing excessive air leakage.

Built-in Bearing Replacement System

The bearings used in the EXCLU-SIEVE® units provide a long life with minimal maintenance. The external pillow block bearings simplify any replacements should this ever become necessary. The rotor remains in the casing and none of the rotor or media has to be removed.

Optional Extended Service Contract

The EXCLU-SIEVE® units are designed to provide long and reliable operation. As a statement of our commitment to quality, the EXCLU-SIEVE® wheels are available with an optional extended service contract to cover any unforeseen mechanical deficiencies or performance degradations. The coverage period can be as long as five years.

Complete details can be obtained from your local SEMCO sales representative.

Recovering "Total Energy"

SEMCO EXCLU-SIEVE® enthalpy exchanger recovers both sensible (temperature) and latent (moisture) energy, and does so far more effectively than other competitive offerings.

This performance edge is a result of EXCLU-SIEVE®'s unique transfer core. This "honeycomb like" media utilizes an aluminum substrate coated with a fast-acting, 3Å molecular sieve desiccant.
As the transfer core slowly rotates between the outdoor and return airstream, the higher temperature air stream gives up its sensible energy to the aluminum. This energy is then transferred to the cooler airstream during the second half of the revolution.

Just as the temperature is captured and released, so is the moisture (latent energy.) This is accomplished by the desiccant coating of the wheel. The desiccant has a very strong affinity for water and an enormous internal surface area to bind the water on its surface. Since the opposing airstreams have different temperatures and moisture contents, their vapor pressures on their surfaces differ. This vapor pressure differential is the driving force necessary for the transfer of water vapor (See *Figure 2*.)

The ability to recover latent energy is one of the major benefits of SEMCO's EXCLU-SIEVE® technology. It will do this both in the cooling and the heating season. During the cooling season the outdoor air is dehumidified and precooled. (See *Figure 2*.) This significantly reduces the cooling requirements of the conditioned space. In the heating season, the process reverses and the outdoor air is humidified and preheated. This reduces the costly humidification of ventilation air as well as the heating requirements of the indoor space.

Latent recovery doubles the energy savings potential recognized with the use of the sensible-only technology. It allows for cuts in chiller and boiler capacities. System designs incorporating total energy recovery are first cost equivalent to conventional designs when achieving the same ventilation requirements and supply air conditions. In addition, they provide operating cost savings year-in and year-out.

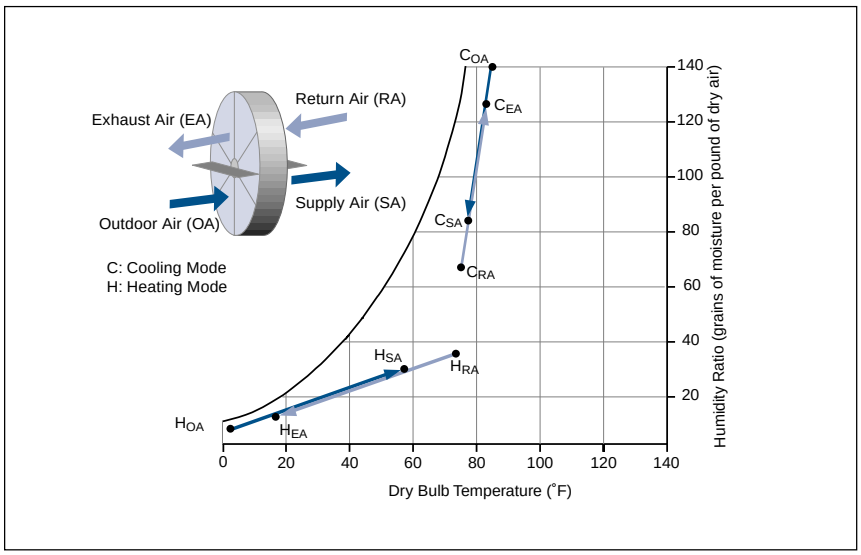


Figure 2. *Typical operating conditions encountered in the cooling and heating mode of a total energy recovery unit.*

Recovering "Sensible Only"

The SEMCO TS series of sensible only energy wheels is specifically designed to recover temperature only. The transfer media is not desiccant coated but is polymer coated to avoid oxidation over time. Oxidation reduces the structural integrity of the media over time and can also cause modest latent transfer which is usually undesirable in sensible only applications (please see “Sensible Wheel Applications” on page 23 of this brochure).

As shown in *Figure 3*, the airstreams entering and leaving the sensible only wheel are heated or cooled. Since no latent recovery is accomplished, the moisture content of each airstream remains the same. A comparison of the processes in *Figures 2 and 3* reveals two key advantages offered by total energy recovery. First, the total energy wheel recovers far more energy due to the latent component. Second, the sensible wheel will approach moisture saturation far more easily in the heating mode. This can cause frost formation.

For these reasons, sensible wheels should only be used in applications where moisture transfer is undesirable. Examples of such applications include indirect evaporative cooling systems, desiccant cooling systems and reheat wheels as used in the SEMCO Fresh Air Dehumidification systems.

In every other way the SEMCO TS wheel is similar to the EXCLU-SIEVE® wheel and shares the benefits of superior performance and compact design.

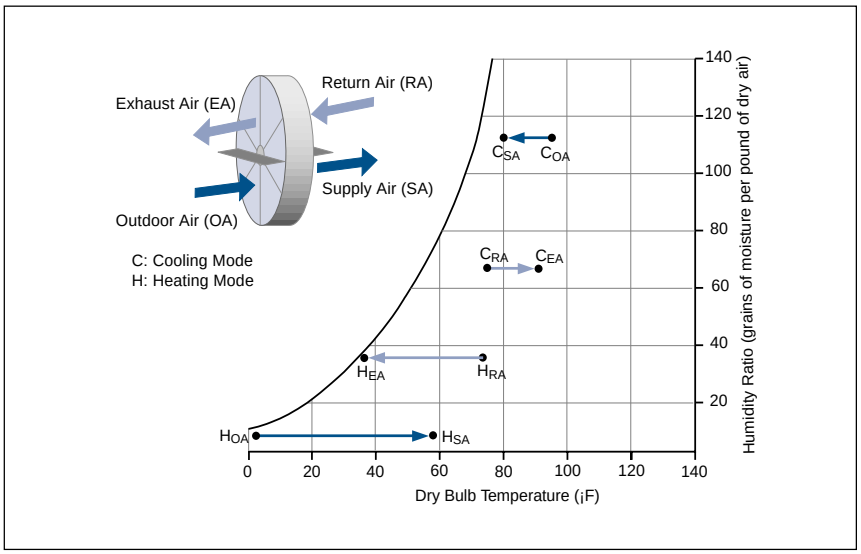


Figure 3. *Typical operating conditions encountered in the cooling and heating mode of a sensible only energy recovery unit.*

Unit Selection

1 Wheel Selection

Wheel selection is based on face velocity. The energy recovery wheel has been optimized for a face velocity of about 800. This achieves the best balance between energy recovery effectiveness, pressure loss and first cost.

Using the EXCLU-SIEVE® Performance Chart (See *Figure 4*), find the desired airflow volume on the left hand margin of the performance chart. Selection is always based on the smaller of the supply or return airflow when using unequal airflows. Read across until intersecting the appropriate EXCLU-SIEVE® TE3 model number, then read down to obtain the face velocity. Reading down the chart further will give the associated pressure loss for this face velocity. This procedure must be repeated at the larger airflow volume to determine the pressure loss for the opposite airstream in unequal flow applications.

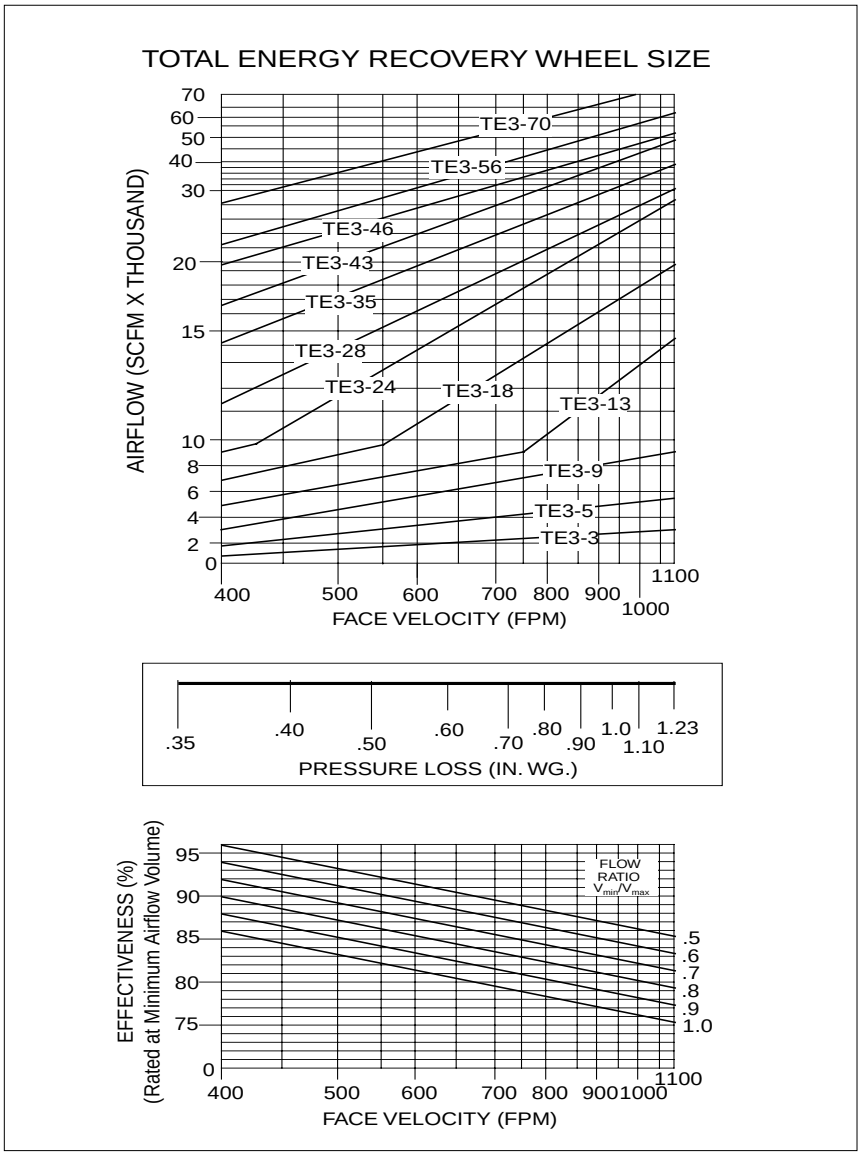


Figure 4. *Performance charts for TE3 Series Total Energy Recovery Wheels.*

2 Unit Effectiveness

To calculate the supply and exhaust air conditions leaving the module, the ASHRAE defined "unit effectiveness" must be determined as shown in *Figure 5*.

Since the supply and exhaust air quantities often differ, the unit effectiveness and the airflow ratio must be used in order to find the efficiency (the amount of temperature or moisture transferred) for both the supply and return airstreams.

Figure 5. *Definition of exchanger heat transfer effectiveness.*

The exchanger heat transfer effectiveness ε is defined as the amount of energy recovered, e.g. sensible or latent, divided by the maximum amount of energy that could theoratically be recovered.

The supply air volume heat transfer effectiveness ε_S is defined as

$$\varepsilon_S = \frac{V_s (X_1 - X_2)}{V_{min} (X_1 - X_3)}$$

The return air volume heat transfer effectiveness ε_r is defined as

$$\varepsilon_r = \frac{V_r (X_4 - X_3)}{V_{min} (X_1 - X_3)}$$

Based on the above definitions, the supply air condition X_2 can be calculated from

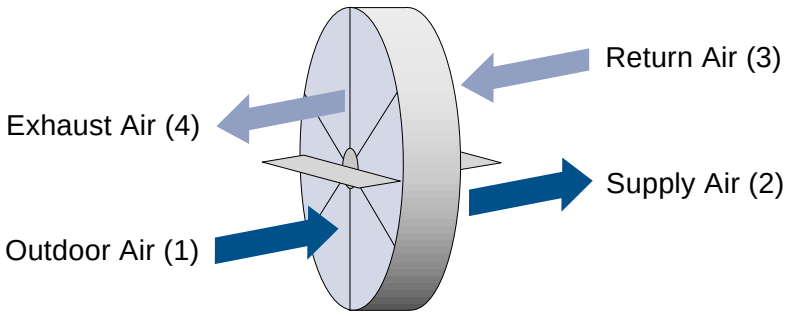
$$X_2 = X_1 - \varepsilon_S \frac{V_{min}}{V_s} (X_1 - X_3)$$

and the exhaust air condition X_3 can be calculated from

$$X_4 = X_3 + \varepsilon_S \frac{V_{min}}{V_r} (X_1 - X_3)$$

where V_S = Supply air volume, scfm
V_r = Return air volume, scfm
$V_{min} = V_r$ if V_r is smaller than V_S or $V_{min} = V_S$ if V_S is smaller than V_r
X = dry bulb temperture (¡F) or moisture content (gr/lb) or enthalpy (Btu/lb)

The indices refer to the following air streams, as indicated in the figure below:
1 = Outdoor air condition
2 = Supply air condition
3 = Return air condition
4 = Exhaust air condition



3 Unit Performance

Once the unit effectiveness is known, the equations provided by *Figure 5* are used to calculate the dry bulb temperature (T_{db}), moisture content (w) and enthalpy (h) conditions leaving the exchanger.

NOTE: Wet bulb temperatures cannot be substituted for grains or pounds of moisture per pound of dry air.

Exhaust Air Conditions

In most cases, the supply air leaving condition (as shown above) will be required for both the heating and cooling modes. In many cases, the exhaust air conditions must be calculated as well. This is required for applications in colder climates, where ambient temperatures fall below 15°F and where condensation and frost may form. (See *page 19, "Avoiding Frost and Condensation"*.)

4 Purge Volume

A purge section is utilized to avoid carry-over of exhaust air into the supply airstream. A small portion of outdoor air, in addition to that required for space conditioning, is required for purge operation. *Figure 8 on page 15* will provide the quantity of purge air required by your application. This air volume must be added to the capacity of the appropriate system fan(s) as shown by *Figure 9* (indicated as Vp).

5 Chiller & Boiler Reduction

The SEMCO total energy recovery wheel reduces the energy required to heat, cool and humidify the outdoor air volume to the return air condition by as much as 90 percent. This results from its ability to recover both latent and sensible energy at unprecedented efficiency levels.

This reduction in required chiller and/or boiler capacity should be carefully evaluated when making final unit selections since even a modest cut in the mechanical plant will offset the cost of the SEMCO total energy recovery wheel.

Utilizing the equations provided below, the potential chiller and boiler reduction can be estimated as follows.

$$\text{Chiller Capacity} = \{\text{supply air volume}\}\,(\,\text{Enthalpy}_{IN} - \text{Enthalpy}_{OUT}\,)\,\frac{4.5}{12{,}000}\ \text{in tons of cooling}$$

$$\text{Boiler Capacity} = \{\text{supply air volume}\}\,(\,\text{Enthalpy}_{IN} - \text{Enthalpy}_{OUT}\,)\,\frac{4.5}{33{,}000}\ \text{in boiler horse power}$$

The actual reduction made in the mechanical plant capacity, as compared to the potential reduction as determined above, will change from project to project. Factors such as weather data, hours of operation and multiple modules on the project and the need for redundant capacity must be carefully considered.

Unit Selection Example

Consider an example with design conditions presented in Table 2. This design data is the 0.4 percent wet bulb/mean coincident dry bulb data for St. Louis, Missouri as published in the ASHRAE 1997 Fundamentals Handbook, page 26.15.

Table 2. Example wheel selection design data.

Design Data	Cooling		Heating	
Supply Air Flow	12,000	scfm	12,000	scfm
Return Air Flow	10,800	scfm	10,800	scfm
Outdoor Air Conditions:				
Temperature	90	°F	2	°F
Moisture Content	133	gr/lb	4	gr/lb
Enthalpy	45.2	Btu/lb	1.1	Btu/lb
Return Air Conditions:				
Temperature	75	°F	70	°F
Moisture Content	64	gr/lb	43	gr/lb
Enthalpy	28.0	Btu/	23.5	Btu/lb
Purge Pressure Difference	3.0	in. w.g.	3.0	in. w.g.

1 Wheel Selection

Wheel selection is based on face velocity and the smaller of the return or supply airflow rates. Based on the return airflow rate of 10,800 scfm, the initial wheel size selected is TE3-13.

Figure 6 shows the basic selection procedure using the performance chart. The first step is to find the return airflow volume value of 10.8 (corresponding to 10,800 scfm). Drawing a straight line across the graph, we find that a TE3-13 wheel is sized for the optimal velocity between 700 and 900 fpm. Drawing a straight line from the intersection of the 10.8 line and the TE3-13 performance line, we read an approximate velocity of 840 fpm through the wheel.

We can check this value by calculating it from the dimensional data table on page 28. The flow area per face of the TE3-13 wheel is listed to be 13.1 ft^2. Thus, the return air volume of 10,800 scfm provides a face velocity of 10,800 / 13.1 = 840 ft/min.

By extending the line from the face velocity axis to the pressure loss scale, we find the pressure loss to be about 0.87 in.wg.

2 Determine Effectiveness

To determine unit effectiveness, we first calculate the airflow ratio. This is the smaller of the supply or return air volumes divided by the larger of the two. In this example, the airflow ratio is 10,800 / 12,000 or 0.9.

Once again, using the minimum airflow quantity, enter the performance chart (See *Figure 6*), traverse to the right until intersecting the desired model number, then read down until reaching the appropriate

airflow ratio curve. Finally, traverse left until intersecting the result unit effectiveness value. For our example, the unit effectiveness is approximately 0.8.

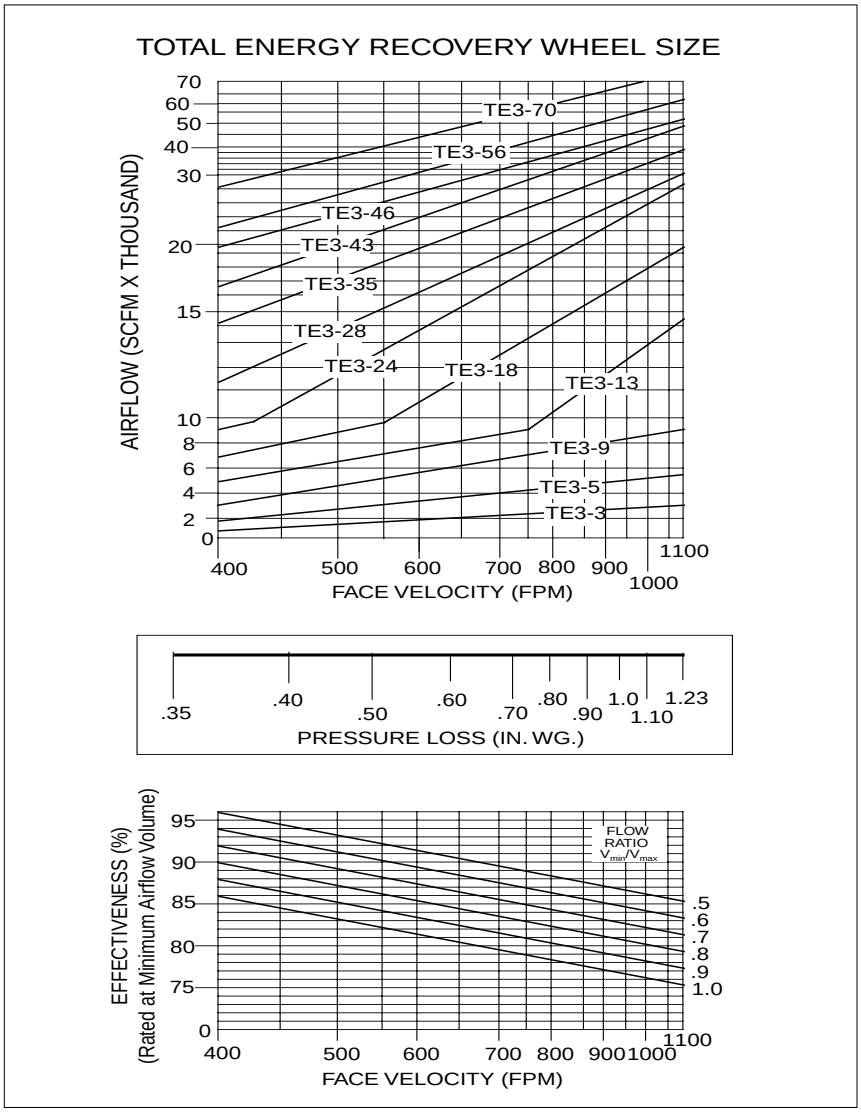


Figure 6. *Using the EXCLU-SIEVE® performanace chart to select wheel size and determine pressure drop and wheel effectiveness.*

3 Calculate Performance

Having determined the unit effectiveness to be 0.8, we can now calculate the supply air conditions for our example:

Supply Air Condition: Cooling Mode
$X(T_{db})_2$ = 90°F - [.80 (10,800/12,000) (90°F - 75°F)]
$X(T_{db})_2$ = dry bulb temperature = 79.2 °F

$X(w)_2$ = 133 gr/lb. - [.80 (10,800/12,000) (133 - 64)]
$X(w)_2$ = humidity ratio = 83.3 gr/lb

$X(h)_2$ = 43.5 Btu/lb - [.80 (10,800/12,000) (43.5 - 28.0)]
$X(h)_2$ = enthalpy = 32.3 Btu/lb

Supply Air Condition: Heating Mode

$X(T_{db})_2$ = 2°F - [.80 (10,800/12,000) (2°F - 70°F)]
$X(T_{db})_2$ = dry bulb temperature = 51.0 °F

$X(w)_2$ = 4 gr/lb - [.80 (10,800/12,000) (4 - 43) gr/lb]
$X(w)_2$ = humidity ratio = 32.1 gr/lb

$X(h)_2$ = 1.1 Btu/lb - [.80 (10,800/12,000) (1.1 - 23.5)]
$X(h)_2$ = enthalpy = 17.2 Btu/lb

4 Determine Purge Volume

From Table 2 we know that the purge pressure difference is 3 in.wg. Using the procedure described on *page 15 and Figure 8*, we estimate the purge volume to be about 1,100 scfm.

5 Potential Chiller and Boiler Reduction

C = [12,000 scfm x 4.5 x (43.5 - 32.3) Btu/lb]/12,000 btu/ton
C = Chiller reduction capacity = 50.4 tons

B = [12,000 scfm x 4.5 x (17.2 - 1.1) btu/lb]/33,000 btu/bhp
B = Boiler reduction capacity = 26.4 boiler h.p.

Table 3 summarizes the results of our example.

Table 3. Calculated results of the EXCLU-SIEVE® wheel selection example.

Calculacted Design Data	Cooling	Heating
EXCLU-SIEVE® Model	TE3-13	
Outdoor Air Face Velocity	1000 fpm	1000 fpm
Return Air Face Velocity	840 fpm	840 fpm
Unit Effectiveness	.80	.80
Supply Air Condition Dry Bulb Temperature Moisture Content Enthalpy	 79.2 °F 83.3 gr/lb 32.3 Btu/lb	 51.0 °F 32.1 gr/lb 17.2 Btu/lb
Exhaust Air Condition Dry Bulb Temperature Moisture Content	 85.8 °F 100 gr/lb	 21.0 °F 22.8 gr/lb
Supply Air Pressure Loss	1.0 in.wg.	1.0 in.wg.
Return Air Pressure Loss	.88 in.wg.	.88 in.wg.
Purge & Seal Volume	1,100 cfm	1,100 cfm
Purge Angle	2°	2°

Purge Section

Operation

As energy recovery wheel rotates from the exhaust airstream into the supply airstream, a small amount of the exhaust air is traversing the flutes of the wheel media as it passes by the seal separating the two airstreams. If this volume of exhaust air were allowed to mix with the clean supply airstream, “cross-contamination” would occur.

Cross-contamination is virtually eliminated by a “purge section”, which is an integral part of the casing design. The purge section utilizes the pressure difference which exists between the outdoor and return airstreams to “purge” the transfer media with clean outdoor air prior to its rotation into the supply airstream. *Figure 7* provides a graphic representation of the purge section operation.

The purge section is adjustable. This allows for optimizing the required purge volume during system startup, regardless of the pressure difference between the outdoor and return airstreams (provided that the return air pressure is lower than that of the outdoor air).

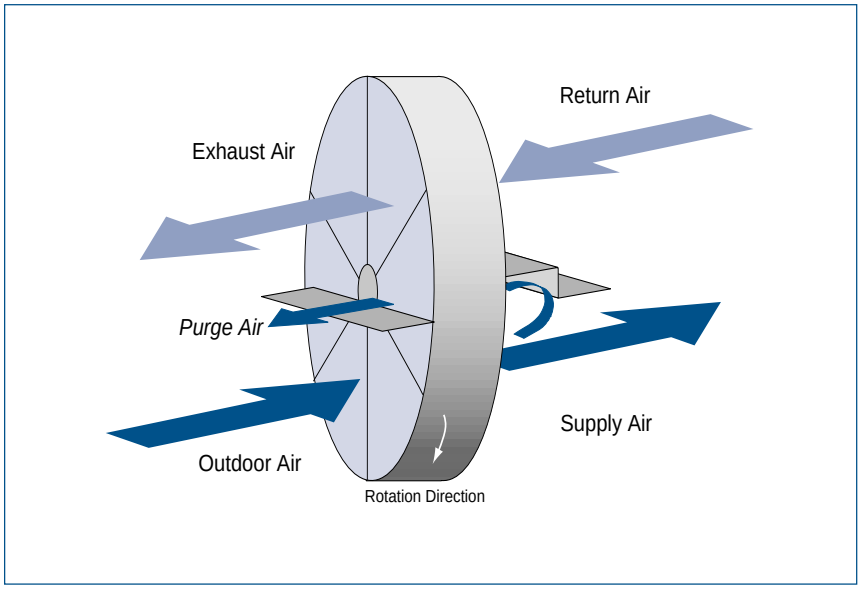


Figure 7. *Schematic of the purge operation.*

Selection

The required purge volume is determined by using the chart provided in *Figure 8*.

First, the wheel size and the estimated pressure difference between the outdoor and return airstream is determined. Traverse upward until intersecting the appropriate wheel size. Reading to the left at the intersection provides the air volume required for purge and seal leakage.

After determining the difference between the return and outdoor pressures, use *Table 4* to determine the correct purge index.

Figure 8. *Chart to determine required purge volume and corresponding purge index.*

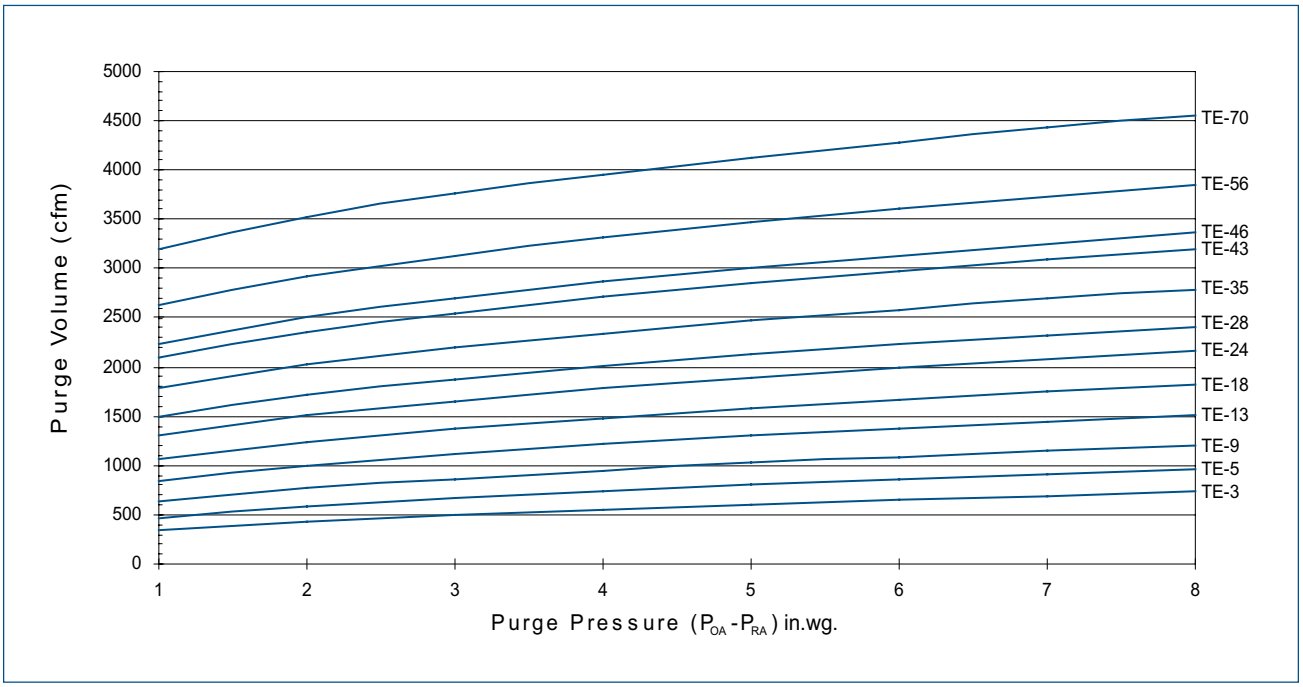


Table 4. Relationship between pressure difference and purge index.

Pressure Difference Range (in.wg.)	Purge Index Setting
0.00 - 0.99	Consult SEMCO
1.0 - 1.5	6
1.6 - 2.0	5
2.1 - 3.0	4
3.1 - 6.0	3
6.1 - 10.0	2
> 10.0	1

Fan Location Options

To assure effective purge operation and limit cross-contamination, the pressure of the return airstream must be lower than that of the outdoor airstream. As shown in *Figure 9*, three fan locations allow for effective purge operation. The fourth fan arrangement, draw-through supply and blow-through exhaust, must not be utilized if cross-contamination is of concern. In that arrangement the pressure of the exhaust side will always be greater than that of the return air and the purge section will not operate under such conditions.

The purge and seal leakage air volume must be added to the appropriate fan(s) depending on the fan arrangement. *Figure 9* shows which fans must be sized to handle this additional air volume (Vp) for the different fan arrangements.

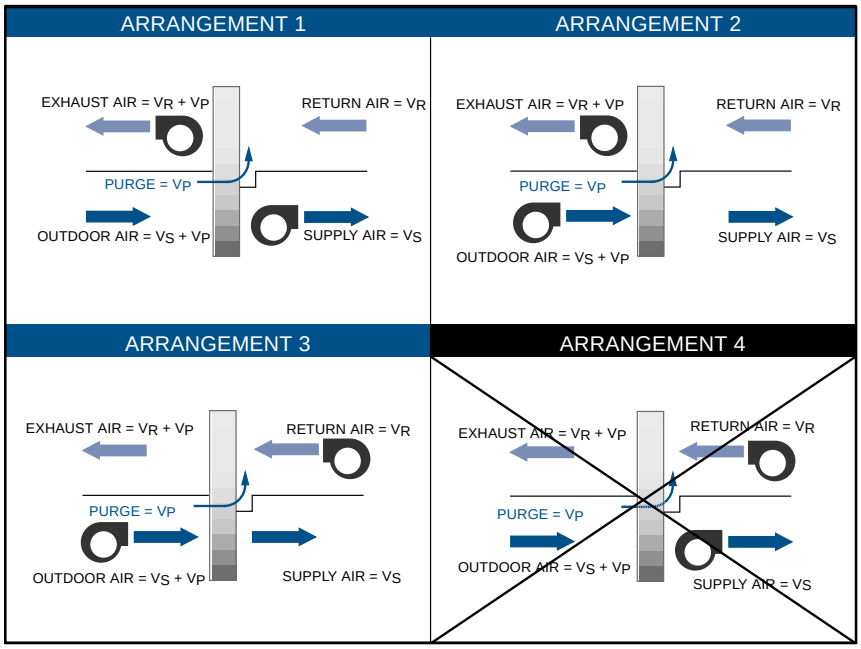


Figure 9. *Fan arrangements for proper purge operation.*

Drive Motor Location

The standard mounting location for the EXCLU-SIEVE® drive motor is in the supply airstream. The motor is located in the lower right hand corner of the unit when looking at the conditioned air side.

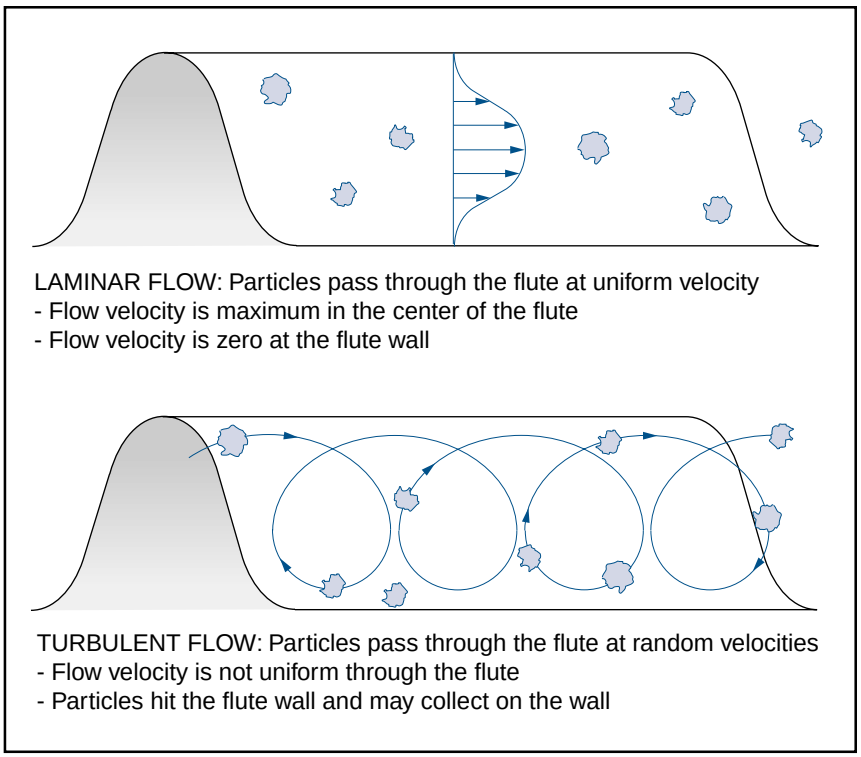
Filtration Requirements

The EXCLU-SIEVE® media is designed to induce laminar flow under all conditions. This results in a flow profile which causes airborne particles smaller than approximately 800 microns, to pass freely through the rotor media (See *Figure 10*).

Self Cleaning Feature

As the EXCLU-SIEVE® rotor operates between two opposing air streams, the continuous reversal of airflow results in a very efficient "self cleaning" process. This process is further enhanced by the very high velocity of the airflow in the purge section. As a result, only minimal filtration is required for efficient operation of the EXCLU-SIEVE® unit under conditions encountered most typically in commercial and institutional buildings.

Figure 10. *Comparison of laminar and turbulent flow profiles in the transfer media.*



Outdoor and Supply Airstreams

An insect screen should be placed behind the outdoor air intake louver in order to prohibit large items such as insects, leaves and debris from entering the EXCLU-SIEVE® energy wheel. It is also recommended that low efficiency (20 - 30 percent), cleanable or pleated filters be provided prior to the EXCLU-SIEVE® energy wheel.

Return Airstream

For applications where the return air is relatively clean (such as general office areas), no filtration is required prior to the EXCLU-SIEVE® energy wheel. In industrial or institutional applications where the return air contains bacteria, lint, oil mist, or animal hair, the appropriate filtration must be incorporated. Please contact SEMCO Incorporated for specific recommendations.

Odors and Contaminants

The EXCLU-SIEVE® product was specifically developed for applications involving contaminated airstreams. Its field adjustable purge section and four pass non-wearing labyrinth sealing system limits "airstream cross-contamination" to less than .04 percent of the exhaust air concentration by volume.

"Selective adsorption," the ability to transfer water vapor to and from the exhausted airstream while allowing other gaseous contaminants to pass unadsorbed, is a necessity for most all energy recovery applications. Recirculating some portion of these contaminants back to the space is undesirable since it reduces the dilution ventilation efficiency (requiring more ventilation air), can cause buildup of odors and, in some applications, result in an unhealthy environment.

The EXCLU-SIEVE® wheel provides selective adsorption through the application of a 3 angstrom molecular sieve desiccant material. Desiccants such as silica gel, activated alumina, oxidized aluminum, and even other types of molecular sieves, do not provide selective adsorption.

Adsorbents trap water vapor and/or other components within their complex internal surface area, which is comprised of a network of holes or "pores". "Molecular sieves" are different than all other desiccants. Their "pore diameter" is completely uniform and in the case of a 3Å molecular sieve, it can be controlled to precisely 3 angstroms. This configuration excludes the adsorption of molecules that have a kinetic diameter greater than 3 angstroms (practically all contaminants) while having a strong affinity for and adsorbing water vapor (2.8 angstroms).

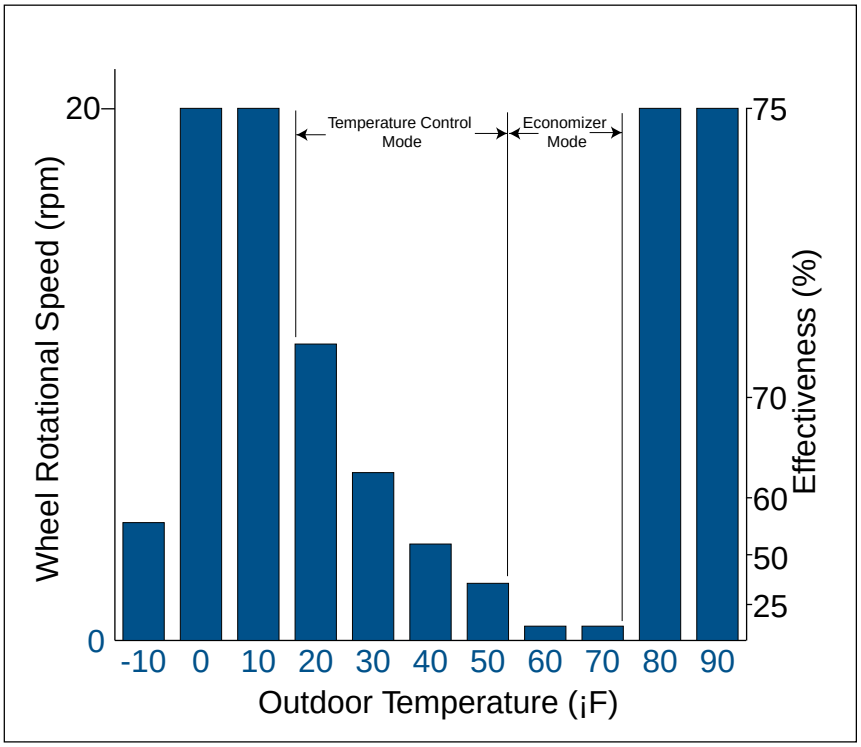
Pollutant Tested	Pollutant Concentration*	Measured Cross-Contamination
Isopropanol	20 ppm	None
Methyl-Isobutyl-Ketone	1840 ppb	None
Xylenes	7100 ppb	None
Carbon Dioxide	500 ppm	None
Propane	82 ppm	None
Sulfur Hexafloride	212 ppm	None
Water Vapor	4000 ppm	80%
*Concentrations selected by GTRI to reflect worst case for typical application		

Table 5. A summary of independent testing conducted by the Georgia Tech Research Institute confirming the ability of the EXCLU-SIEVE® wheel to avoid contaminant cross-contamination. For more information, request a copy of the GTRI cross-contamination report.

Wheel Speed Control

An important design advantage provided by rotary energy recovery technology is the ability to control performance by varying the rotational speed of the rotor media. EXCLU-SIEVE® utilizes an A/C frequency inverter and temperature sensors to control the leaving air temperature during the various modes of operation.

Figure 11. *Example of wheel speed modulation.*



Avoiding Frost Formation and Condensation

For applications in extremely cold outdoor air conditions, the risk of frost formation should always be analyzed. EXCLU-SIEVE® provides a significant advantage over sensible only recovery (temperature only) devices. It dehumidifies the exhaust airstream as it is cooled. This prohibits the exhaust airstream from reaching saturation under all but extreme conditions. If the saturation condition is avoided, frost will not form on the exchange surface.

Frosting can also be avoided during the extreme conditions by monitoring the exhaust air temperature and reducing the recovery effectiveness by the amount required to avoid saturation. Additionally, frosting can be avoided by preheating the outdoor air, heating the return air or bypassing the exchanger. Preheating or speed control are the most common methods.

Preheating to Avoid Frost Formation

Applications that involve humidity control during the heating season (above 30 percent relative humidity) and when the outdoor air temperature is frequently below 0°F, preheating the outdoor air to avoid frost formation is usually the most energy efficient approach. This is because the total energy wheel is allowed to operate at full recovery on very cold days, thereby providing for maximum humidification recovery. Reducing the wheel speed to cut temperature recovery also reduces the latent recovery.

The preheat temperature required is determined by:

1. Locating the return air condition on a psychrometric chart
2. Drawing a line tangent to the saturation curve
3. Connecting to the heating design outdoor air humidity content
4. Reading the dry bulb intercept value, as shown in *Figure 12*, line RA-OA_1
5. Preheating the outdoor air to the dry bulb intercept value, as shown by *Figure 12*, line OA_2-OA_1

Controlling Wheel Speed To Avoid Frost Formation

Applications where humidification is not provided during the heating season (below 30 percent RH during cold days) and where the number of hours below 0°F each year are few, varying wheel speed to avoid frost formation is probably the best choice.

The dew point control setpoint is determined by:

1. Locating the return air condition (RA) that exists when the winter outdoor air design condition is reached.

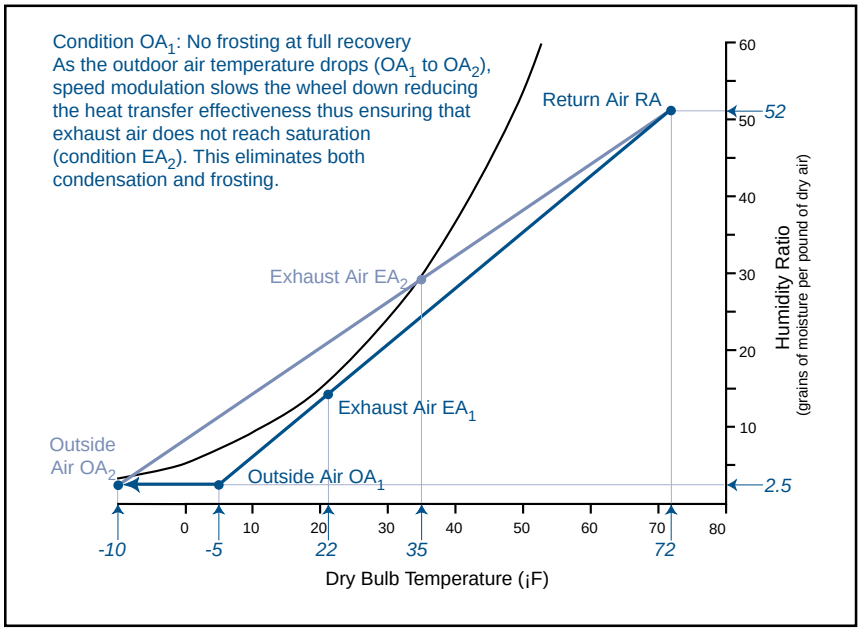


Figure 12. *Example of preheat or wheel speed modulation to avoid frost formation.*

2. Plot the RA point on the psychrometric chart and draw a line between it and the winter design point.
3. Determine the higher dry bulb temperature at which this line intercepts the saturation curve (EA_2 on *Figure 12*).
4. Add 2°F to this temperature and this becomes the control (winter) setpoint.

Avoiding Overheating (Economizer Cycle)

During the Spring and Fall seasons, when the outdoor air temperature is close to that being supplied to the space, the EXCLU-SIEVE® control system will slow the media rotational speed in response to a supply air set point. This decreases the recovery effectiveness by the amout required to provide the desired supply air temperature (See *Figure 11*).

Automatic Summer-Winter Change Over

By monitoring the difference between the outdoor air condition and the return air condition, the cooling mode is selected whenever the outdoor air is warmer than the return air. This calls for full recovery effectiveness once again. Full recovery is maintained automatically until the outdoor air condition drops to the point where the economizer cycle is most efficient.

Condensation on Sensible Only Wheels

Variable wheel speed and reheat approaches can be used for sensible energy wheels. Consult SEMCO Incorporated for assistance.

Sensible Wheel Performance

The performance chart shown below presents the performance for the SEMCO TS series of sensible (temperature transfer only) energy recovery wheels. This performance chart would be utilized along with the selection procedure, outlined on pages 8 through 10 of this brochure for selection of a TE3 series total energy (temperature and moisture transfer) wheel, to calculate supply and exhaust air efficiencies, dry bulb temperature conditions and pressure loss data. Since sensible only wheels are not designed to transfer moisture, the supply and exhaust air humidity content is equal to that of the outdoor and return airstreams respectively. Some moisture will be transferred if condensation occurs on the surface of the TS wheel and this situation should be avoided in most cases (See *"Condensation and Frosting"*).

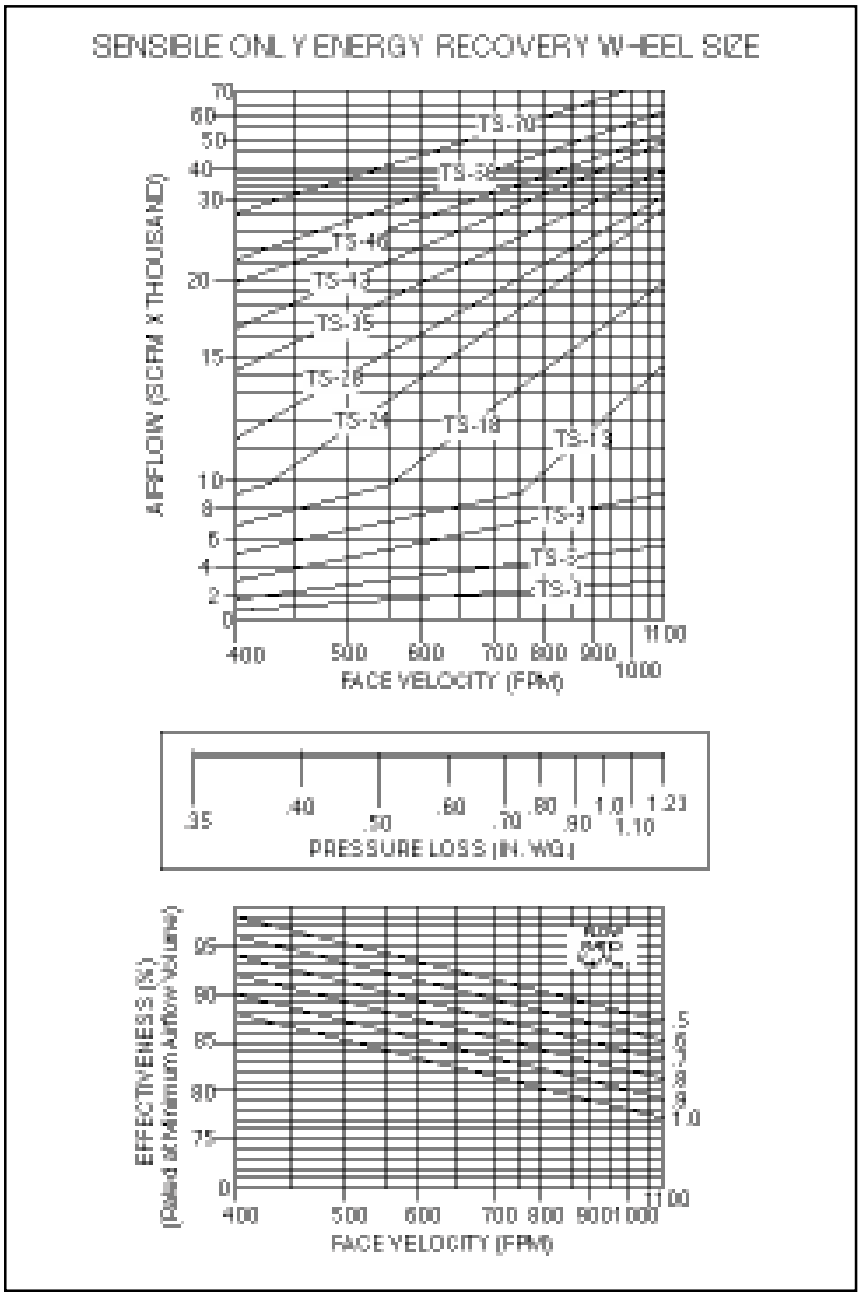


Figure 13. *Performance charts for TS series sensible only recovery wheels.*

Sensible Wheel Applications

Sensible wheels should only be applied to applications where the transfer of moisture is undesirable. This is due to the fact that the EXCLU-SIEVE® total energy wheel is approximately the same cost, but offers the advantage of latent recovery and the associated frost control advantage, which makes it the product of choice for even heating mode only applications.

Examples of sensible only applications include indirect evaporative cooling, direct/indirect evaporative cooling, desiccant based cooling (second wheel) and in the reheat position in the SEMCO EPD system concept.

The common element for all of these applications is the importance of avoiding any moisture transfer. To avoid moisture transfer, it is critical that the aluminum wheel media be carefully coated to avoid the inherent oxidation that would otherwise take place over time, turning a sensible wheel into a moderately effective latent wheel. As a result, all SEMCO TS sensible only wheels are made from a polymer coated aluminum substrate, which is carefully coated prior to being formed into the honeycomb transfer media.

Condensation & Frosting

Unlike the EXCLU-SIEVE® total energy wheel where the supply air leaving the wheel follows a straight path between the return air and the outdoor air, a plot of the supply air condition leaving a sensible only wheel on a psychrometric chart resembles that of a chilled water coil. Since no moisture is transferred by a sensible wheel, the temperature of the air streams are changed as the sensible energy is exchanged, but the moisture level remains constant unless the supply air or exhaust airstreams are cooled to below their dew points.

If this occurs, one of three things will happen:

1. If the exhaust airstream is cooled to less than approximately 20°F below its dew point, and if the leaving temperature of the airstream is above 32°F, a thin film of condensate will form on the vast surfaces of the wheel media, and this condensate will re-evaporate into the warmed supply airstream. If this moisture transfer is a problem, it can best be avoided by limiting the exhaust side recovery with controls to vary wheel speed based on a dew point temperature sensor.
2. If the exhaust airstream is cooled more than 20°F below its dew point, and if the leaving temperature of the airstream is above 32°F, some condensate will re-evaporate into the warmed supply airstream and the remainder will blow off of the wheel surface. This is not advised and, as a result, the variable wheel speed controller should once again be applied.
3. If the exhaust airstream is cooled below 32°F and reaches its dew point, frost may form on the face of the wheel, reducing airflow. Preheat should be applied in this case to avoid cooling the exhaust airstream below its dew point.

Cleaning The Wheel Media

The SEMCO EXCLU-SIEVE® energy recovery wheel has been designed so that a laminar flow is maintained within the transfer media at all operating conditions. This means that the air and all other particles in the airstream pass straight through the wheel.

Due to the laminar flow profile through the EXCLU-SIEVE® energy wheel, any collection of dust or particulate matter will occur at the entering and leaving edges of the transfer media. Such buildup can usually be vacuumed, purged with compressed air or wiped from the rotor surface. In rare cases where a more thorough cleaning is required, low temperature steam or hot water and detergent may be used. Consult SEMCO for instructions when using cleaning methods other than compressed air or vacuuming.

Installation Guidelines

Provisions should be made to allow access to all four sides of the module to facilitate seal adjustment and routine inspection.

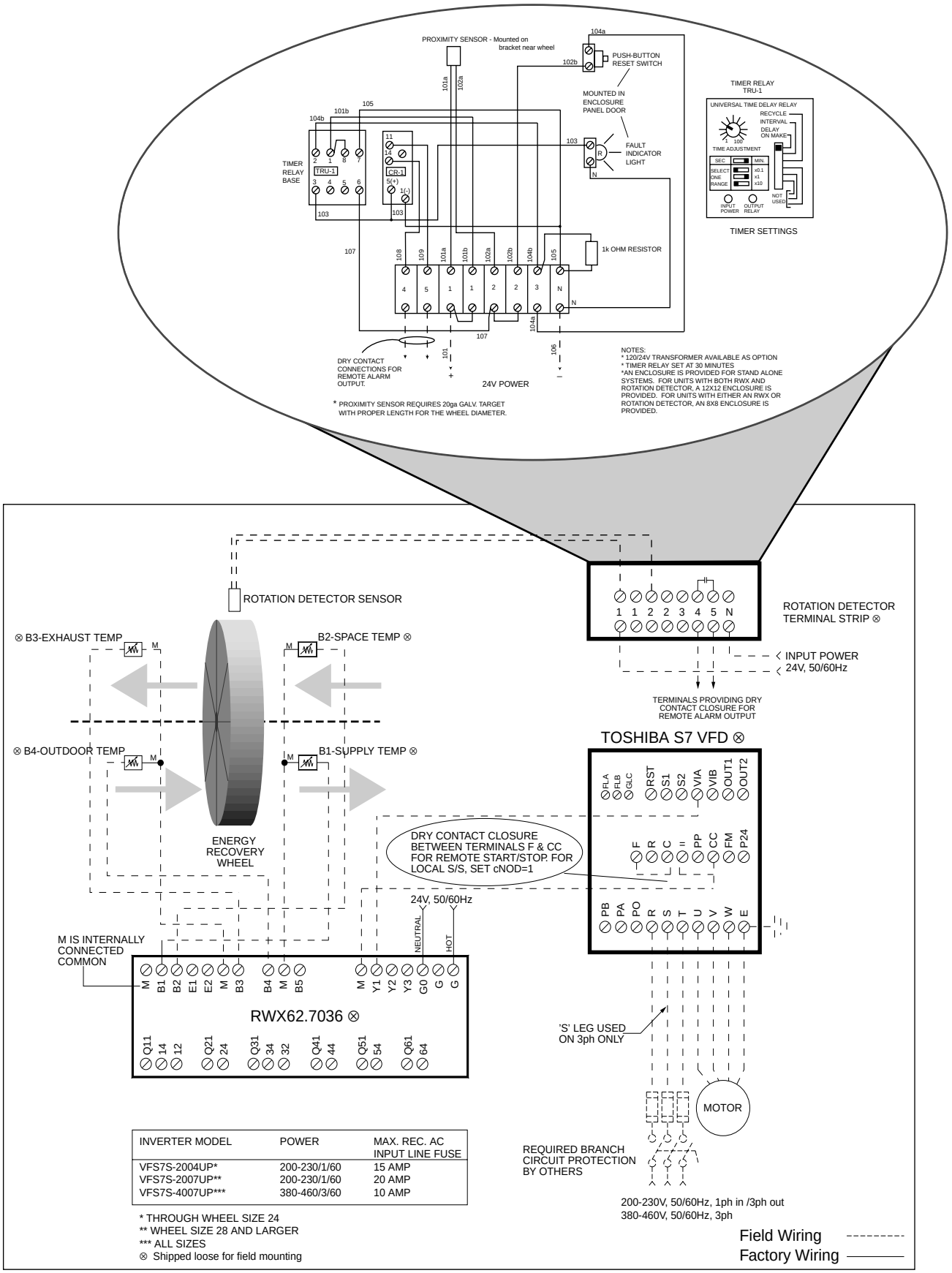
Locate the A/C inverter control panel in a dry, conditioned space which is clearly visible to the operations personnel. A rotation detector should be included as a part of the control package for all critical applications.

The purge section must always face the conditioned air side of the system. Rotation is such that a spot on the media in the return air section would rotate towards the purge section without first passing into the supply section.

Carefully review the purge, fan location and filter recommendations covered by this brochure prior to completing any design. Select the appropriate control option for the application. Please consult SEMCO for any additional design assistance required.

Consult SEMCO for design recommendations with applications involving hazardous contaminants, exhaust air temperatures in excess of 180°F and/or high humidity conditions (drying ovens, swimming pools, etc.).

Typical Wiring Schematic



INVERTER MODEL	POWER	MAX. REC. AC INPUT LINE FUSE
VFS7S-2004UP*	200-230/1/60	15 AMP
VFS7S-2007UP**	200-230/1/60	20 AMP
VFS7S-4007UP***	380-460/3/60	10 AMP

* THROUGH WHEEL SIZE 24
** WHEEL SIZE 28 AND LARGER
*** ALL SIZES
⊗ Shipped loose for field mounting

Mounting Arrangements

The EXCLU-SIEVE® units can be mounted in six different positions (see *Figure 14*). The number of support points required for horizontal mounting may vary depending on the size of the unit. Consult SEMCO for support details.

When installing an EXCLU-SIEVE® unit, the purge section must always face the conditioned air side of the system. Rotation is such that a spot on the media in the return air section would rotate towards the purge section without first passing into the supply section.

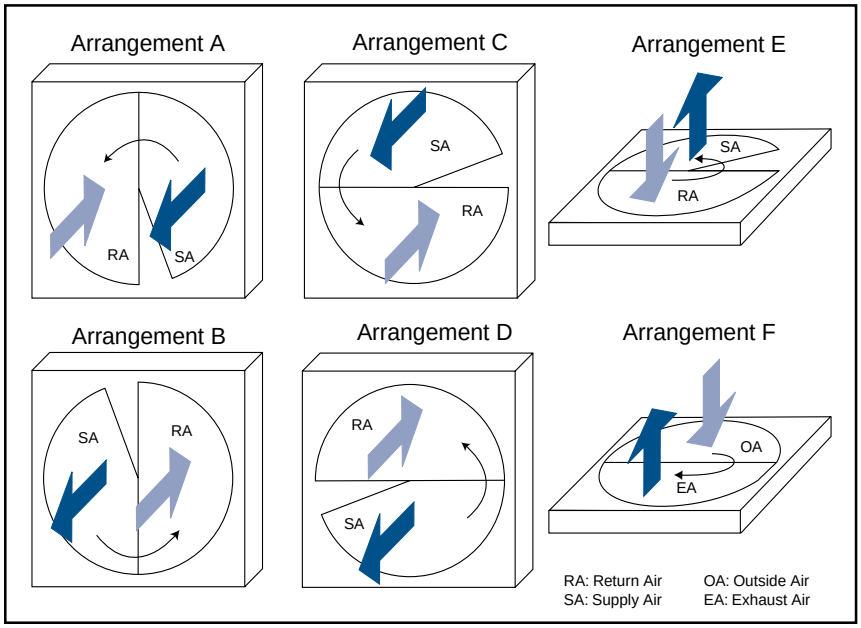


Figure 14. *Wheel mounting arrangements.*

Wheel Drive Options

There are three different control options that can be ordered with the Total Energy Recovery unit:

No Controls:

Power is connected directly to the motor. The wheel rotates at a constant speed (20 rpm).

Variable Frequency Drive (VFD) ONLY:

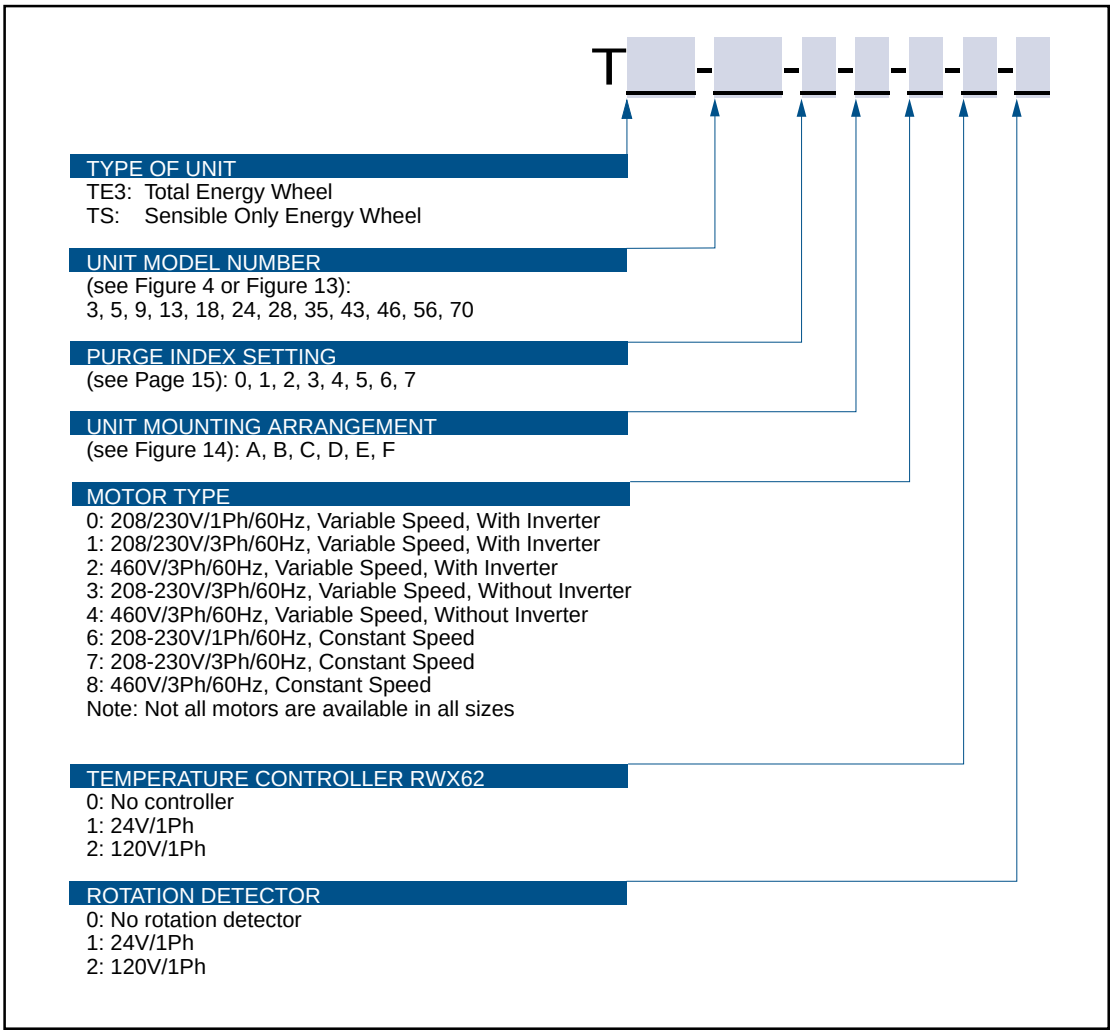
SEMCO ships a pre-qualified variable frequency drive with the unit for field mounting. The VFD has the same voltage as the motor and can modulate the motor from 20 rpm to 1/4 rpm. Four temperature sensors (one in each air stream), and a PCM must be field provided, mounted, wired and programmed.

Variable Frequency Drive (VFD) & Controls:

SEMCO ships the same variable frequency drive mentioned above, along with four temperature sensors and a solid state controller with the module. All of these accessories are to be field mounted and wired. The advantage of this option is that it is a pre-packaged stand alone system.

A rotation detector can be ordered with any of the control options mentioned above. This rotation detector will ship with the unit for field mounting.

Ordering Key

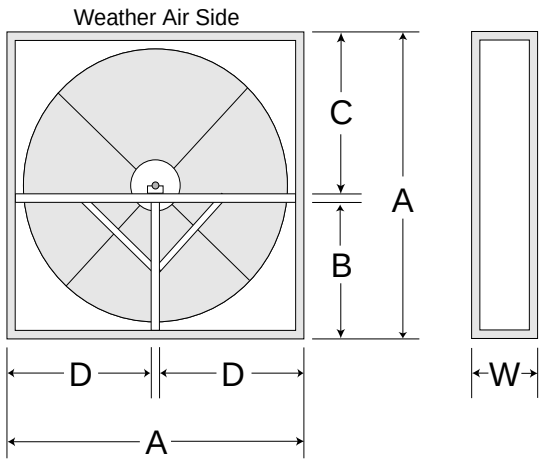


Performance Data For TE3 & TS

Velocity fpm	Efficie-ncy %	Press. Drop in.wg		Wheel Size											
				3	5	9	13	18	24	28	35	43	46	56	70
300	88.0	0.29	Air Flow Rate (in cfm) ▶	840	1,590	2,580	3,930	5,430	7,140	8,490	10,560	12,870	13,920	16,800	21,120
400	86.0	0.37		1,120	2,120	3,440	5,240	7,240	9,520	11,320	14,080	17,160	18,560	22,400	28,160
500	82.5	0.45		1,400	2,650	4,300	6,550	9,050	11,900	14,150	17,600	21,450	23,200	28,000	35,200
600	80.5	0.56		1,680	3,180	5,160	7,860	10,860	14,280	16,980	21,120	25,740	27,840	33,600	42,240
700	78.5	0.67		1,960	3,710	6,020	9,170	12,670	16,660	19,810	24,640	30,030	32,480	39,200	49,280
800	77.0	0.79		2,240	4,420	6,880	10,480	14,480	19,040	22,640	28,160	34,320	37,120	44,800	56,320
900	76.0	0.94		2,520	4.770	7,740	11,790	16,290	21,420	25,470	31,680	38,610	41,760	50,400	63,360
1000	74.5	1.05		2,800	5,300	8,600	13,100	18,100	23,800	28,300	35,200	42,900	46,400	56,000	70,400
1100	73.5	1.18		3,080	5,830	9,460	14,410	19,910	26,180	31,130	38,720	47,190	51,040	61,600	77,440

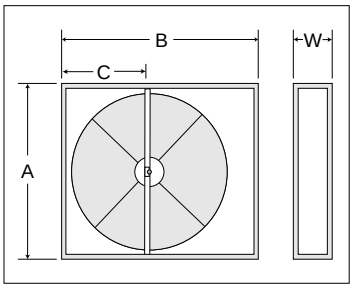
Unit Dimensions

Wheel Sizes 13 - 70



Wheel Sizes 3, 5, 9

Mounting Arrangements A, B, C, D, E, and F (see Figure 14)



All dimensions in inches

Sample Specification

A. Total Energy Recovery Wheel Unit - The rotor media shall be made of aluminum which is coated to prohibit corrosion. All media surfaces shall be coated with a non-migrating solid adsorbent layer prior to being formed into the honeycomb media structure to insure that all surfaces are coated and that adequate latent capacity is provided. The media shall have a flame spread of less than 25 and a smoke developed of less than 50 when rated in accordance with ASTM E87. In addition to the desiccant coating that is applied to the surfaces of the aluminum substrate, the two faces of the total energy recovery wheel shall be covered and sealed with a two part polymer heavy duty coating specifically chosen for chemical resistance.

The desiccant shall be inorganic and specifically developed for the selective adsorption of water vapor. The desiccant shall utilize a 3A molecular sieve certified by the manufacturer to have an internal pore diameter distribution which limits adsorption to materials not larger than the critical diameter of a water molecule (2.8 angstroms).

Submit certification by a qualified independent organization documenting equal sensible and latent recovery efficiencies conducted in accordance with ASHRAE 84-78P and the results presented in accordance with ARI 1060 standards.

An independent wheel test from a credible test laboratory shall document that the desiccant material utilized does not transfer pollutants typically encountered in the indoor air environment. The cross-contamination and performance certification reports shall be provided upon written request for engineering review.

Media Cleaning - The media shall be cleanable with low pressure steam(less than 5 PSI), hot water or light detergent, without degrading the latent recovery. Dry particles up to 800 microns shall pass freely through the media.

Purge Sector - The unit shall be provided with a factory set, field adjustable purge sector designed to limit cross contamination to less than .04 percent of that of the exhaust airstream concentration when operated under appropriate conditions.

Rotor Seals - The rotor shall be supplied with labyrinth seals only, which at no time shall make contact with any rotating surface of the exchanger rotor face. These multi-pass seals shall utilize four labyrinth stages for optimum performance.

Rotor Support System - The rotor media shall be provided in segmented fashion to allow for field erection or replacement of one section at a time without requiring side access. The media shall be rigidly held in place by a structural spoke system made of extruded aluminum.

Rotor Housing - The rotor housing shall be a structural framework which limits the deflection of the rotor due to air pressure loss to less than 1/32". The housing is made of galvanized steel to prevent corrosion. The rotor is supported by two pillow block bearings which can be maintained or replaced without the removal of the rotor from its casing or the media from its spoke system.

Optional Temperature Control Panel - Variable speed control shall be accomplished by the use of an A/C inverter. The inverter shall include all digital programming with a manual speed adjustment on the front of the inverter. The drive system shall allow for a turndown ratio of 80:1 (20 rpm to 1/4 rpm). The control system shall include four linearized thermistor sensors as follows: (1) Proportional temperature controller mounted in the supply airstream. (2) differential summer/winter changeover sensors mounted in the outdoor and return airstreams. (3) Frost prevention sensor located in the exhaust airstream. (4) Digital readout of the temperature readings recorded by these sensors and control setpoints is displayed by the control panel.

Digital Performance Display Module - Digital read out confirming the effectiveness of the energy wheel via temperature readings recorded by these sensors and control set points shall be displayed by the control panel.

B. Warranty - The unit manufacturer shall warrant to the Buyer that for a period of eighteen months from the date of shipment the goods to be delivered to the Buyer shall in all material respects be free from defects in material and workmanship when used in a proper and normal manner. Should any failure to conform to the above appear within eighteen months after the date of shipment, the unit manufacturer shall upon prompt notification thereof during the Warranty Period and confirmation to the unit manufacturer's satisfaction that the goods have been stored, installed, operated and maintained properly and in accordance with standard industry practice, correct the non-conformity at the unit manufacturer's option either by repairing any defective part or parts or by making available at the unit manufacturer's plant a repaired or replacement part.

How to Reach SEMCO

You can reach SEMCO Incorporated by phone, fax, mail, or e-mail.

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1800 East Pointe Drive
Columbia, MO 65201-3508

888-4SEMCOINC (888-473-6264)
573-443-1481
Fax: 573-886-5408
e-mail: aqpinfo@semcoinc.com

For information about SEMCO Incorporated, our air quality products and services, please point your web browser to www.semcoinc.com. There, you will also find the latest news from SEMCO and examples of how SEMCO's energy recovery systems are being applied on a daily basis in a multitude of applications.

Wheel Configuration Checklist

SEMCO INCORPORATED

Desiccant Wheel Products

JOB NAME _____

UNIT TAG _____ **DATE** _____

T ☐ ☐ - ☐ ☐ - ☐ ☐ - ☐ ☐ - ☐ ☐ - ☐ ☐ - ☐ ☐

TYPE OF UNIT
TE3: Total Energy Wheel
TS: Sensible Only Energy Wheel

UNIT MODEL NUMBER
3, 5, 9, 13, 18, 24, 28, 35, 43, 46, 56, 70

PURGE ANGLE
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

UNIT MOUNTING ARRANGEMENT
A, B, C, D, E, F

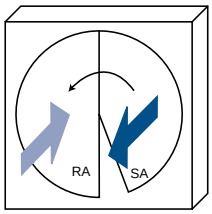
MOTOR TYPE
0: 208/230V/1Ph/60Hz, Variable Speed, With Inverter
1: 208/230V/3Ph/60Hz, Variable Speed, With Inverter
2: 460V/3Ph/60Hz, Variable Speed, With Inverter
3: 208-230V/3Ph/60Hz, Variable Speed, Without Inverter
4: 460V/3Ph/60Hz, Variable Speed, Without Inverter
6: 208-230V/1Ph/60Hz, Constant Speed
7: 208-230V/3Ph/60Hz, Constant Speed
8: 460V/3Ph/60Hz, Constant Speed
Note: Not all motors are available in all sizes

TEMPERATURE CONTROLLER RWX62
0: No controller
1: 24V/1Ph
2: 120V/1Ph

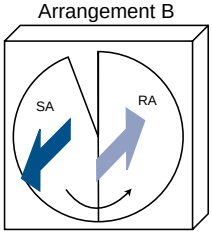
ROTATION DETECTOR
0: No rotation detector
1: 24V/1Ph
2: 120V/1Ph

WHEEL ARRANGEMENTS

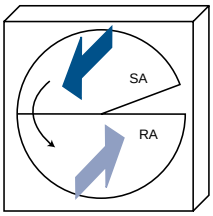
Arrangement A



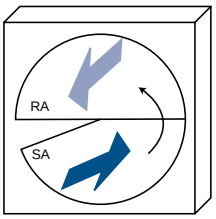
Arrangement B



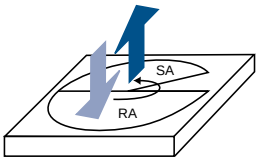
Arrangement C



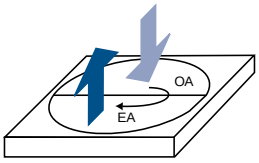
Arrangement D



Arrangement E



Arrangement F



RA: Return Air
SA: Supply Air
OA: Outside Air
EA: Exhaust Air

Please check one:

☐ **Hold for Approval** ☐ **Release for Production**

Signature _____

SEMCO® INCORPORATED

Certified, Specified, Proven™

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0702 1K B