FINAL REPORT

UNIVERSITY BUILDING
UNIVERSITY, MID ATLANTIC REGION, UNITED STATES

Jeremy Feath

Dr. Dubler

4/9/2014

UNIVERSITY ENGINEERING BUILDING

University, Mid Atlantic Region, United States

Project Team:

Architect—Stantec Architecture, Inc.

MEP Engineer—Stantec Architecture, Inc.

Structural Engineer—Barber & Hoffman

General Contractor—Massaro Corporation

Clean Room (Design) - Innovate Labs Systems

General Information:

Location—University, Mid Atlantic Region

Function—Education/Research

Size—95,000 GSF

Stories Above Grade/Total Stories—4/6

Total Project Cost—$43 M

Dates of Construction—Jan. 2013—Nov. 2014

Project Delivery Method—Design/Bid/Build

Architecture:

Features 2 separate wings connected via a main corridor

East Wing & Subgrade Level house Laboratory space

West Wing houses Office and Classroom Space

Masonry veneer, red brick and limestone, with Curtain Walls

Utilizes a fully adhered single ply TPO roofing system

Structural:

Foundation consists of Caissons and a 2' thick foundation wall

Level 1—Penthouse framed using structural steel

Greater reinforcement to handle mechanical room in Penthouse

3-1/2" thick concrete slabs on deck

Mechanical:

Building requires 2 full size mechanical rooms

Level 0 Mechanical Room assigned to clean room and part of Level 1

Penthouse Mechanical Room assigned to the rest of the building

A total of 8 AHU's (4400—23750 CFM) and 4 Heat Recovery Coils handle all the heating and cooling (transportation of hot and chilled water)

Electrical:

Dual service entry points into building (2500 kVA Transfoirmer at each point)

Backup generators and main equipment located outside of the Southeast corner of the building

480Y/277V, 3 PH main switchboard supplies power to the entire building via (2) main distribution panels

Jeremy Feath
Construction Option

Executive Summary

During the 2013-2014 academic year, the University Engineering Building located at a Mid-Atlantic University was analyzed to identify key areas in which alternative solutions would enhance the project as a whole. The main topics for analysis in this report included: a study of the Clean Room coordination, a roof system study, a study of the underground spring and finally the information delivery between CMs and Facility Managers. It must be stated that this thesis is solely for educational purposes and is not intended in any way to be a critique of the project team.

Analysis 1: Clean Room Coordination

The first analysis topic studies the project organization of the UEB and how the coordination involving the Clean Room is affected. The contract situation was changed so that Hodess has a preconstruction contract with the University and a construction contract with Massaro. A coordination schedule was created focusing on the Clean Room to manage any potential constructability problems and save time during construction.

Analysis 2: Roof System Redesign

One of the main problems plaguing the project schedule was the fully-adhered roof system, which was delayed because of the extreme cold temperatures early in 2014. The final result was to switch the fully-adhered TPO system for Firestone's InvisiWeld system, which reduced costs, greatly reduced the scheduled activities and was easily constructed in the extreme cold weather from the 2014 winter. Finally the InvisiWeld system had the same warranty as the fully-adhered system, which is what the owner wanted. A built-up roof system was also studied as a possible alternate.

Analysis 3: Underground Spring Analysis

A unique feature of the UEB was the underground spring that along with rain caused delays and issues during excavation and foundations. The result of this analysis was to incorporate the sump pump that the project team used as a solution with a waterproofing membrane for the Lab wing foundation walls to add an extra layer of protection from moisture at Level 0 where the Clean Room is located. The waterproofing membrane does increase the cost by roughly $20,000 but does not affect the schedule.

Analysis 4: CM to FM Information Delivery

The research topic for this thesis focused on the transfer of project information between the contractor and facility manager at the end of a project. It was discovered that the method of transfer was more important to the facility manager than the actual information. Since the owner of the UEB, like most, has not incorporated the amount of technology that Penn State has, an outline was created highlighting key areas for facility managers/owners to focus on in terms of beginning to incorporate new technologies for building turnover, operation and maintenance.

Acknowledgements

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Dr. Ed Gannon

Dr. Robert Leicht

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My Family and Friends

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Project Information

Background

The conception of the University Engineering Building (UEB) began in January 2012 when a prominent alumnus from the Mid-Atlantic University's College of Engineering made a donation to the University for a new, landmark engineering building. Also because of this donation, the College of Engineering will be named after this alumnus. The donation accounted for $32 million out of the $43 million total project costs, with the remainder matched by the state.

The University Engineering Building is a 95,000 GSF, 6 total stories building that is separated into two distinct wings connected via an entrance corridor. The function of the UEB is for educational and research purposes. The west wing of the building serves the educational function housing faculty offices and classrooms, while the east wing and basement level serves the research function. The research/laboratory wing features large, open lab spaces and a state-of-the-art clean room located in the basement.

The project team is composed of Stantec Architecture Inc. as the lead designer and engineer, with Barber & Hoffman as the structural engineer. The clean room was designed by Innovate Labs Systems Design, while the contractor for the clean room is Hodess Construction Corporation. The general contractor is Massaro Corporation. Construction began in January 2013 and is currently scheduled to be completed in January 2015. The project delivery method is similar to most public universities: design-bid-build.

Figure 1: Rendering of the UEB

Systems Overview

The architecture of the University Engineering Building is a traditional masonry and cast stone exterior building, as seen in figure 1. The cast stone is used to differentiate the first floor Office wing from the second and third floors, along with highlighting the entrance of the UEB at the connector space between the two wings. The basement is a typical concrete and cast stone foundation wall that transition into traditional brick for the Lab wing above grade floors. A mechanical penthouse is located on the Lab wing, which can be seen also in figure 1. The interior space of the building is divided based on the particular wings of the building. From figure 1, the east wing, also known as the Lab wing houses roughly 22,000 SF devoted entirely to laboratory and research needs. The west wing, also known as the Office wing occupies roughly 30,000 SF that is spread among faculty offices, classrooms, computer labs, a learning center and graduate student areas. The clean room located in the basement and connector make up the remaining area, along with 15,000 SF currently left undesignated for future renovations.

Structural:

The UEB uses a concrete foundation system with a structural steel frame. The footing system is caissons, with each wing of the building utilizing caissons of different depths. A concrete retaining wall sets upon 2' thick grade beams of varying widths, 2' – 4', and the wall itself is 24' in height for the laboratory portion, while the office is only 10'. The laboratory building features slabs on grade at thicknesses of4" to 12" in specific areas based on loading. Slabs on deck are placed on 20 gage metal decking with slab thicknesses of 2.5" and 3". All concrete, except the retaining wall (5000 psi), is 4000 psi strength. The framing system was sequenced for the laboratory and office as separate structures with a connecting structure. Typical wide flange members were used for both beams and columns and feature moment connections in specific areas. Steel erection will be completed using one 80-ton crawler crane that will maneuver around the building perimeter.

Mechanical:

The mechanical system for the University Engineering Building is the most complex of all the building systems, due to the required need of extensive environmental controls. The UEB features two separate mechanical systems, one located at Level 0 and the Mezzanine, which sole purpose is to supply air to the clean room, level 0, mezzanine and part of the laboratory level 1. This system features 8 custom-built air-handling units equipped with fans and heat recovery units that can supply at the largest 44,000 CFM. To get a better grasp on the size of these units, they were installed during the steel erection phase because at no other point afterwards would they physically fit into the building.

The other mechanical system is located in the building penthouse on the laboratory wing of the building. This mechanical room supplies the remaining lab levels along with all three office levels. It features 6 custom-built air-handling units, smaller in size and output than the ones located in the Mezzanine. These units are elevated on reinforced concrete curbs to minimize the effect of vibrations on the UEB's structural system and reduce noise. These units also have to be installed early than usual during the construction phase, when the slab on deck has been poured and cured but prior to the erection of the steel for the penthouse roof.

The laboratory spaces feature extensive exhaust systems centrally located to ease of construction and to collect all exhaust air from the three lab levels into one area. These shafts located in the labs house all necessary supply and return duct as well.

Electrical:

The UEB's electrical system features two building service points, each including a 2500 kVA, 4160 V, 450 A transformer, furnished by the owner, and they both meet at the main building switchgear, 4000 A. From this point, power is supplied to two main distribution panels, 800 and 1200 A, then to panelboards ranging in sizes to feed power to the entire building. Temporary power is currently being supplied by the Soils and Foundations building located directly east of the UEB and will then supply its own power after construction is completed. Finally an emergency generator is located adjacent to the building to supply power to the labs in the case of an outage.

Fire Protection:

The University Engineering Building utilizes a wet-pipe sprinkler system that covers 100% of the building area. Special exceptions have been made for fire suppression in particular areas, which include autoclave areas, electrical switchgear, transformer rooms, electrical closets, mechanical rooms and other areas in which high temperatures are experienced. Laboratory, mechanical room, electrical room, interstitial spaces, storage and the clean room area are all designated "Ordinary Hazard 2" sprinkler application schedule, while the remaining areas are designated light hazard.

Clean Room:

The key feature unique to the University Engineering Building is the clean room located in the basement level, Level 0. Design of the clean room was contracted out by the architect to Innovate Labs Systems Design, while construction of the space was contracted to Hodess Construction Corp. by the owner directly.

The clean room itself is free-standing and self-supported from the floor of the building, with lateral loads supported from the existing building by diagonal bracing with light gauge metal studs to the overhead structure. Air cleanliness classification and the definition of terms for clean room work are in accordance with ISO Class 1, 2, 3, 4, 5, 6 and 7.

Some design requirements for the clean room include; ambient room temperature must be held at 68°F ± 2°F, with relative humidity at 50% ±10%. Also, the overall leakage rate of the entire room and air handling system shall not exceed 3.5% of the total air supplied with the condition that all doors are closed and the room is in occupied condition. Lighting fixtures must be located so as to not conflict with equipment layout and the sound level within the clean room shall not exceed the (NC60) curve as determined by octave band analysis.

Analysis 1 – Clean Room Coordination

Problem Identification

The most important feature of the University Engineering Building is the clean room, but at the same time is also one of the most confusing aspects from the construction management standpoint. One contractor has the scope of work for the clean room and was hired specifically because of their past experience with constructing clean rooms. The problem arises because Hodess Construction, the clean room contractor, has a contract directly with the owner and not Massaro, making it difficult to sort out coordination issues and who has priority over the other in terms of scopes of work.

Figure 2: Sample Clean Room by Hodess
(Courtesy Hodess Construction)

Another area where this issue arises is the MEP systems located at the basement level of the UEB. The air-handling units and other mechanical equipment for the clean room are housed in the Mezzanine level and the duct and mechanical pipes pass from that level into the clean room. Plumbing and electrical runs are located outside of the clean room at the basement level and pass into it to supply that room. The problem is determining who owns the scopes for outside and inside the clean room and also if the MEP subcontractors own all of the work then how will they coordinate with Hodess Construction.

Analysis Goals

The goals of this analysis deal with coordination and the positives and negatives of the project organizational chart in its current state. After analyzing the different methods of coordination sorting out the different scopes of work, changes will be suggested to streamline these processes and create a more efficient project organization chart. Most of the results from this analysis will be qualitative but will also focus on potential quantitative savings via time and cost. This situation will be studied from Massaro's point of view along with the University's point of view to weigh the advantages and disadvantages for both.

Process

A better way to understand this situation is to first examine the project organizational chart and determine where potential problems could arise. As seen in figure 3, the organization is confusing and difficult to follow from a first glance. The main takeaway is the fact that Hodess and Massaro both have separate contracts with the University. The clean room itself is located within the basement of the UEB meaning that Massaro oversees the entire building except for a certain area in the basement, that Hodess has the scope for.

The first step in the process of gaining all the necessary information begins with an interview with

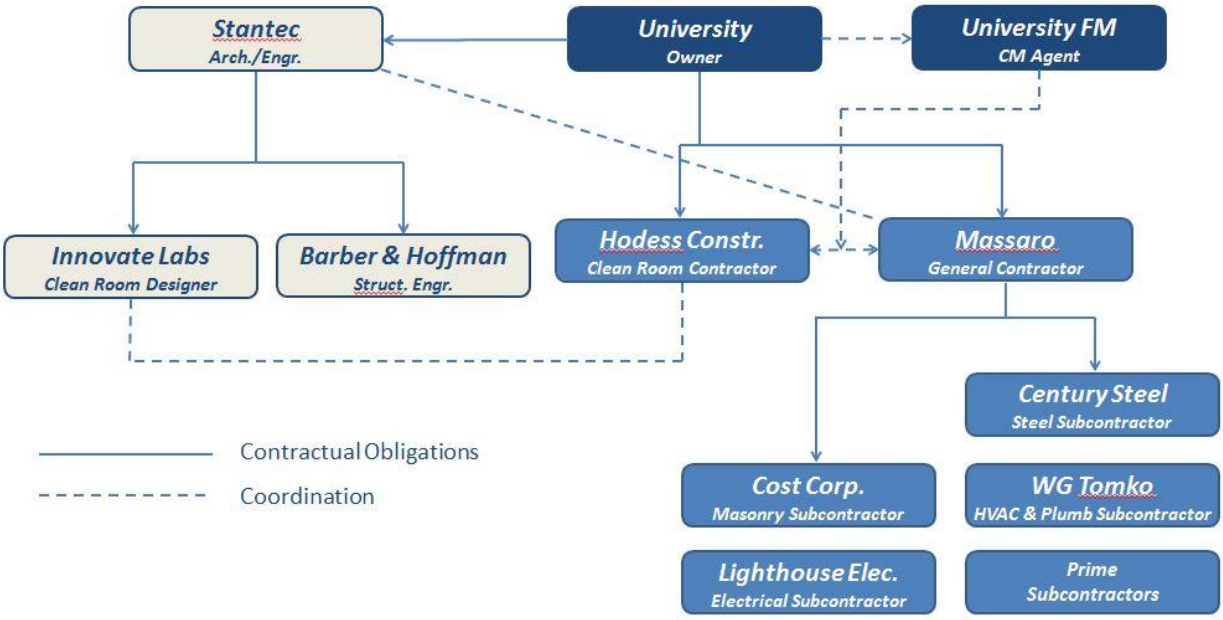


Figure 3: Project Organization Chart

Massaro's project manager to discuss this situation and to understand their side of this analysis.

University Representative Interview

Getting at the source of this analysis, an interview was conducted with the University representative to gain their perspective and reasoning on why Hodess was contracted directly to the owner. The main reason behind directly hiring Hodess was because they were brought on board during the Design Development phase as a consultant to provide coordination input for the clean room and MEP system designs affecting that area. The main area of focus for coordination was the MEP tie-ins, especially all HVAC equipment and runs. The scope of work is set up so that Hodess owns all final connections within the clean room and all MEP equipment and runs are owned by the MEP contractors. And because of this, the University decided to bring Hodess on earlier, before the general contractor and any subcontractors.

Another key reason in hiring Hodess directly, early on in the design process, was to guarantee that Hodess would be the clean room contractor and that the eventual general contractor would not have hired a subcontractor that the University didn't feel would have enough experience with clean room construction. The University representative also said that there are only a handful of contractors experienced enough to build a clean room and that aside from Hodess, the other he is familiar with was started by an ex-Hodess employee.

The question was also raised about whether the University contemplated the idea of transferring Hodess' contract to Massaro, once they were hired to be the general contractor. The University representative stated that it was the University's intention to do so, but due to state laws regarding public institutions, they were unable to transfer the contract. Also because Hodess was paid part of their contract for preconstruction services, it was financially difficult to transfer the remaining amount left in the contract to Massaro. He did state though that it is Massaro's responsibility for all coordination regarding the clean room and Hodess.

Massaro Project Manager Interview

While the University was able to provide details on the reasoning behind the contractual situation for the UEB project, Massaro's PM was able to provide information on the steps already taken in the coordination process for the UEB. In terms of the contract situation, the benefits for Massaro include less liability financially, but because the coordination requirements were included in the contract, Massaro can still be held responsible for any problems with the clean room.

The main method of coordination used on the UEB project involved the 3D model that was created specifically for MEP and clean room coordination. An example of how the model has proved useful is for the ceiling grid for the clean room. During the clean room coordination process, the details for hangers for the clean room ceiling were added to the model. The threaded hangers are 3/8" diameter, spaced every 4" O.C. The MEP equipment located in the space between the ceiling grid and the Mezzanine did not leave a straight shot in certain areas for the hangers to reach the deck above. Using clash detection in the 3D model allowed all the problem areas to be discovered and fix prior to the beginning of construction on the clean room. Massaro's PM stated the project team spent 2-3 months working on coordination for Level 0 and the Mezzanine during the early phases of construction. After a year into construction on the project, there have been very few mechanical related RFIs and of those that have been issued, none have negatively impacted work completed on the project.

Results & Recommendations

The University Engineering Building is unique because of the clean room and the intensive MEP systems that run throughout the building. Massaro's project manager stated in an interview with him this project has been the most coordination intensive he has ever worked on because of the MEP systems and the clean room. While there are benefits for each party under the current contractual organization, there is a better project organizational chart that would provide other benefits, as well as ease some of the coordination between parties.

Design-Build Project Delivery

Due to the complexity of the UEB, mainly the clean room, the best project delivery system would be either design-build or design-bid-build with a CM Agent. The reason for this is having the builders or a CM Agent included early during the design process. The University had the right idea by bringing Hodess Construction on board during the design phase, but due to guidelines and laws regarding public institutions was unable to bring the general contractor on early. Going on the assumption that for the UEB project, those laws and guidelines can be ignored, and then the project delivery method would be design-build. As seen in figure 4, the organizational chart is that of what the project team would look like being design-build.

A note about figure 4, the design build firm hired for the UEB project would have experience with both designing and building clean rooms or would bring Hodess Construction, or contractor of similar qualifications and experience, to provide input for the design of the clean room and coordination input for the MEP systems and ways to make the clean room construction the most efficient.

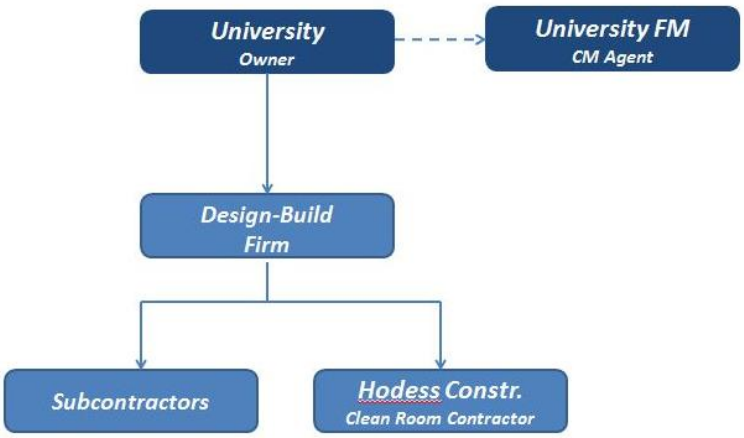


Figure 4: Design-Build Organization Chart

In terms of contracts and legal obligations between parties, there would be one contract between the University and the Design-Build firm instead of separating the two entities as done with the design-bid-build delivery system. By having one contract, this would save the University some money because the fee for the design-build firm would amount to less than the fee charged by Stantec and Massaro. Exact figures were unable to be obtained for a direct quantitative comparison, but it was assumed to be 5% for Massaro and 20% for Stantec, compared to 20% for the design-build firm. Based on total construction costs of $32.7 million, see table 1, for a cost breakdown on fees for the UEB project.

Table 1: Fee Costs Design-Bid-Build vs. Design-Build

Firm	*Total Constr. $ (M)*	*Fee %*	*Fee $ (M)*
Massaro	32.7	0.05	1.64
Stantec	32.7	0.20	6.54
Total			***8.18***
Design-Build Firm	32.7	0.20	6.54
Difference			***1.64***

Aside from the difference in fees, the cost of the project will not change drastically because the University has a set budget because the money was donated for the project. While the cost savings are minimal with this change in project delivery, the big savings are seen in the schedule via coordination and time saved because of the coordination.

The whole idea behind design-build project delivery is to make coordination as efficient as possible by including the builder side of the design-build firm. All of the coordination would take place during design which saves time later during construction. A summary schedule was updated from technical report 1 and can be viewed in Appendix A, which shows the combination of design and coordination and the added time between the beginning of the design process and notice to proceed for construction. This added time allows for a more thorough and precise design of the UEB and allows the builder and Hodess Construction the time to solve any problems with the MEP systems and the clean room itself. The duration from the original summary schedule for design was 173 days, using assumptions based on the date of receiving the funding for the project and the start of construction. The design-build method adds an extra 73 days for design improvements and coordination, along with getting all necessary documentation prepared for the start of construction. These 73 extra days can eliminate potential RFIs, constructability issues and make sure the entire project team is on the right page. Since the clean room is the focal point of the building, a good portion of that time should be spent in studying how the MEP systems transition into the clean room.

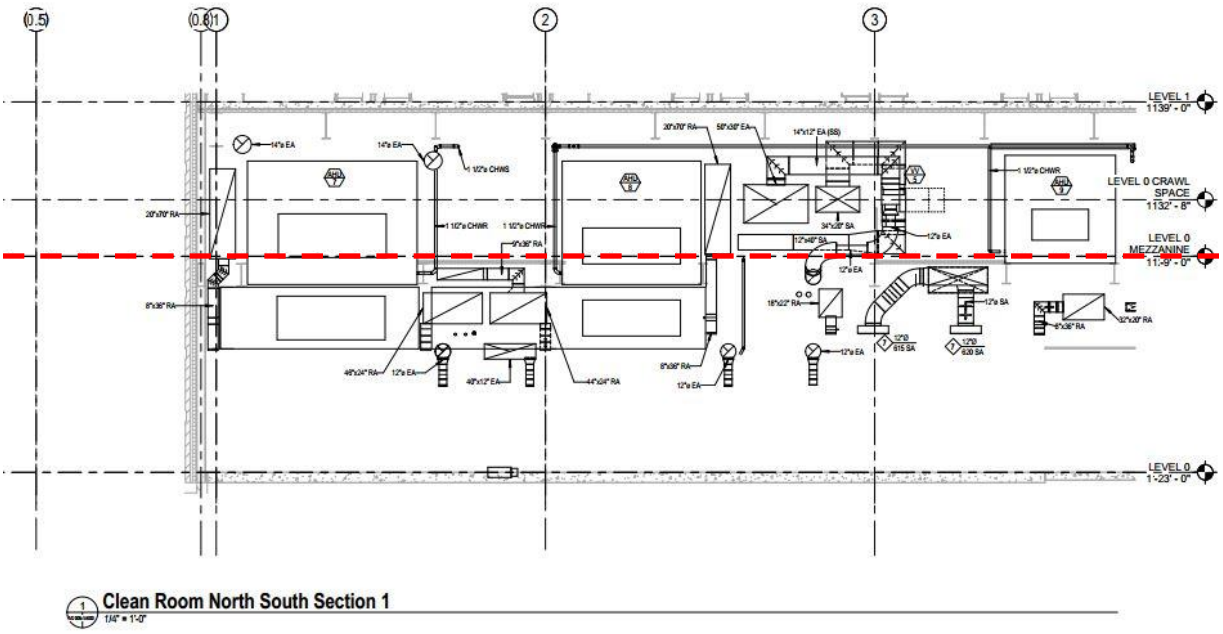


Figure 5: Clean Room Mechanical Section

As seen in figure 5 above, this section provides some detail into how the mechanical system transitions from the Mezzanine into Level 0, highlighted by the red dashed line. Instead of creating the 3D coordination model closer towards the beginning of construction and early on through that process, the model can be created once the design has been finalized and during that design and coordination phase, all the complicated transitions can be solved and reduce the amount of questions and issues with

constructing the mechanical system. The most difficult aspect still remains that the mechanical subcontractor will own the mechanical equipment, while the clean room contractor owns the termination fittings.

While it's difficult to quantify the time savings, aside the extra 73 days of coordination, there still are time savings during construction. Instead of needing weekly coordination meetings to prepare for upcoming work, all of this will have been completed prior to construction so the meetings can be spent highlighting key takeaways from the earlier coordination sessions and focusing on other matters, such as quality control. Along with saving time during meetings, hours spent on RFIs and other paperwork and spent communicating with other team members to get questions answered can be kept to a minimum if not eliminated for the most part, which will again free up time for the project team to accomplish other goals and focus on other issues at hand.

This delivery method is preferable, but in reality, impossible because of the guidelines restricting public institutions and requiring public bidding. Given more time for research this method could be explored more for transitioning it to a private project that features clean rooms but the bulk of the focus is set on how to make coordination more efficient given the project delivery method. The next solution will look into an alteration of the delivery method used on the University Engineering Building.

Altered Design-Bid-Build

The main solution to this analysis involves altering the current project organization, along with including a more detailed focus on the interaction between the clean room and MEP systems how coordination affects those two items.

First, the project organization would be better suited if Hodess was contracted directly to Massaro. Even with Hodess currently being contracted to the owner, Massaro still bears the responsibility of completing the entire project including the clean room and would be considered at fault if unable to deliver the project by the given deadline. To be able to do this, along with still bringing Hodess Construction on during the design phase, the contractual situation will be changed. Hodess would receive a preconstruction contract from the University and once those services are completed, would then receive a construction based contract from Massaro to then be considered a subcontractor. As you can see in figure _, this eliminates a lot of channels to pass information through to get from one party to another.

Previously Massaro would have to contact the University when requesting particular things from Hodess because Massaro did not have a direct line of communication. Now Massaro would be in the direct line of communication with the designers and owner when questions need answered and submittals and other paperwork are needed. This will save time throughout the course of the project but can't be quantified since the savings would be in hours per week in saved time on phone calls, emails, other means of communication and waiting on others to receive the information from.

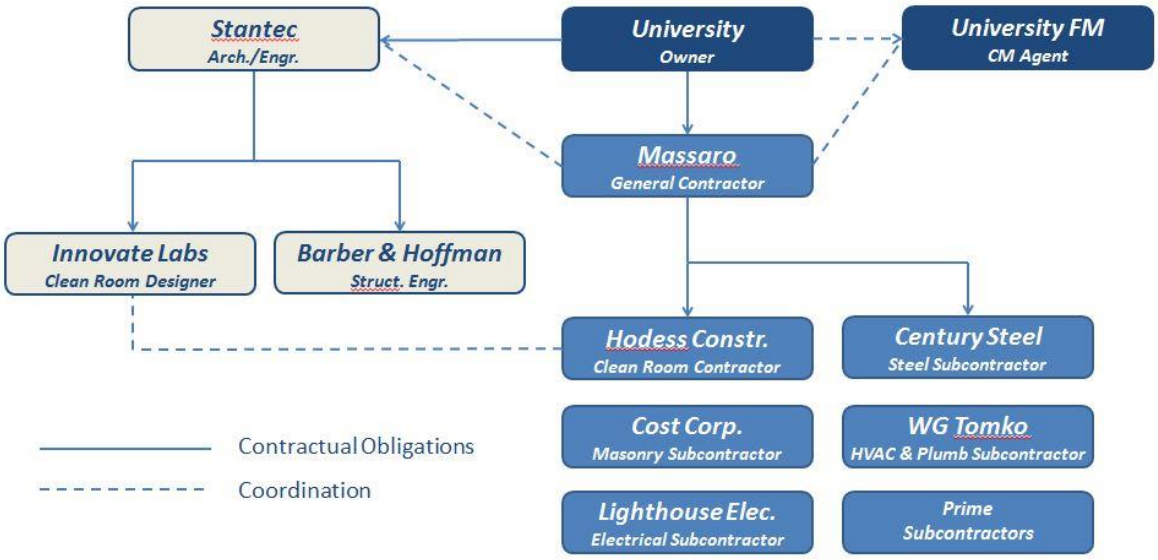


Figure 6: Altered Design-Bid-Build Project Org Chart

The change in contractual obligations acts as a means to reach the ultimate goal of the most efficient methods of coordination as possible. Reiterating what Massaro's project manager said before is that this was the most coordination intensive project he has ever worked on, so the need to make the time spent on coordination as useful as possible is apparent. Therefore, the first task that was necessary was to create a coordination schedule to get all project team members on board and layout what was expected of each of them in order to begin and complete the coordination process. This schedule can be viewed in Appendix A. The coordination schedule was created based on the assumption that Massaro was awarded the project on September 17, 2012, with the coordination process beginning then and construction beginning on January 14, 2013. Because this analysis focuses on the clean room specifically, the coordination schedule reflects this. The 3D model is the key to the success of the project. The MEP systems are too complicated that simply using the old method of tracing over drawings or dealing with clashes when they occur during construction are not acceptable and would delay the project even further.

At the time the clean room construction process has begun, the UEB had already gone through some major delays because of weather and other issues that were out of the project team's hands. Even with the change order adding 20 additional work days, there was still potential to make up for lost time during the construction of the clean room and MEP systems. The first task of coordination was to create the necessary 3D models of the systems. Giving each subcontractor and Massaro roughly one month to create the model allows for two months to coordinate any and all clashes between the systems before construction begins.

After the model was completed, the next key step in the coordination process on the schedule is coordinating the clean room. Coordinating the scopes of work between Hodess and the MEP

contractors is the goal of this process. One issue that was described above by Massaro's project manager, shows the benefits of 3D modeling and clash coordination early during planning phases instead of later during construction. Located directly above the clean room ceiling is the Mezzanine level and plenum space where mechanical duct, pipes, plumbing pipes and electrical tracks run. The ceiling grid for the clean room was designed to be suspended via hangars that are attached to the structural members for the Mezzanine floor. This area, located in Appendix C, is extremely congested and since the hangars were required to be every 4" o.c. and 3/8" in diameter. The clash detection capabilities will show where the hangars intersect with duct, pipes, etc. and solving these clashes early saves time and costs. Aside from the hangars that were discussed as an actual issue that needed solved, other potential scope problems still existed and needed coordinated.

Hodess' scope of work is interesting because they own certain items and equipment, which located anywhere else in UEB would be owned by the respective subcontractor. For instance, Hodess owns the light fixtures in the clean room, but does not own wiring and powering of those fixtures. This issue falls under the electrical equipment activity in the clean room coordination. What the project team needed to understand and outline was when the light fixtures needed ordered and once they were ordered and ready to be installed, how does Hodess notify and work with the electrical subcontractor so that the electrical sub can complete the wiring and powering of all the clean room fixtures. This issue doesn't directly fall under 3D model coordination, but still needed to be addressed and solved because items like this have the potential to be causes for arguments, lawsuits and even liens on the UEB.

Another key area of coordination involves the air-handling units located in the Mezzanine. The air-handling units were crucial for the operation of the clean room, meaning the coordination between Hodess and the mechanical contractor must be beneficial. This ties into the coordination schedule activity, determining long lead items because the air-handling were custom-made, requiring weeks to be manufactured. Also those AHUs had to be installed during the steel erection phase of construction because their sizes were so large, there was no other point during construction when they could be installed. The difficulty arose with coordinating the clean room ceiling grid and all of the transitions where duct enters the clean room because the air-handling units could not be altered or moved or changed after they were installed. All of this had to be sorted out prior to steel erection, which is why the coordination schedule was created, to handle as many potential problems early enough to avoid them later during construction.

Time and cost savings are difficult to quantify for this analysis because coordination early during a project does not directly correlate to time savings during construction. But, early coordination does ease the construction process later and does save time with paperwork and other tasks that take up project team member's days. Halfway through construction on the University Engineering Building, there were not any mechanical related RFIs for the clean room. The fact that there haven't been any RFIs means that hours are saved during the week composing and sending emails, making phone calls and waiting for the design team to answer any questions. Those hours can be better spent managing quality on the project and preparing for activities that will take place weeks ahead of time. Especially when the project has been delayed and time is of the essence, eliminating the need to waste it on

menial tasks and spend on thinking ahead and finding ways to accelerate the schedule and keep the project on track will result in a successful project.

As with the remaining analyses, having the ability to spend more time on it would produce more results. This analysis was difficult because it was tough to provide accurate quantitative results, but by following the project from start to finish would allow for a better grasp on how successful early coordination would be. Since the project had 2 year duration, this report will be unable to provide more results. More research into methods of coordination and the having access to the coordination model would allow for a more detailed coordination schedule. Also spending more time with the project throughout construction could provide quantitative results to the success of the clean room upon completion.

Analysis 2 – Roof Systems Design

Problem Identification

During an interview with the project manager for Massaro Construction, he discussed the desire to use a built-up roof system instead of the self-adhered, single-ply TPO membrane system, which is called out in the drawings and specifications. The reason behind this is due to the cold weather during the winter months that could potentially affect the installation of the roof system because of temperature and other material requirements. Cost and time savings are driving the decision on Massaro's part, especially time, due to the need to gain time back after delays during the excavation and foundation phase of construction.

Analysis Goals

The goals of this analysis will be the basis of the research performed for each different roof system. Regarding the TPO membrane system the goal of the research is to determine whether the schedule can be re-sequenced and/or accelerated to reduce the extra costs associated with the construction of the roof. For the alternate systems, the first goal is to complete research that will narrow three alternate systems down to one system that will be used for comparison to the TPO membrane. The final goal of this analysis is to make a final recommendation based on the information gathered as to whether the TPO membrane system can still be successful from a cost and schedule perspective or whether an alternate system is better suited for the UEB based on the following factors: cold weather construction, contractor familiarity, cost, schedule and owner approval.

A key assumption made for this analysis involves the rock deck analysis that acts as a structural breadth. In the specifications for the University Engineering Building were included details on a potential green/garden roof that could have been used for the UEB. In terms of the analysis, the green roof will not be studied as a viable option because early research concluded that it would not produce results that meet the expected requirements of the new system analysis. Also, the University never considered it as a potential roof system because of budget constraints. However, the green roof is included as part of the roof deck study because the weight of a green roof would greatly affect the choice in metal decking used on the UEB roofs.

Fully-Adhered TPO Membrane

The Firestone UltraPly TPO Membrane is a fully adhered system that is the design choice on the UEB project. As shown in figure 7, the system is comprised of 4" rigid insulation, ½" protection board, expansion joint, and then the single-ply TPO membrane.

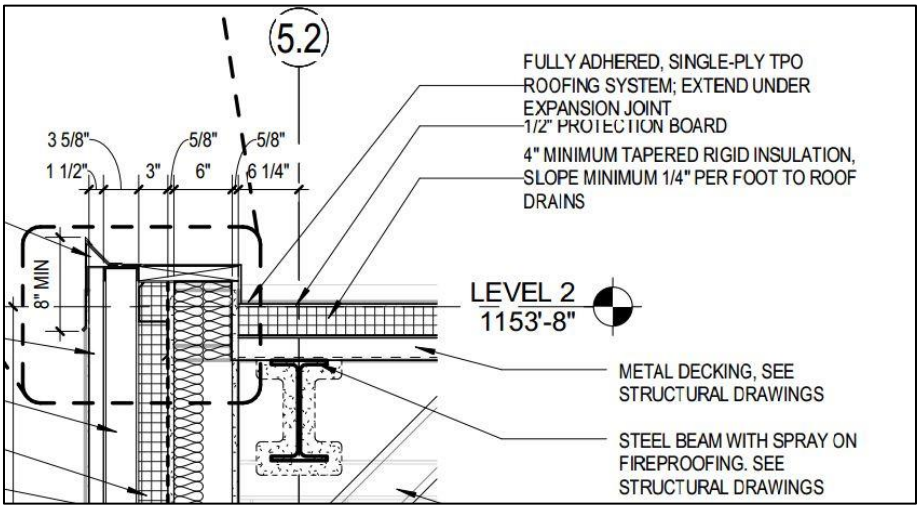


Figure 7: Roof System (Courtesy of Stantec)

Cold Weather Constructability

The main issue plaguing the project team regarding the UEB roof is because of the cold and below freezing temperatures that have occurred throughout January and carried over into February. The materials are not as much of the issue as the adhesives required to make the system fully-adhered. The bonding adhesive for the membrane used on the University Engineering Building is Firestone's Single-Ply LVOC Bonding Adhesive, which the technical information sheet can be viewed in Appendix B. The bonding adhesive's main drawback is that it must be stored and kept at a minimum of 60 °F to achieve maximum results. The polar vortex that has caused temperatures to be in the single digits for days at a time has severely affected construction on both the lab and office roof systems.

Originally the entire system was supposed to be fully adhered, including the layers of insulation to the metal deck. For that, Firestone's I.S.O.Spray S Adhesive was going to be used, but again the below freezing temperatures have caused corrections to be made. After speaking with Massaro's project manager, he was able to convince the architect to agree to have the first 2" layer of insulation be mechanically fastened to the metal deck, allowing for easier installation and the ability to do so in less acclimating temperatures. The main reason behind this analysis was because of the inability to easily construct the approved roof system in cold weather.

Schedule Re-sequencing

The project schedule is broken into two main components, Lab and Office, each representing their corresponding wings of the building. The Lab portion of the roof was originally scheduled to take 61

days, with the roof system itself having duration of 15 days. This part of the schedule can be seen in figure 8.

Building Roof & Exterior Enclosure		133	133		11-Nov-13	19-May-14
Lab		133	133		11-Nov-13	19-May-14
Lab - Roof		61	61		12-Dec-13	10-Mar-14
Lab-30000	Roof Blocking - Lab Roof	5	5	0%	12-Dec-13	18-Dec-13
Lab-30010	Roof Drains - Lab Roof	4	4	0%	13-Dec-13	18-Dec-13
Lab-30020	Roofing System - Lab Roof	15	15	0%	11-Feb-14	03-Mar-14
Lab-30030	Lightning Protection - Lab Roof	5	5	0%	04-Mar-14	10-Mar-14
Lab-30035	Install Roof Crane	5	5	0%	04-Mar-14	10-Mar-14

Figure 8: Lab Roof Activities

The Office wing of the building, which has a smaller area than the Lab roof, was originally scheduled to take 30 to complete, with the roof system occupying 20 of those days, as seen in figure 9.

Office		101	101		25-Nov-13	17-Apr-14
Office - Roof		30	30		07-Jan-14	17-Feb-14
Off-30000	Roof Blocking - Office Roof	5	5	0%	07-Jan-14	13-Jan-14
Off-30010	Roof Drains - Office Roof	4	4	0%	08-Jan-14	13-Jan-14
Off-30020	Roofing System - Office Roof	20	20	0%	14-Jan-14	10-Feb-14
Off-30030	Lightning Protection - Office Roof	5	5	0%	11-Feb-14	17-Feb-14

Figure 9: Office Roof Activities

By looking at the schedules, it is clear that the Lab roof was supposed to start after the Office by almost a month. After speaking with Massaro's project manager, it was deemed necessary to re-sequence the Lab roof to be completed first. The reasons behind this were that the Lab wing of the UEB was more important to the critical path and would have affected too many other activities if left to wait for later. The mechanical penthouse is located in the Lab wing of the building, so enclosing the roof to protect the custom-built and expensive air-handling units and other equipment is a major priority.

Trying to accelerate these activities has proven difficult because of the unpredictability of the weather and temperature. The fact that later in January and through the first couple weeks of February, the weather, when reasonable enough for construction hadn't last longer than a day or two, so re-sequencing where possible or using an alternative system that is easier to construct seems like a better solution to the roof construction problem.

The resequenced schedule shifts the Lab roof system to occur prior to the Office and adjust some of the start dates for particular activities. The Lab Roof System activity shifted to January 14th, moving up the end of that task to February 3rd. The Office roof system activity was then bumped back to February 11th and completed by March 10th. The complete roof system schedule can be viewed in Appendix B.

Cost

The fully adhered TPO roof system had a cost impact for the materials needed for the system, as well as affecting the general conditions costs for Massaro because of the need for temporary heating and enclosure. Temporary heat and enclosure are necessary and very common for construction projects during the colder weather months, but on the University Engineering Building those costs were higher than normal because of the issues with the roof system and the frigid, below-freezing temperatures.

After speaking with Massaro's project manager, the amount of temporary heat required he said increased because of having to maintain roughly 60°F during times when the temperatures were in the teens and twenties.

Adjusting the general conditions costs to meet the increased need and temporary enclosure, the revised general conditions costs increased by roughly $8,000. These values can be seen in the following tables.

Table 2: Original General Conditions Estimate

TOTAL			$1,610,845.00
TOTAL CONSTRUCTION COSTS * 6%			$1,962,000.00
COST DIFFERENCE			$351,155.00
% DIFFERENCE			17.90

Table 3: Revised General Conditions Estimate

TOTAL			$1,618,545.00
TOTAL CONSTRUCTION COSTS * 6%			$1,962,000.00
COST DIFFERENCE			$343,455.00
% DIFFERENCE			17.51

The basis for comparison between the 3 roof systems costs was compiled using the materials included in the fully-adhered TPO system. The key with this system compared to the InvisiWeld system is the inclusion of adhesives, which are the main reason behind the schedule affects on the UEB roof systems. The fully-adhered TPO estimate came to a total of just under $94,000 and the breakdown can be viewed in table 4.

Table 4: Fully-Adhered TPO Estimate

Fully Adhered TPO Membrane Roof				
Material	*Quantity*	*Unit*	*Cost/Unit*	*Total Cost*
TPO Membrane (80 mil)	24000	SF	$1.03	$24,720.00
Multipurpose Adhesives	40	600 SF	$145.00	$5,800.00
Expansion Joint	800	LF	$2.00	$1,600.00
1/2" Protection Board	24000	SF	$0.53	$12,720.00
(2) 2" Rigid Insulation	24000	SF	$0.65	$15,600.00
Single-Ply Memb. Sealants	100	1 gal. Pail	$75.00	$7,500.00
Sealant Primers	100	1 gal. Pail	$67.00	$6,700.00
Sheet Flashing	24	100 SF	$251.00	$6,024.00
Bonding Adhesive	54	450 SF Pail	$145.00	$7,830.00
Fasteners	25	5" HD 1000/Pail	$190.00	$4,750.00
Metal Termination Bar	80	10 LF	$7.00	$560.00
Total				***$93,804.00***

Contractor Familiarity & Owner Approval

The fully-adhered TPO system satisfies both of these requirements, otherwise, this wouldn't have been the design choice or different contractors would be performing the work. Massaro has worked on many previous projects that utilized TPO roof systems including mechanically, self and fully adhered. The roofing contractor, Kalkreuth Roofing has vast experience and expertise when it comes to TPO roof systems. There is nothing out of the ordinary involving this roof system construction-wise, just the adverse temperatures and weather have made it more difficult than one would expect.

This was not the original design for the roof system, but this will be discussed later. The University did agree during the design phase to a change in roof systems to the fully adhered TPO system. This was mostly a cost driven measure, but the University feels that the same quality will be present even though maintenance is not as easy as with other roof systems. Familiarity and Owner Approval, therefore, will play no part in the final decision for the fully-adhered TPO system.

Traditional Built-Up Roof

The first alternative system to be researched to determine whether it is a viable option to replace the fully-adhered TPO membrane is a traditional built-up roof system.

Cold Weather Constructability

This is the most important determining factor for the UEB project because finding a roof system that can be constructed easier in cold weather will save the project team time as well as costs. Compared to the fully-adhered system, the built-up roof is much easier to construct in colder temperatures. Instead of using adhesives, which must be kept at temperatures above freezing and often around room temperature, the built-up roof can be constructed with hot asphalt acting as the bonding agent. Consulting Firestone's "BUR Roof System Application Guide" the insulation layer can be attached via mechanical methods, asphalt or adhesive. The clear choice would be asphalt since the rest of the layers for the roof will be bonded with asphalt. The asphalt can be delivered to the site every day ensuring it is kept at optimal working temperatures and minimizes the time between arrival and use. The ply used for the built-up roof can also be kept at lower temperatures compared to the TPO membrane, with the BUR at a minimum of 40 °F and the TPO at 60 °F. After speaking with the project manager, he stated that from past experience and the conditions they have been facing that a built-up roof system would be far easier to construct and plan with because they wouldn't have to worry about the temperature every day and finding time to fit construction in based on the temperature and working conditions.

The make-up of the roof system can be viewed in figure 10. While this is not the exact and final make-up, the built-up roof will be four layers with the cover board and rigid insulation beneath it, similar to the TPO roof make-up.

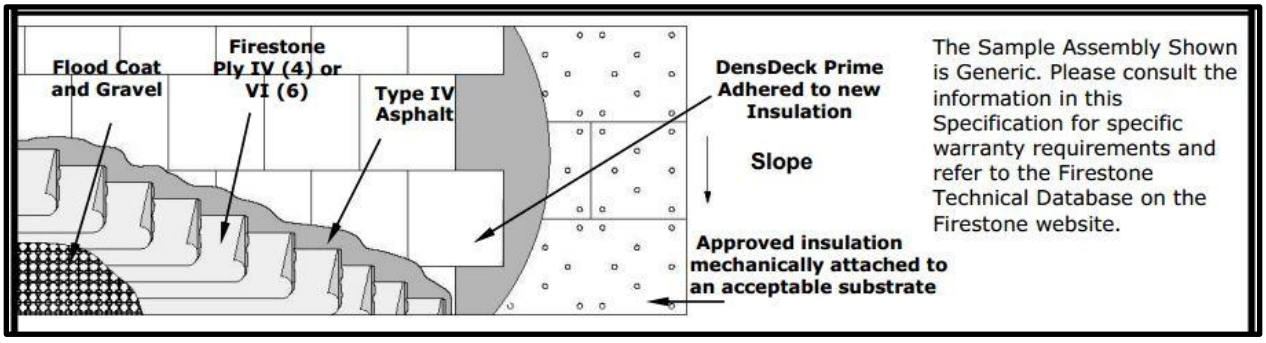


Figure 10: Built-Up Roof (Courtesy Firestone Building Products)

Cost & Schedule

Both cost and schedule are main driving factors in whether the alternate roof systems are feasible over the fully-adhered TPO system. The built-up roof system does not include as many materials as the other roof system because of the simplicity of the design. However, the estimate shows that the cost of the built-up roof system is much greater than the fully-adhered TPO system. The exact figure can be seen in table 5.

Table 5: Built-Up Roof Estimate

Traditional Built-Up Roof				
Material	*Quantity*	*Unit*	*Cost/Unit*	*Total Cost*
Ply VI Membrane (4 Layers)	96000	SF (1 - Layer)	$0.85	$81,600.00
Asphalt	30	ton	$820.00	$24,600.00
(2) 2" Rigid Insulation	24000	SF	$0.65	$15,600.00
Cover Board	24000	SF	$0.53	$12,720.00
Total				***$134,520.00***

The built-up is over $40,000 more than the fully-adhered TPO system and with a strict budget, the University most likely would not approve of a change order for such a large price increase for the roof systems.

The roof activities were altered to reflect the ease in cold weather construction of the built-up roof compared to the TPO membrane roof. This schedule uses the assumption that the resequencing moving the Lab roof before the Office roof because it is logical to get the Lab roof completed first since it covers

the Penthouse level and the air-handling units located there needed protected from the elements and to allow for fire-proofing to begin on the 3rd Floor structure.

The blocking and the drain installation activities do not change from the TPO system and again fall on the same days in December. The system activity duration is based on the roofing contractor's statement that his crews were able to complete roughly 2,000 SF per day. This 2,000 SF per day amounts to only one layer of the built-up roof so the duration would last by multiplying the roof area by 4 and then dividing by the output. This can be seen in table 6 and is the source of the schedule durations.

Table 6: Built-Up Roof Durations

Location	*# of Layers*	*Area (SF)*	*Area/Day (SF)*	*Total Days*
Lab	4	14,000	2,000	28.00
Office	4	10,000	2,000	20.00

As seen above, the Lab roof duration lasted 28 days, which is much greater than the fully adhered TPO system. However, the Office roof system duration lasts 20 days, which is the same as the fully adhered TPO. Overall, because of the resequencing, this didn't drastically affect the completion date of both roof systems, but the Lab roof did take longer than planned and did have a negative impact on the final results. The full schedule for the built-up roof systems can be viewed in Appendix B.

Contractor Familiarity & Owner Approval

Massaro's project manager originally made the suggestion about using a built-up roof system, when speaking with him regarding technical report 3. Massaro has vast experience with built-up roofs, as does Kalkreuth Roofing. Contractor familiarity is a non-issue for this system. Built-up roof was the original design choice for the University Engineering Building, but due to budget issues, was value engineered out and replaced with the fully adhered TPO membrane. The University normally expects and requires a built-up to be included in the design, so again the owner would have no problems with approving this change in system with a built-up roof.

Firestone InvisiWeld TPO System

The InvisiWeld system is an alternative to a traditional mechanically-adhered TPO roof system. This system allows for TPO membranes to be attached with a method that is different from fully and mechanically adhered. This is the summation of the installation guide according to Firestone's application guide, "Following the installation of the approved roof insulation using a special TPO coated InvisiWeld metal insulation plate, the membrane system is attached using a non-penetrating, induction welding technology, whereby the TPO membrane is welded to the plates using an induction welding tool …. In doing so, the insulation plate acts as the point of attachment for both the membrane and the insulation."

The plate described above can be seen in figure 11, along with its proper installation.

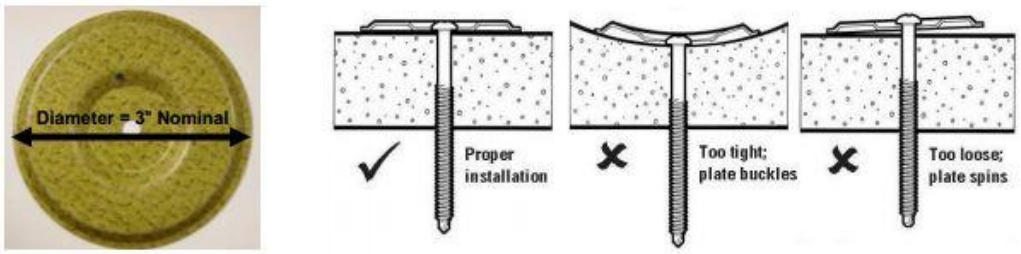


Figure 11: InvisiWeld Plate & Proper Installation (Courtesy Firestone)

The induction welding machine along with a magnetic tool can be viewed in figure 12. The magnetic tool is used after the weld has been completed and used to help secure the weld and to ensure the membrane is properly attached to the plate.

The assembly does not differ from the approved design by the architect, other than the presence of the InvisiWeld plates. A comparison between the two assemblies can be seen in Appendix B.

The benefit of this system over a traditional mechanically-adhered system is the non-penetrating nature of the bond, meaning increased air-tightness and less of a chance for rain water and other moisture to reach the bottom layers of the roof system.

Figure 12: InvisiWeld Machine & Magnetic Tool (Courtesy Firestone)

Cold Weather Constructability

There isn't a large difference between the fully-adhered and the InvisiWeld system, but the InvisiWeld does have an advantage in cold weather. The induction welding tool pictured above means the bond is a weld, which does not require the use of adhesives. Using the architect's change in allowing the bottom layer of insulation to be mechanically fastened to the metal deck along with the welded connection, the InvisiWeld system can be constructed in almost any temperature. The membrane itself is the same as the one used for the fully-adhered system, so the only requirement would be to abide by proper storage requirements for it, keeping it at 60 °F.

Cost & Schedule

After studying Firestone's product literature, the InvisiWeld system can save both material and labor costs over the fully-adhered and other mechanically-adhered TPO systems. Also due to the decrease in fasteners required and system installation methods, the InvisiWeld system would also decrease the duration of the roof activities, allowing for more cost decreases to extra enclosure and heating.

First to asses are the costs of the InvisiWeld system. Without first analyzing the cost differences, the material differences must be mentioned to fully understand how the two systems will be different. First the InvisiWeld is not fully-adhered and also the insulation and cover board will be mechanically fastened to remove the need for adhesives, since they were the main problem for constructing in the cold weather. The insulation and cover board are still the same as with the fully-adhered system because they are compatible between the two systems. On top of the cover board go the InvisiWeld plates, which are an addition and will be an added cost. Also included with the plates is the potential added cost of the InvisiWeld machine. The final difference is the t-patches needed for repairs on the InvisiWeld system.

The cost total can be viewed in table 7. The quantities listed reflect the coverage area for both the Lab and Office roofs and the units are based on material order costs provided by Allied Building Products and all materials are Firestone brand to maintain consistency with the other systems included.

Table 7: InvisiWeld Roof Estimate

InvisiWeld TPO Membrane Roof				
Material	*Quantity*	*Unit*	*Cost/Unit*	*Total Cost*
TPO Membrane (80 mil)	24000	SF	$1.03	$24,720.00
Expansion Joint	800	LF	$2.00	$1,600.00
1/2" Protection Board	24000	SF	$0.53	$12,720.00
(2) 2" Rigid Insulation	24000	SF	$0.65	$15,600.00
Single-Ply Memb. Sealants	100	1 gal. Pail	$75.00	$7,500.00
Sealant Primers	100	1 gal. Pail	$67.00	$6,700.00
Sheet Flashing	24	100 SF	$251.00	$6,024.00
Fasteners	25	5" HD 1000/Pail	$190.00	$4,750.00
InvisiWeld Plates	21	500 Pail	$90.00	$1,890.00
InvisiWeld Machine	1	EA	$7,500.00	$7,500.00
T-Patches	5250	EA	$0.44	$2,310.00
Pipe Boots	10	EA	$23.00	$230.00
Total				***$91,544.00***

Even with the additional costs of the InvisiWeld machine, plates and patches the entire cost is still roughly $2,000 less than the fully-adhered TPO system and over $40,000 less than the built-up roof. This cost information in addition to the schedule savings and the cold weather constructability, easily make the InvisiWeld system the most feasible and recommended system for the University Engineering Building.

Another aspect when comparing InvisiWeld to the Fully-Adhered system, is general conditions impacts. Since the InvisiWeld system is entirely mechanically fastened, there was no need for adhesives, which caused the need for more temporary heating and enclosure because the adhesives needed the time to

settle after installation. This means that the increase in general conditions that were part of the Fully-Adhered, do not exist for InvisiWeld saving Massaro roughly $8,000.

To calculate the duration savings for the InvisiWeld system a few factors must be taken into account. First, the lack of adhesives for the InvisiWeld compared to the fully-adhered membrane means that the temperature does not affect whether work can be completed. The temperatures and weather are based on current January temperatures and the polar vortex that has hit much of the east coast including the location of the University. Second, the assumption is made that the roofing crew can weld 300 plates per hour; this is based on contractor familiarity and Firestone's published statement that a seasoned operator can weld that many plates per hour. Finally, the plate pattern will be based on Firestone's Insulation Attachment and Application Guide, which can be viewed in Appendix B.

Using those assumptions table 8 was created to calculate the number of days needed to weld the membrane to all of the plates.

Table 8: InvisiWeld Plate Weld Durations

Location	Area (SF)	4'x8' Board (SF)	# Boards	Avg. # of Plates	Total Plates	# Plates/Hr.	Total Hrs.	**Total Days**
Lab	14000	32	437.5	14	6125	300	20.42	**2.55**
Office	10000	32	312.5	14	4375	300	14.58	**1.82**

Even with adding a couple days to each wing due to cold weather, the duration for installing the roof system is drastically less than the current duration for the fully adhered, which will only increase as long as the snow and below freezing temperatures continue. Originally the lab was to take 15 days to install the roof system, but with InvisiWeld, that is one-fifth the duration. The office is an even greater reduction at one-tenth the original duration. The key to these savings are the fact that this system can be installed in those frigid temperatures without the fear of complications during application and curing, like with the fully-adhered system. After adjusting the activities based on the results from the installation assumptions for the InvisiWeld system, the Lab roof system was determined to take 35 days, while the Office roof system would take 25 days.

The activities for the actual system were broken down into 4 sub-activities. The first is the installation of the rigid insulation and cover board. These items were assumed to be mechanically fastened, as stated above because of the problems with the adhesives. Following the build of the roof system, the next activity was to layout the InvisiWeld plates along with laying the TPO membrane. The final necessary step is to perform all of the plate welds to form the bond on the membrane. The weld durations were based on table 8, and were completed as the membrane was laid out.

Contractor Familiarity & Owner Approval

While not new, the InvisiWeld system is not a typical TPO style roof, but after speaking with both the project manager and the foreman for Kalkreuth Roofing, they both are familiar with the system.

Kalkreuth has used this system in the past and would consider themselves experienced enough to install the system to the quality expected by the University. The University has not used this system before on another building, but showing them the data collected along with the information on the system, it is an easy pitch to convince them that InvisiWeld is a viable roofing option that maintains quality and saves time and cost. Another key is that InvisiWeld carries the same warranty as a fully-adhered TPO system, making it beneficial for the owner in the long run.

Results & Recommendations

After studying the three systems, based on the outlined criteria, the InvisiWeld roof system was the most feasible and logical given the problems that affected the UEB.

Cold Weather Constructability

The benefits of the InvisiWeld system were already stated for cold weather constructability, but the key factor is the fact that it is mechanically fastened. Removing the adhesives removed most of the problems with constructing the roof in January and February and the speed of construction was increased because of the ease and speed at which the membrane can be welded to the plates. These results can be seen in the schedule savings which are listed below.

Schedule

Taking in all assumptions and comparing the created schedules, table 9, was created to display the schedule difference between the three roof systems and to show the big difference between InvisiWeld and the other systems.

Table 9: Roof System Duration Comparison

Roof System	*Lab Duration*	*Office Duration*	*Total Duration*
Fully-Adhered TPO	43	50	68
InvisiWeld	**35**	**25**	**43**
Built-Up Roof	51	47	65

The durations were split into both Lab and Office, with the total duration being the total number of days from the start of the Lab roof to the end of the Office roof. There was an overlap in work being completed that can be seen in all three schedules located in Appendix B. The benefit of the InvisiWeld roof system is very apparent from the start since it is at the very least eight days faster than the other systems. The other added benefit is that the Lab roof system was completed at the end of January, meaning that spray-on fireproofing began and the interior work followed soon after instead of having to wait until late February and building more temporary enclosures/covers to allow fireproofing to begin. Another benefit is the penthouse mechanical units were protected from the elements and the connection work could begin with mechanical rough-ins. A revised detailed project schedule can be viewed in Appendix B.

Cost

As stated above, the InvisiWeld system cost is less than both of the other roof systems, while providing equivalent quality as the fully-adhered TPO system. The total cost breakdown for the systems can be seen in table 10.

Table 10: Roof System Cost Comparison

Roof System	*Total Cost*
Fully-Adhered TPO	$93,804.00
InvisiWeld	**$91,544.00**
Built-Up Roof	$134,520.00

Owner Approval & Contractor Familiarity

As stated above, these two checks did not present any problems as the roofing contractor has built many InvisiWeld systems on past projects and the University did not object as long as it met similar quality as the fully-adhered system and included the same warranty, which a Firestone Building Products representative confirmed.

Based on the above information and findings, it is clear that the Firestone InvisiWeld TPO system provided the University with a comparable roof system to the original Fully-Adhered TPO and provided Massaro and the roofing contractor the added ease of schedule savings to help bring the UEB project back on schedule.

Roof Deck Study (Structural Breadth)

Branching naturally from the roof system analysis, a roof deck study was chosen to act as a structural breadth, since a change in the roof system could potentially lead to a change in the metal decking used. As with any study, assumptions were generated.

- Green Roof System is included to see the structural effect it causes on the metal deck
- Fully-adhered TPO and InvisiWeld are of equal weight and would not require any drastic change in metal deck
- Vulcraft Steel Roof and Floor Deck catalog was used when determining the type and gauges of metal deck
- From Drawing S000 (See Appendix B)
    - Minimum Roof Live Load = 30 psf
    - Roof Garden/Assembly = 100 psf
    - Allowance for Hanging loads for roofs over Mechanical Equipment Room = 30 psf
    - Ground Snow Load = 30 psf
- Structural members can withstand loading from changes in metal decking and roof system
- Lab and Office separated because of span factors

The process for the roof deck study began with studying the lab roof plan. The design was simplified so that it was represented as a 150’-4” x 60’ rectangle with 5’-4” spans between joists, triple span condition

and 4" of rigid insulation, per the roof design shown in figure 7. The loads for the different materials were then determined based on previous assumptions and listed within the drawings. The built-up and TPO roofs were calculated to be the same at 100 psf and the garden roof was calculated to be 166 psf. The next step in the process was to find a potential deck type and size that would work with the constraints of the spanning and loading.

For the built-up and TPO roof systems, Vulcraft's 1.5B roof deck was used as a starting point. From there based on the max construction span needed, the B24, 24 gauge, was chosen because its max span is 5'-10". Next the total weight of the roof loads were analyzed based on the joist spanning and for the two remaining conditions did not affect the outcome so the B24 deck was chosen to be used for the lab roof. The exact process can be viewed in detail in Appendix B.

The garden roof however, required a different deck to be used because of the increased loading. Again, the 1.5B deck was determined a potential option, but unlike the BUR and TPO, the B19 had to be chosen. The B19 passed all 3 necessary criteria and therefore was chosen to be used.

Similar results were witnessed with the office roof but some changes were made because of the structural layout. First the assumption for 30 psf because of mechanical equipment was not needed because the mechanical penthouse is located in the lab wing, which changed that load from 30 to 10 psf to account for miscellaneous dead loads. The second change was the span between joists was reduced to 5'-0". Following the same process in meeting the three necessary criteria, the built-up and TPO roof systems would use the Vulcraft 1.5B, B24 roof deck, as would the garden roof, using the same B24 deck.

To complete this study, the results from metal deck analyses are compared to the metal decks chosen by the structural engineers on the UEB. According to note 2 on drawing S206, the metal deck used on the lab roof is 1 ½" – 20 gauge galvanized metal roof deck. This means that the B24 deck chosen for the built-up or TPO roof system would be thinner since it is 24 gauge. This would mean a cost saving because deck costs decrease as the gauge increases. For the garden roof, it was surprising to see the gauge was only a difference of 2 with the calculations producing 18 gauge and the design professional using 20 gauge for a lighter roof system. The 18 gauge deck would come with a cost increase, but would be overshadowed by the increased costs of a garden roof.

While the results for the lab roof were slightly surprising, they were expected, at least in terms of the garden roof. On the other hand, the office roof, because of the decreased joist span, made for some interesting results. The built-up and TPO were similar to the lab, with increasing the gauge from 20 to 22, again a cost savings. Now the interesting results were with the garden roof. The expectation would be that the deck gauge would decrease, meaning a thicker deck to account for the increased loads. The deck determined from the Vulcraft catalog that would be suitable is the B24, meaning the gauge increases from 20 to 24. The 4" span decrease was enough to allow for a thinner metal deck to be used.

Analysis 3 – Underground Spring Analysis

Problem Identification

During the excavation and foundations phase of construction on the University Engineering Building, an underground spring was discovered that was previously not found during the geotechnical evaluation. This spring in conjunction with poor weather caused delays in foundation pours and affected the formwork and rebar cages for the grade beams and other components of the foundation wall. These delays pushed the critical path back, causing Massaro to seek and receive a change order to add an additional 20 working days to the schedule. The project team's solution to the underground spring involved installing a sump pump that will become a permanent feature of the building. A point that is worth noting is that since the underground spring was not discovered until the excavation phase, Massaro had little time to determine a solution to this problem. This analysis presents the other options, that had the project team been aware of the problem earlier could have considered for the final solution.

Analysis Goals

The goals for this analysis revolve around different systems that exist to deal with an underground spring. Alternative systems will be analyzed based on cost, schedule and long term effectiveness to determine whether they would be a more feasible solution than a permanent sump pump. The final solution will be based on the results of the research and what benefits the project most.

A mechanical breadth will also be completed as a natural extension of the analysis, to determine the plumbing design loads and size a sump pump and back-up sump pump based on the solution put in use by Massaro and the project team.

Site Existing Conditions

The University Engineering Building is located on land that up to that point only had asphalt drive and walkways. As shown in figure 13, this map view of the University campus displays the relative openness of the site from the North, with the exception of a few roads. The red block represents the location of the UEB compared to the neighboring buildings and surrounding space.

An existing conditions plan was created based off the information provided by the architect and geotechnical report for existing utilities and other information on the area. This plan can be viewed in Appendix C and features the locations of the test bores that were taken as part of the geotechnical report. The test bores from the geotechnical report discovered the groundwater table to be located at a depth of 23' at the northeast corner of the UEB and at 18' at the southwest area of the building.

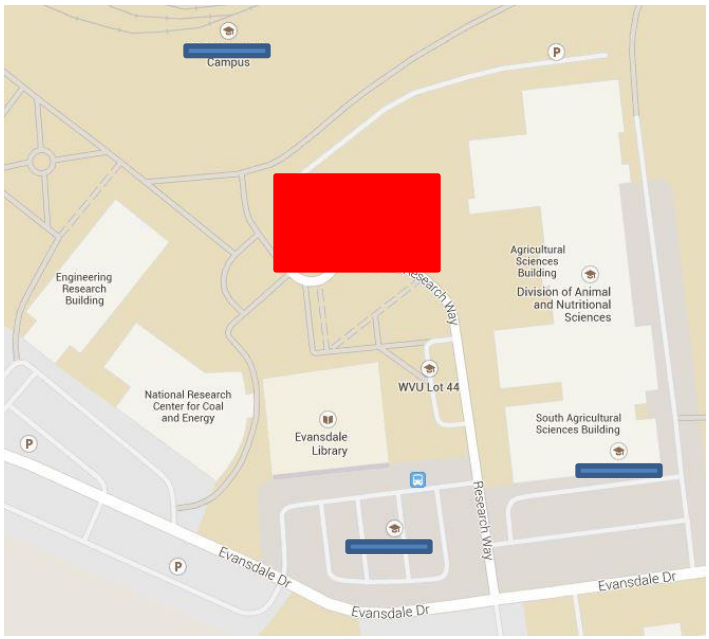


Figure 13: University Campus Map (Courtesy Google Maps)

Another aspect that affected the site is the Monongahela River, which runs from East to South of the University campus. The exact extent at which the river affects the underground spring and the water table was unable to be determined, which would require more in-depth research and time spent studying the entire surrounding area. The location of the Monongahela River compared to the University campus can be viewed in figure 14.

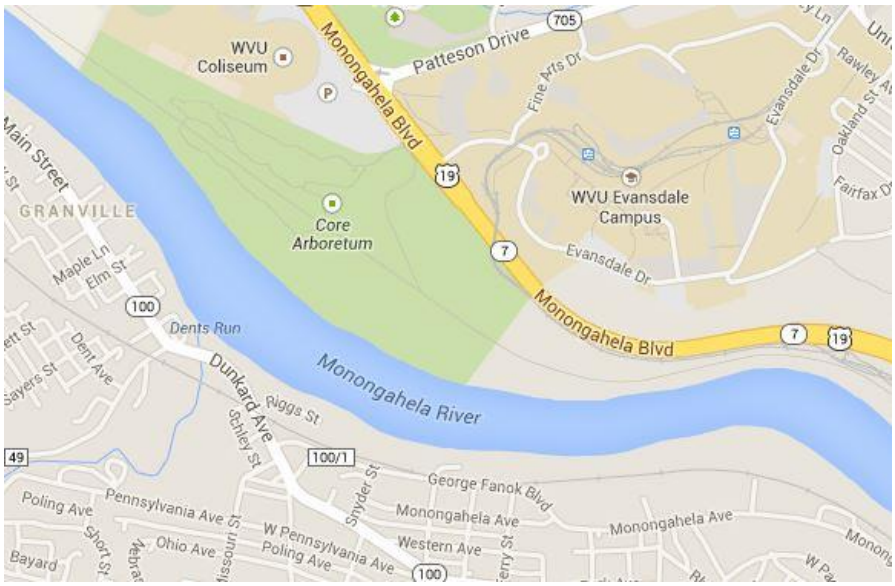


Figure 14: Monongahela River Map (Courtesy Google Maps)

The location of the underground spring was determined to be at the front of the building spanning from the east wall of the Office wing to halfway across the Lab wing. The spring location is included on the existing conditions plan.

Sump Pump

Since the underground spring was discovered during the excavation and foundation phase of construction, the project had to make a quick decision on how to solve this problem. Their solution was the installation of a sump pump to handle dewatering during construction that would transition into a permanent sump pump once the UEB was completed. The following figure highlights where the sump pump well is located and where the water is pumped to.

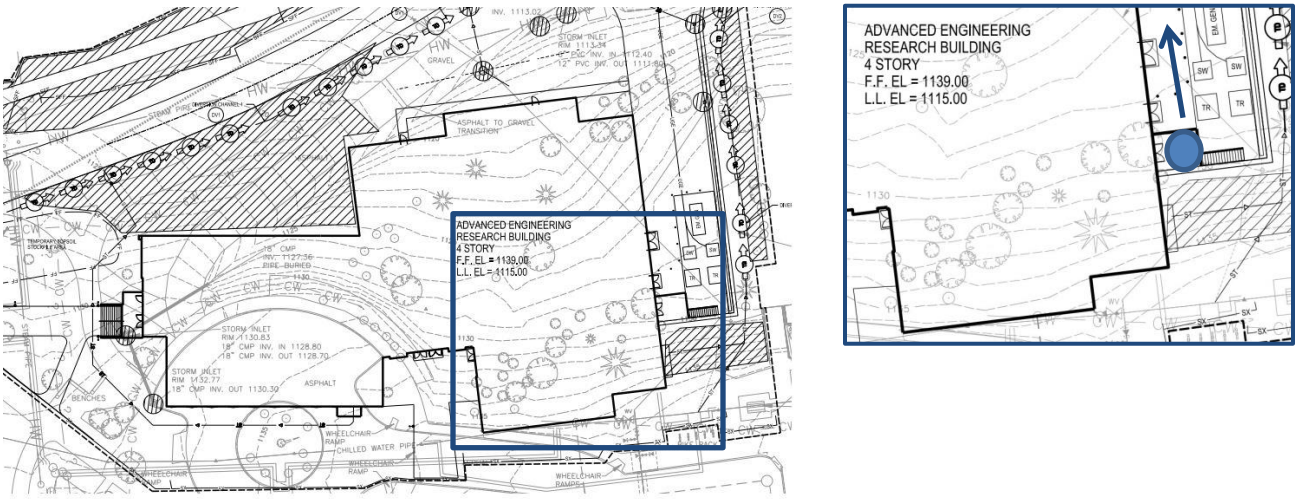


Figure 15: Sump Pump Well Location (Courtesy of Stantec)

Figure 16: Sump Pump Well (Courtesy Jeremy Feath)

The well is located off the east side of the Lab wing, located where the emergency generator is and right outside from the clean room/Level 0. In terms of pumping the water away from the building, the water is pumped north of the building. The actual well can be seen from this picture taken during a site visit.

Aside from the necessity of the sump pump throughout construction, the cost and schedule impacts must still be analyzed in order to determine whether the proposed alternative is more feasible.

The cost impact can be broken down into two main areas, materials and installation. The materials include piping and the actual pump used, while the installation involves excavation, installing the pump and installing the piping. The assumption was made that any equipment required for excavation was still on site at the time of the discovery of the spring and would remain on site to complete any necessary work to install the sump pump.

The cost for the sump pumps were relatively cheap, compared to the other materials needed and because of the necessity, did not have a great impact on the project budget. The total cost for the sump pump system can be seen in table 11.

Table 11: Sump Pump System Estimate

Material	*Quantity*	*Unit*	*Cost per Unit*	*Total Cost*
Sump Pump (Temporary)	1	EA	$120.00	$120.00
Sump Pump (Permanent)	1	EA	$215.00	$215.00
2" PVC	160	LF	$12.09	$1,934.40
Check Valve	1	EA	$37.25	$37.25
90° Elbow	1	EA	$46.86	$46.86
45° Elbow	3	EA	$36.48	$109.44
Total				***$2,462.95***

When creating the schedule to install the sump pump, the location of the well was taken into account, so it did not coincide with any foundation work on the east Lab side of the building. It was determined that the excavation for the sump pump and pipe would take place after the east Lab foundation wall was poured. This work took place at the same time as the other foundation walls and would not affect the critical path of the schedule because only 2 – 3 crewmen were needed at any one time to complete the activities.

Exterior Foundation Waterproofing

The alternative solution that seemed the most feasible and logical, had the underground spring been discovered during the geotechnical study, was adding a waterproofing membrane to the exterior of the foundation wall. After studying the structural drawings, there was no mention of any sort of membrane or sealant that was used on the exterior of the foundation walls as a means of water or damp-proofing, which can be seen in Appendix C.

The detail shows a foundation drain provided at the base of the exterior of the Level 0 foundation wall with different soil fills above it, but nothing to protect the wall from moisture penetration. The added benefit of having the waterproofing membrane on the foundation wall means the sump pump would not need to be permanently running and provide an extra layer of moisture protection for Level 0, which houses the clean room. However, with those benefits, there are schedule and cost impacts because of the addition of the membrane.

This analysis used Tamko's TW-60 waterproofing membrane as a basis for the different areas included in it. The first area of study was the impact adding the waterproofing made on the project schedule. Table 12 outlines the duration required to install the membrane on the Level 0 and Mezzanine walls, with both being subgrade and the most important in terms of rooms and equipment housed in them.

Table 12: Foundation Waterproofing Membrane Durations

Level 0 & Mezzanine (Lab)	*LF Coverage*	*Wall Height*	*Daily Output (LF)*	*Daily Output (SF)*	*Coverage Area*	*Duration*
N Line 1 - 6	141.87	24	80	1920	3404.88	1.77
6 Line N - G	173.89	24	80	1920	4173.36	2.17
G Line 1 - 6	104.04	24	80	1920	2496.96	1.30
1 Line G - N	157.87	14	80	1120	2210.18	1.97
Total						**7.22**

The assumption was made that the daily output was 80 – 100 LF per day based on the output from the new dorm building at South Halls at Penn State. 80 was used to calculate the durations to discover what the maximum duration would be so the absolute maximum time can be recommended with the possibility that the activity could potentially take less time. The wall was broken down into the same sections that the concrete pours took place so that when added to the schedule, the waterproofing activities could be completed as the wall was being completed. The updated foundation schedule can be seen in Appendix C. The original schedule had the Lab foundation walls start with N Line 1 – 6 and part way through 6 Line N – G, the Office foundation walls were started, which accounts for the jump from mid-April to near the end of May. To make the comparison, the start and finish dates were the basis because of confusion between the listed start and finish dates with the duration listed on the original schedule. In terms of each section of the wall, the waterproofing membrane only adds one extra work day to all of the sections of the foundation walls.

Even though the schedule increase was not enough to rule out the use of waterproofing membrane, the cost was also analyzed to make a final decision. The largest sized roll that the Tamko TW-60 comes in is 39-3/8”x61’. This roll has a coverage area of 200 SF and was chosen to maximize the amount of coverage per material on the walls. The following table includes the breakdown in cost per foundation wall and the total cost of materials.

Table 13: Tamko TW-60 Material Foundation Wall Costs

Level 0 & Mezzanine (Lab)	*Roll Width (in.)*	*Roll Size*	*Area Coverage*	*Wall Area*	*# Rolls Needed*	*Cost per Roll*	*Total Cost*
N Line 1 - 6	39.375	39.375" x 61'	200	3404.88	18	$292.00	$5,256.00
6 Line N - G	39.375	39.375" x 61'	200	4173.36	21	$292.00	$6,132.00
G Line 1 - 6	39.375	39.375" x 61'	200	2496.96	13	$292.00	$3,796.00
1 Line G - N	39.375	39.375" x 61'	200	2210.18	12	$292.00	$3,504.00
Total							$18,688.00

The results from the cost analysis are that to add the waterproofing membrane, it would be roughly an additional $1.50 per SF of wall space. Labor costs would be negligible because the added day to each section of wall would just be included with the concrete contractor's contract value and 32 hours at an estimated $15.00 per hour comes out to just under $2,000 for a 4 man crew installing the membrane. That $2,000 in labor costs can be easily saved later during construction of the UEB.

The final area of study to determine feasibility is whether this solution is viable long term. Tamko TW-60 waterproofing membrane is covered by a 5 year limited warranty, which is included in Appendix C. Even though it's a 5 year warranty, the membrane has proven to be an effective means in controlling moisture penetration into buildings and since the most important feature of the UEB is housed below grade. Even if the sump pump still remained as part of the dewatering system, it would not need to be permanently powered.

Results & Recommendations

Based on the results determined from this analysis, the final recommendation is to incorporate both the sump pump and the exterior foundation wall waterproofing. In this instance the sump pump would not be continuously running and would only power on when water reaches a particular level around the foundation of the building. The addition of the waterproofing membrane, while adding almost $20,000, includes more benefits than not having it. The membrane is an added level of protection to keep almost all of the moisture out of Level 0 and out of the clean room. The waterproofing membrane also will not breakdown like a piece of machinery, such as the sump pump. The ability to add a sensor to the sump pump to turn on/off when necessary is feasible and will not add any additional loads to the electrical system, which is described in depth below in the mechanical breadth.

The underground spring is an interesting analysis topic because it is not a typical feature of many buildings. Had there been more time to conduct research and study the spring more in depth the affect the Monongahela River casts on the surrounding area. Also more time would have been spent studying other potential solutions and tailoring a specific solution for the University Engineering Building and the surrounding land and other buildings.

Sizing of a Sump Pump (Mechanical Breadth)

Since the project team on the UEB needed to come up with a solution in little time, the ability to perform a quick rough estimate for sizing a sump pump proves useful. This mechanical breadth explores the steps and information required to accurately size a sump pump by performing a few quick calculations in order to compare with specifications for different sump pump models. The two main pieces of information required to correctly size a sump pump include the system capacity and the total dynamic head.

Normally the system capacity is determined by placing a basin of known diameter on the ground during a rain storm and measuring the amount of rainfall in the basin over a predetermined amount of time. Since the UEB's problem is an underground spring, this technique is not useful and won't produce desired results. The system capacity for the underground spring at the University Engineering Building was determined based on the area of the affected region of the site and the depth of the standing

water. This was discussed with the project team to gain a better understanding and they agreed that sizing a pump for 30 gallons per minute was a reasonable assumption.

The next step in this process was to determine total dynamic head. Total dynamic head is defined as static head plus friction head. Static head is defined as the vertical height that the water rises through the discharge pipe. For the UEB, the static head was chosen to be 10' because the sump pump was placed in a 12.5' well in order to have the discharge pipe be a few feet below grade.

The second part of total dynamic head is friction head, which is defined as the equivalent length of pipe plus the actual length of pipe multiplied by the friction loss divided by 100. The equivalent length of pipe takes into account 90° elbows, check valves and 45° elbows. In this instance, the sump pump discharge system will include 1 – check valve, 1 - 90° elbow and 3 - 45° elbows. The 45° elbows allow the horizontal discharge pipe to gradually drop in slope to allow gravity to carry the water once it is horizontal. The equivalent lengths were calculated using a table included in the document on how to properly size sump pumps and can be seen in the following figure. 2" diameter pipe was assumed to be used making the equivalent lengths:

- Check Valve = 17.2'
- 1 - 90° Elbow = 5.2'
- 3 - 45° Elbow = 8.4

Table 1. Equivalent Length of Pipe Due to Fittings

Pipe size	90° elbow	45° elbow	Check valve (swing pipe)
	⟸	(*feet*)	⟹
1-1/4 inch	3.5	1.8	11.5
1-1/2 inch	4.0	2.2	13.4
2 inch	5.2	2.8	17.2
2-1/2 inch	6.2	3.3	20.6
3 inch	7.7	4.1	25.5

Figure 17: Equivalent Pipe Lengths

The actual length of pipe was determined based on the distance from the well to where the slope of the grade begins to decrease. This distance is roughly 150' from the well and can be seen in figure 18.

The final variable that needed to be determined was friction loss, which is found in another table from the document used to size the sump pump. Using the 30 gpm system capacity, with the 2" pipe size, the friction loss was shown to be 1.81.

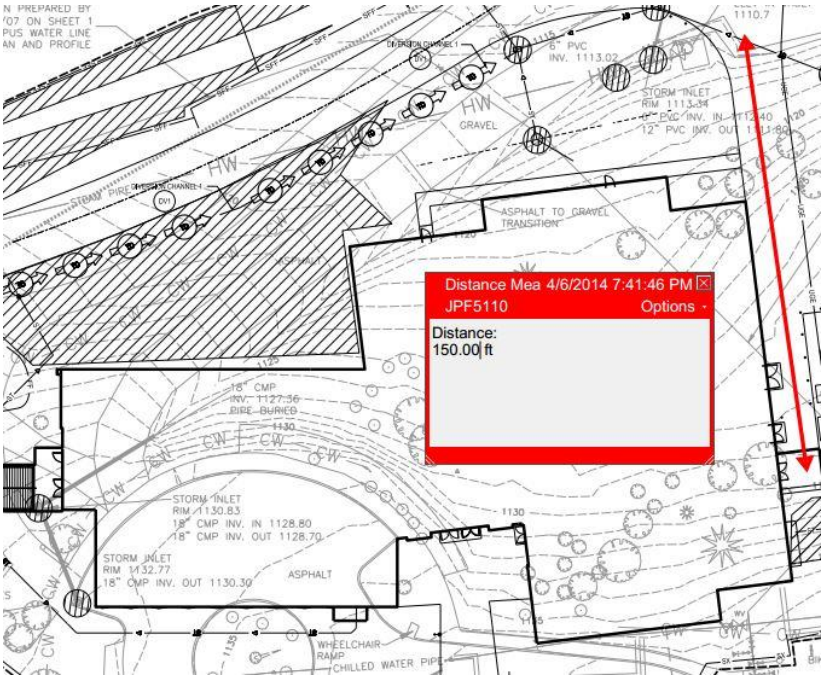


Figure 18: Actual Pipe Length (Courtesy Stantec)

Finally using the three variables, the friction head was calculated by performing the following equation:

$$\frac{(Actual + Equivalent)(Friction\ Loss)}{100}$$

$$\frac{(150 + 30.8)(1.81)}{100} = 3.27$$

Finally the total dynamic head was calculated to be 13.27 which was rounded up to 14. The Hydromatic High-Temperature 1/3 & ½ HP Cast Iron Sump Pumps were used for comparison with the information found during the sizing calculations. The maximum head for the Hydromatic is 21', which is 7' greater than the calculated 14', so this requirement was fulfilled. The next requirement was the system capacity which, was calculated to be 30 gpm and the Hydromatic has a 45 gpm flow at 10' lift, which is the same as the lift used, therefore, that also checks out.

Table 2. Friction Loss Per 100 Feet of Plastic Schedule 40 Pipe

Gallons per minute (GPM)	Size of pipe				
	3/4"	1"	1-1/4"	1-1/2"	2"
4	3.7	1.2	.34		
6	7.9	2.4	.71	.33	
8	13.4	4.1	1.19	.56	
10		6.3	1.78	.83	
12		8.8	2.48	1.16	.34
14		11.7	3.29	1.54	.45
16			4.21	1.97	.58
18			5.25	2.41	.72
20			6.42	2.96	.88
25			10.39	4.8	1.38
30			13.6	6.27	1.81
35			19.2	8.82	2.4

Figure 19: Friction Loss

Before just installing the sump pump, one final aspect needed to be reviewed; whether or not the electrical system was capable of handling the addition of a sump pump on a panelboard. Due to the

redundancies built into the UEB's electrical system, this was feasible. The amp draw on the Hydromatic is 12 amps with a voltage of 115 V, 60 Hz.

PANEL NAME	VOLTAGE INFORMATION					PANEL INFORMATION							FEEDER INFORMATION	
PLN-GB7	VOLTAGE		208/120V			BUSS			200A				FROM	DPLN-GB
RECESSED	PHASE		3			MAIN/MLO			MAIN BREAKER - 150A				TYPE	NORMAL
GROUND FLOOR	WIRE		4			AIC RATING			10,000				SIZE	SEE RISER ON E601
LOCATION/ITEM	LOAD WATTS	NOTES	WIRE	COND	BREAKER	CKT	PHS	CKT	BREAKER	COND	WIRE	NOTES	LOAD WATTS	LOCATION/ITEM
RCPT LAB 009	540		#12	3/4"	20A-1P	1	A----	2	20A-1P	3/4"	#12		540	RCPT LAB 011
RCPT LAB 009	540		#12	3/4"	20A-1P	3	--B--	4	20A-1P	3/4"	#12		540	RCPT LAB 011
RCPT LAB 009	540		#12	3/4"	20A-1P	5	----C	6	20A-1P	3/4"	#12		540	RCPT LAB 011
RCPT LAB 009	540		#12	3/4"	20A-1P	7	A----	8	20A-1P	3/4"	#12		540	RCPT LAB 011
RCPT LAB 009	540		#12	3/4"	20A-1P	9	--B--	10	20A-1P	3/4"	#12		540	RCPT LAB 011
RCPT LAB 009	1000		#10	3/4"	30A-1P	11	----C	12	30A-1P	3/4"	#10		1000	RCPT LAB 011
RCPT LAB 009	1000		#10	3/4"	30A-1P	13	A----	14	30A-1P	3/4"	#10		1000	RCPT LAB 011
SPC RCPT LAB 009	1200		#10	3/4"	30A-2P	15	--B--	16	30A-2P	3/4"	#10		1200	SPC RCPT LAB 011
	1200					17	----C	18					1200	
SPC RCPT LAB 009	1200		#10	3/4"	30A-2P	19	A----	20	30A-2P	3/4"	#10		1200	SPC RCPT LAB 011
	1200					21	--B--	22					1200	
FUME HOOD 000H	400		#12	3/4"	20A-1P	23	----C	24	20A-1P	3/4"	#12		400	EM SHWR
FUME HOOD 000H	400		#12	3/4"	20A-1P	25	A----	26	20A-1P					SPARE
RCPT LAB 000H	540		#12	3/4"	20A-1P	27	--B--	28	20A-1P					SPARE
RCPT LAB 000H	540		#12	3/4"	20A-1P	29	----C	30	20A-1P					SPARE
RCPT LAB 000H	540		#12	3/4"	20A-1P	31	A----	32	20A-1P					SPARE
SPARE					20A-1P	33	--B--	34	20A-1P					SPARE
SPARE					20A-1P	35	----C	36	20A-1P					SPARE
SPARE					20A-1P	37	A----	38	20A-1P					SPARE
SPARE					20A-1P	39	--B--	40	20A-1P					SPARE
SPARE					20A-1P	41	----C	42	20A-1P					SPARE
NOTES:														

Figure 20: Panelboard PLN-GB7 (Courtesy Stantec)

Panelboard PLN-GB7 is located at Level 0 of the University Engineering Building and was used to determine whether the added load of a sump pump was feasible or not. Based on the panelboard layout, the additional 12 amp load of the sump pump can be easily picked up and handled without adding any burden on the board. The breaker's located at all of the spare circuits are 20 A breakers, which will handle the 12 A of the sump pump and also the voltage of the sump pump can be easily handled by a typical receptacle.

In conclusion, this study of sizing a sump pump, drew the results that a middle of the road sump pump is required to handle the underground spring with a system capacity of 30 gpm and total dynamic head of 14'. Also, the electrical loading was taken into account, so that any additional loads would not break any panelboards. This was determined to be a non-issue since the redundancy built into the UEB electrical system freed up more than enough circuits on the Level 0 panelboards that the sump pump was accommodated.

Analysis 4 – CM to FM Information Delivery

Problem Identification

The University Engineering Building will become the landmark building for the Mid-Atlantic University upon completion, featuring a technically advanced mechanical system, state-of-the-art clean room and 3 levels of laboratory space. In order to properly maintain and operate this building the need to research how information is delivered from the contractor to the owner/facility manager is needed. Communication between both parties is the key to the success of this project during and after construction.

Analysis Goals

The goals of this analysis include; first outlining what information the owner has requested from the contractor and via what formats do they want the information delivered. Second, to understand the means and methods Massaro is taking to deliver this information. Third, is to research alternate sources for different methods of information delivery and different perspectives on the topic. The final goal of this analysis involves compiling a guide that the Mid-Atlantic University and other facility managers could potentially use in the future to be better informed and more aware of how to ensure proper maintenance and operation of their buildings.

Research

PACE Roundtable – 11/7/2013

The preliminary research on this topic began during the PACE Roundtable, during the breakout session focusing on this topic and would later help shape the direction of the guidelines created for facility management. Two key areas this research will deal directly with are personnel training and the role technology plays with it and the ease of accessing information. The last key takeaway from the Roundtable came from speaking with John O'Keefe. His stated that when it comes to information delivery the building must be analyzed. Since the UEB is primarily a research/laboratory building, information regarding energy efficiency and other system efficiency can be ignored because the most important aspect is making sure the building operates and functions properly at all times. This will aid in determining what the University should be looking for in terms of information from Massaro, so that operations personnel can keep the building up and running.

Figure 21: BIM Planning Guide for Facility Owners (Courtesy Penn State)

BIM Planning Guide for Facility Owners

BIM use on the University Engineering Building was minimal, but the principles and steps outlined in the BIM Planning Guide for Facility Owners, lend themselves to the delivery of information to the owner and

how the owner can use that information, whether it's BIM related or not, to maintain and operate the UEB. A 3D coordination model of the structural, mechanical, electrical and plumbing systems was made to coordinate between trades and solve any potential problems prior to construction. This model has the potential to function more than a coordination tool between the general contractor and the various subcontractors.

Outlined in the Guide are "The BIM Planning Elements," as seen in figure 22, these items are key to successfully managing the project from beginning and in some instances can be applied outside of the world of BIM as defined in the planning guide.

In terms of building maintenance, the element, "Uses," has the biggest impact. In terms of the UEB and based on the current state of the 3D model , record modeling is still possible but would require the coordination model to be updated with the architectural aspects of building. Having a record model is useful because it can minimize complications during the building turnover. With the mechanical system and other aspects of the building being extremely complicated, having access to the 3D model can ease some of the difficulties in fully understanding the building. Along with accessing the model, data and information can be stored there as well, decreasing the amount of items to turnover to the University as well as condensing all the information into one specific area.

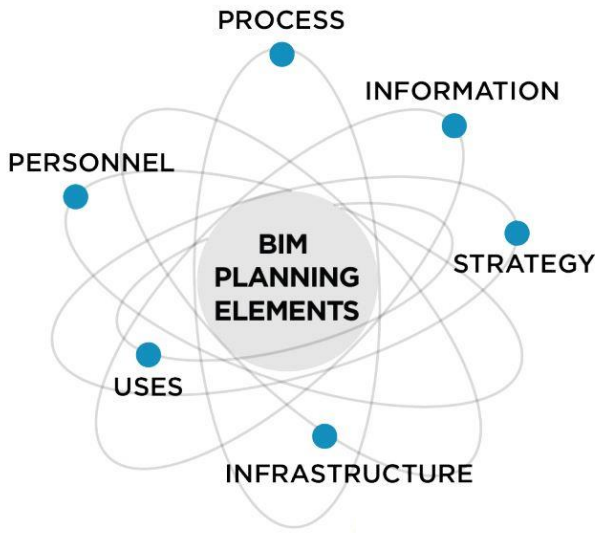


Figure 22: BIM Planning Elements
(Courtesy BIM Planning Guide for Facility Owners)

Even with the UEB model's current state, the ability to perform building scheduling is the most important part of properly operating the building. At any one time, millions of dollars' worth of research can going on and all the UEB's systems much be functioning properly. Having the ability to create and review maintenance schedules for all the equipment means the facility management personnel can plan in advance any necessary precautions in order to not disturb ongoing research. The value of building maintenance scheduling includes tracking maintenance history, increasing productivity of staff since there is less confusion regarding locations of equipment and cost effective solutions based on advanced knowledge of maintenance needs.

A building systems analysis is used to measure the building's performance compared to the design. More often than not for a typical building, this means energy efficiency and if the MEP systems are functioning efficiently to reduce energy costs. As stated earlier, based on the conversation with Mr. O'Keefe, this idea takes a different form for the University Engineering Building. Due to the research

that building is being used for, energy efficiency does not matter to the owner and facility manager, instead, ensuring the building's systems operate as designed to allow research to continue is the top priority, mostly ignoring energy output as long as it's not below design specifications. The values of this include, aside from measuring whether the building is operating as designed, but also the ability to identify areas to modify and improve system performance.

For all facility managers, asset management is a necessity to ensure their building is managed and operated correctly. Having the ability to store all the required documentation in one easily accessible area provides the most efficient way to manage the building. Even if there is no record model, the University can still employ the use of asset management systems and software that will allow the following benefits; performing and analyzing facility and equipment condition assessments, maintaining up-to-date facility and equipment data, which ties into maintenance schedules and building system analysis. Asset management also provides cost information and the ability to modify based on the information gathered.

The one major issue discussed at the Roundtable involved training/education the facility management and operations personnel would need to remain on par with the technological advancements in information delivery. The 3D MEP coordination model that Massaro created would be beneficial for the owner to use to aid in properly managing the UEB. In order to gain the most of the model, all personnel, especially those performing the maintenance and other duties must have the ability to navigate a model and easily find what they are looking for. The question now becomes, exactly what should be taught to whom and what methods should be used for the training. Coordinating these factors early during the preconstruction or construction phases provides an easier transition when the time comes for said training and the building turnover.

Massaro Project Manager Interview

The topic of building information delivery affects the owner/facility manager since it is their job to operate and maintain the building, but the contractor is the one to provide that information and understanding their process will aid in determining the keys to successful information delivery. Massaro follows a set approach when turning-over a building. Documentation includes hard copy binders of all necessary documents including warranties, user and maintenance manuals, as-built shop drawings and construction drawings, emergency contacts and others. The binders are laid out based on CSI divisions and depending on the building means the number of binders required. The project manager also stated that they now make a digital copy the Operations and Maintenance (O&M) Manuals, which certain owners request instead of hard copies.

In terms of the UEB project, Massaro has not met with owner representatives directly about what information is expected to be provided. The PM said that this will occur closer to the end of construction during the close-out process. Massaro has begun the process of scheduling training sessions for essential personnel. These training sessions are for the major systems and include the subcontractor and respective vendors to train the maintenance staff on the operation of all materials and equipment.

The original purpose of the 3D model created by Massaro was for MEP system coordination for the project team. The University was not going to pay for the model and did not request it as part of the project, since BIM is not used or thought of as completely necessary. Massaro's project manager did offer to give a presentation on BIM in general, not specific to the UEB, as a means of showing the University BIM's different capabilities, especially being able to store information and documentation in the model and easily access everything from one central location. After that meeting, the University has expressed interest in possibly purchasing the model and possibly growing the building process to incorporate different forms of technology, but the model is not in the stage that it can be easily interpreted by maintenance staff, so the PM said it will have to be enriched.

Based on past experience with different owners, the project manager stated that he feels that what Penn State is doing for facility management, with the technology and the methods used for building and managing buildings will trickle down into larger companies and other universities to the point where BIM will become more mainstream and even more common within the industry.

University Representative Interview

With the improvements in technology, growth has become the main focus of University in terms of facility management. After speaking with a representative, the University is now in the process of finding faster, more efficient ways to access information on their buildings and improve the efficiency of the personnel that maintain those buildings. The process, like with most construction projects, begins with a kick-off meeting with the general contractor (GC) to discuss the project, project goals, the submittal process and most importantly what is required when turning over the completed building. To aid in determining what information must be included, like most other institutions, such as Penn State, the University has an established Design Guidelines and Construction Standards for the GC to follow.

Part of the design process includes consulting with key end users to improve areas of the design for more efficient uses of space and ease maintenance operations. According to the University representative, faculty leaders are brought in to give opinions on space layout, but certain areas, such as offices have pre-defined layouts and sizes based on University standards. For the UEB project though, faculty was consulted to maximize the space for the laboratory areas. The representative stated that along with faculty members, maintenance and facilities personnel are also consulted to determine storage needs, equipment needs and even go into such detail as potential floor finishes keeping maintenance to a minimum. He also stated that by doing this, little problems that could add up over the course of construction, leading sometimes to larger problems are taken care of and allow the project team to stay on schedule and not become side-tracked.

With the discussion on personnel training, the representative reaffirmed what Massaro's project manager stated on training guidelines for the University. Formal training is the responsibility of the GC to schedule and carry out with subcontractors and vendors to train all personnel on the different equipment and systems. In terms of accessing information for the personnel, the University requires all as-built drawings and all O&M manuals to be digitally saved in both CAD and PDF to allow for easier

accessibility. Currently the University is in the process of improving their training guidelines and methods to coincide with changes in their facility management process.

In recent years, the University has seen designers and project teams increase the use of 3D modeling for various projects and have started to see the enormous potential of shifting towards a BIM/3D modeling approach for facility management. Especially after the presentation by Massaro, the push for incorporating the principles of ideas of BIM has become predominate at the University. The University is currently in the process of rewriting their standards and guidelines to include requirements for BIM planning and model usage. The hope is to reach a point where a fully functional 3D model of the entire building will be turned over with the completed building, along with all necessary and pertinent information stored in the model. The University wants to incorporate the model with maintenance so that eventually personnel can be trained to navigate the models and find the information they are searching for. The representative stated that Penn State, compared to other facility managers, is so far ahead of the game in terms of facility management and successful that they along with others are beginning to realize the benefits and transitioning into a similar model/philosophy.

When asked if there was one thing contractors could do that they currently are not doing related to information delivery and building turnover, the University representative stated that more often than not, the turnover process can be improved. Project delivery is standard for the most part, but improving quality control and easing the transition from contractor to facility manager is one thing that could be performed better. Since the University is changing directions with their facility management outlook, issues like this will eventually solve themselves improve building turnover.

Penn State OPP Interview – Dr. Ed Gannon

Every facility manager, maintains and operate their buildings in different ways, so to gain a better understanding of the topic of building information delivery and the role information plays in properly managing a building, an interview was conducted with Dr. Ed Gannon to delve into how Penn State Office of Physical Plant (OPP) manages their buildings.

The foundation for successfully managing a building begins during the design and preconstruction phases. According to Dr. Gannon, Penn State hires mostly Construction Managers (CM) on their building projects, which are brought on early for preconstruction services. The CM and the designer are brought together for a meeting for discussing the design and provide the CM with the opportunity to offer input on the design and suggest any changes that would be beneficial. At this stage the principles of lean are used by Penn State to pull the information that they need from both the designer and the CM. The idea of pulling the information, rather than have excess information pushed by both the CM and the designer, allows Penn State to establish the specific information required from the other parties.

Part of this process involves OPP's BIM Execution Plan, which can be viewed at http://opp.psu.edu/planning-construction/design_and_construction_standards/division-00-procurement-and-contracting-requirements, outlines specifically what information the CM must provide. Along with the execution plan, full Operation & Maintenance (O&M) Manuals must be provided for use by Penn State's Work Control Center. The O&M Manuals, however are digital so that

they can be linked directly to the asset management system for easier access and to decrease waste associated with paper copies.

Having an early collaboration between the CM and the designer serves many benefits, but another information asset for both design and construction are end users. Institutions of higher learning, such as Penn State, operate mainly high-end, state-of-the-art research and lab facilities that must meet the needs of those who will occupy the buildings. Penn State inquires faculty input during early design stages. Dr. Gannon spoke to how not long ago, there were many Owner Requested Change Orders that we brought upon by end users because of changes faculty and others felt different spaces needed. Now with the shift towards 3D models, the faculty members are able to navigate a "finished" room and provide input to the layout and other potential changes. Utilizing this input early, saves both time and money later during the construction phase and later during the building's lifecycle avoids the need for future renovations based on poor space layout.

Technology has grown to simplify and condense the building information into one area. Penn State currently uses two main software packages to handle all information gathering and storage. The one software is IBM's Maximo Facility Asset Management software. According to IBM's Maximo brochure "The IBM Maximo Asset Management solution offers the required visibility, control and automation of key information an organization needs to achieve greater efficiency in asset management by managing all asset types, from traditional IT, physical and emerging smart assets, on a single technology platform." To compliment Maximo, OPP utilizes the Autodesk family of programs for model management. The current goal is to create a link between the two sets of programs, where the information stored in Maximo can be automatically opened when one navigates a Navisworks model and highlights particular equipment or materials and vice versa. The seamless integration between model and data will increase the efficiency of operations personnel and others, but comes with the added cost of having to train individuals for use of both programs to gain the most from them.

Focusing on laboratory/research buildings, OPP took a different approach for the Millennium Science Complex. Due to the large size of the building and its function, Millennium Science was assigned a Building Engineer, whose sole purpose was to manage the building. He was trained to navigate the 3D model of Millennium Science along with other programs so that he has the ability and resources to properly manage the building. While not of the same scale, size-wise, the UEB is still a research building that will require constant check to ensure everything is functioning properly and the end users have the tools and resources to conduct their research. The University could use this as a trial run to see if having one building engineer focus squarely on one building is worth the time and cost.

Aside from the use of technology and the expectations of OPP in terms of building information, the key, according to Dr. Gannon, to the success of the different projects is because of the relationships OPP has with the contractors. He said that by taking a grass roots approach to the CM/FM relationship allows for the other pieces to fall into place, i.e. information delivery. OPP now takes the stance where BIM Facilitators work with the project team and in most cases become another member of that team and not seen just as the owner or owner's representative. Dr. Gannon stated that his one hope is that by building these relationships with contractors is that they will be comfortable in providing constructive

criticism for OPP and their methods of operation. OPP is trying to turn design-bid-build into a modified form of integrated project delivery typically associated with design-build.

Dr. Gannon, summarized OPP's methods as successful, but there is always room to grow and make things more efficient. Financial studies have shown the incorporation of technology and condensing all of the available information into one area digitally has reduced technical services costs by roughly $2.5 million per year. This $2.5 million, means that less time is wasted on menial tasks such as searching for the necessary information on a building and that $2.5 million worth of more repairs can be completed in the same time frame. BIM itself is just a tool used by OPP to reach the end goal of having access to the right information. Penn State is trying to find the most efficient way of gathering the information and using it to maintain and operate its buildings as smoothly as possible.

IBM's Maximo Asset Management Software

Expanding on the conversation with Dr. Ed Gannon, Maximo Asset Management Software is just one of many software's geared specifically toward asset management. Some highlights of Maximo include; collecting, consolidating and analyzing essential information on all types of assets, improving operations through better asset availability, reliability and asset utilization, significantly extend the value of assets and increase flexibility, extending the useful life of all assets or equipment, improving return on investment and defer new purchases and unifying processes for wide-ranging asset management functions across multiple sites.

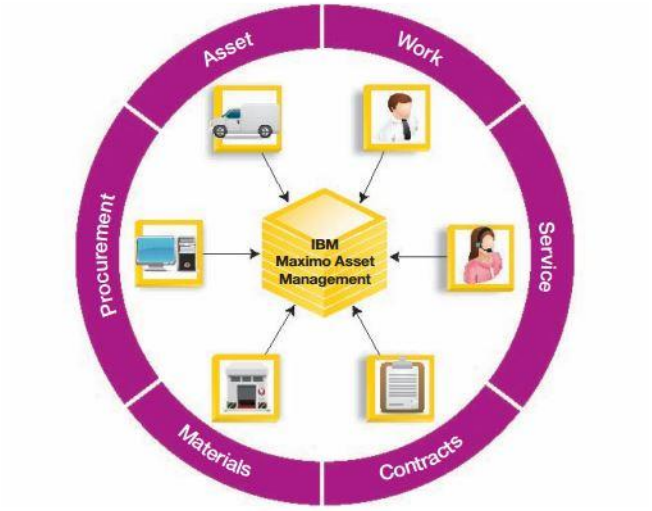


Figure 23: Enterprise Assets
(Courtesy Maximo Brochure)

The key to Maximo's success is the ability to building information but the entire facility management infrastructure. As seen in figure 23, this shows the different aspects of the facility management infrastructure and how they can all be tied together via Maximo. Institutions such as Penn State and the University have more to manage than just buildings. Maintenance personnel, roadways and walkways, end-users, the community are just some of the other assets that must be managed along with the buildings in order to keep the institution operating efficiently. Having the ability to track work, materials and assets increases efficiency and can save both time and money, with the benefits outweighing any cons.

Maximo distinguishes between two main categories: asset management and facility management. Asset management includes operations management, health, safety and environment, supply chain management and service management, while facilities management includes facilities and space management, real estate management, environmental sustainability and capital and project management. This breakdown can be seen in figure 24. More in-depth definitions of these specific topics can be viewed in the Maximo brochure located in Appendix D.

Figure 24: Asset vs. Facility Mangement
(Courtesy Maximo Brochure)

Another benefit of using Maximo software is improving and integrating visibility, control and automation across all assets. Having better control over all assets allows FMs to better manage and secure their investments, increased governance and reduce operational risk and extend asset life. Increased automation has the following benefits; build agility and flexibility into operations and enhancing operational capabilities. Finally increased visibility allows for facility managers to respond to problems/issues faster and make better decisions to handle them.

Finally, Maximo has the capabilities for mobile integration, with the use of tablets, smart phones, etc. Linking these devices to computers and the central location of the stored data eases the transition between the software and the operations personnel performing the work orders. The seamless integration with mobile devices eliminates wasted time, material and money that would be spent on searching for the information and determining what work must be completed to fix the problem.

Results & Conclusion

After completing interviews and research, there have been a few similar key points that can be drawn from how facility managers handle information delivery. The main focus now is not so much what information specifically should be turned over, but how that information should be delivered. Collecting, storing and exchanging information must be successful for proper operation of buildings. In addition to the methods of delivering the information, determining what information is necessary is still important. Factors that must be analyzed to determine what information is necessary include the building, its location and function, building systems and equipment and finishes.

Another takeaway from this research has shown that BIM is a growing means of information delivery. Implementing the BIM process allows for front-end planning and information consolidation that will save both time and money during construction and after turnover during the building's lifecycle. For BIM to be successful, the relationships between owners and CMs/GCs must be built so that there exists

openness between the two parties to work together to deliver the highest quality project possible. Along with building those open relationships, integrating end-users in the design phase and throughout the construction process allows for the best input in creating a building that maximizes the efficiency of its users and maintenance procedures.

The takeaways and results of this research have led to the creation of an outline that owners/FMs can use to determine what information they should require for a building and means and methods for gaining that information. The complete outline can be viewed in Appendix D. This outline in its current state is very basic, touching the main points for FMs to focus on. Also an outline like this is difficult to be detailed because each building is unique and the processes used and information required for an office building or apartment building is completely different from a laboratory or medical facility. The examples in the outline tie back into the University Engineering Building and the interviews with Dr. Gannnon, Massaro's project manager and the University representative. The other point of the outline is to present new methods to owners and FMs that might not have embraced the advances in technology yet and are currently gathering information on particular topics.

Future Research

If there had been more time to focus on this research topic, more input from the industry could have been used. Time spent on interviews is the hardest part to manage because of professional's job loads and times available to grant a half hour or hour long interview. The scope of this research is very limited to just Penn State and the University where the UEB is being built. The other difficulty is that these institutions are public and require public bidding, meaning design-build project delivery systems, especially on new buildings, are more difficult to use. It would be interesting to speak with a private owner/facility manager to gain their perspective on information delivery and maintaining and operating their buildings.

Aside from more research, more time would also be spent on creating the outline for owners to study and use. First, it would be more detailed, but not to the point where it is geared toward a specific building type and function. Second, more research would go into training protocols, but based on the research conducted the training was at the discretion of the CM/GC and the only guidelines were to focus on the different building systems and train personnel on the different equipment, other items, such as floor finishes and other aesthetic features, were more left to the personnel to figure out since those were basic items that were similar from building to building. Finally, end users would be interviewed for their take on input on the building design, but because of the anonymity required by the University, along with the fact that the end user majors and faculty have not been finalized, this was not possible in the time allotted for this analysis topic.

Conclusion

The University Engineering Building is a unique project that resulted in 4 main analysis topics to study for the 2013/2014 academic year. Based on the proposed solutions to these topic areas, the final recommendations resulted in all alternate systems being chosen over the original system. Again, this is by no means a critique of the project team and is strictly for educational purposes. I would like to take this opportunity to thank all of the members involved on the project team for their help and support.

Analysis 1 – Clean Room Coordination

The final results for the Clean Room Coordination include Hodess having two separate contracts, one with the University for preconstruction services and the other with Massaro for all construction services. This allows Hodess to be under Massaro and provide a more direct line of communication and improve the coordination efforts for all involved. The second part of this analysis dove into the coordination efforts for the Clean Room and to find ways to take advantage of the technology used on the project and create a coordination schedule to maximize efficiency. The goal of the coordination schedule was to save time during construction of the Clean Room and eliminate any potential problem areas before they occurred.

Analysis 2 – Roof System Redesign

With the multiple problems that plagued the UEB's roof construction, mainly the extreme cold temperatures throughout the start of 2014, the need for a different system that was capable of being built in those temperatures was apparent. The final recommendations for this analysis was to switch the fully-adhered TPO system with Firestone's InvisiWeld system that was easier to construct in cold weather, saved both time and money and was favorable to the University.

Analysis 3 – Underground Spring

Unique to the University Engineering Building was the presence of an underground spring, that in conjunction with rain caused delays to the project schedule during the excavation and foundation phases of construction. The project team was unable to devote a great amount of time to finding a permanent solution and instead chose to install a permanent sump pump to handle the problem. The recommendation of this analysis is to still incorporate the sump pump with a waterproofing membrane on the Lab foundation walls as a two-step means of protection for Level 0 and most importantly the Clean Room.

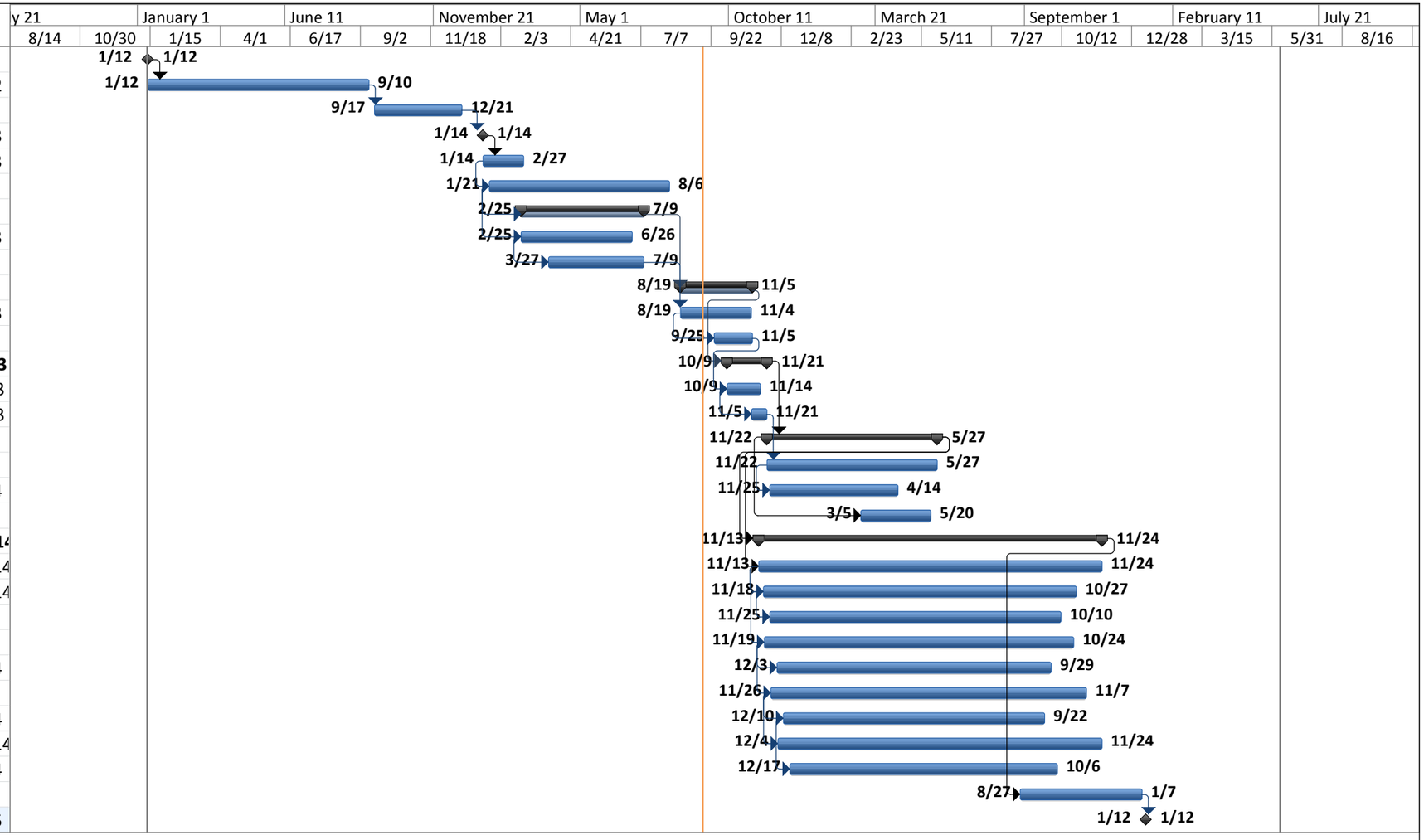
Analysis 4 – CM to FM Information Delivery

The research topic for this thesis, studied the delivery of information between contractors and facility managers. The results of this research proved that it's not the information that affects both parties, but the methods of delivering the information, via different technologies and platforms. An outline was created highlighting key areas for facility managers who are just beginning to incorporate new technologies in their method of operating and maintaining their buildings.

Appendix A – Analysis 1

Appendix A.1 – Original Summary Schedule

ID	Task Name	Duration	Start	Finish
1	Funding (Donation)	0 days	Thu 1/12/12	Thu 1/12/12
2	Design	173 days	Thu 1/12/12	Mon 9/10/12
3	Procurement	70 days	Mon 9/17/12	Fri 12/21/12
4	Notice to Proceed	0 days	Mon 1/14/13	Mon 1/14/13
5	Mobilization & Prep Work	33 days	Mon 1/14/13	Wed 2/27/13
6	Sitework	142 days	Mon 1/21/13	Tue 8/6/13
7	**Foundations**	**97 days**	**Mon 2/25/13**	**Tue 7/9/13**
8	Lab	88 days	Mon 2/25/13	Wed 6/26/13
9	Office	75 days	Wed 3/27/13	Tue 7/9/13
10	**Structural Steel**	**57 days**	**Mon 8/19/13**	**Tue 11/5/13**
11	Lab	56 days	Mon 8/19/13	Mon 11/4/13
12	Office	30 days	Wed 9/25/13	Tue 11/5/13
13	**Concrete Slabs**	**32 days**	**Wed 10/9/13**	**Thu 11/21/13**
14	Lab	27 days	Wed 10/9/13	Thu 11/14/13
15	Office	13 days	Tue 11/5/13	Thu 11/21/13
16	**Building Enclosure**	**133 days**	**Fri 11/22/13**	**Tue 5/27/14**
17	Lab	133 days	Fri 11/22/13	Tue 5/27/14
18	Office	101 days	Mon 11/25/13	Mon 4/14/14
19	Elevators	55 days	Wed 3/5/14	Tue 5/20/14
20	**MEP Rough-In/Finishes**	**269 days**	**Wed 11/13/13**	**Mon 11/24/14**
21	Level 0	269 days	Wed 11/13/13	Mon 11/24/14
22	Mezzanine	246 days	Mon 11/18/13	Mon 10/27/14
23	1st Floor - Lab	230 days	Mon 11/25/13	Fri 10/10/14
24	1st Floor - Office	244 days	Tue 11/19/13	Fri 10/24/14
25	2nd Floor - Lab	215 days	Tue 12/3/13	Mon 9/29/14
26	2nd Floor - Office	249 days	Tue 11/26/13	Fri 11/7/14
27	3rd Floor - Lab	205 days	Tue 12/10/13	Mon 9/22/14
28	3rd Floor - Office	254 days	Wed 12/4/13	Mon 11/24/14
29	Penthouse	210 days	Tue 12/17/13	Mon 10/6/14
30	Testing & Commissioning	96 days	Wed 8/27/14	Wed 1/7/15
31	Occupancy	0 days	Mon 1/12/15	Mon 1/12/15



Project: Project1
Date: Fri 9/13/13

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

Appendix A.2 – Revised Summary Schedule

ID	Task Name	Duration	Start	Finish
1	Funding (Donation Ceremony)	0 days	Thu 1/12/12	Thu 1/12/12
2	Design & Coordination	246 days	Thu 1/12/12	Thu 12/20/12
3	Notice to Proceed	0 days	Fri 12/21/12	Fri 12/21/12
4	Mobilization & Prep Work	33 days	Fri 12/21/12	Tue 2/5/13
5	Sitework	142 days	Wed 2/6/13	Thu 8/22/13
6	**Foundations**	**97 days**	**Mon 2/25/13**	**Tue 7/9/13**
7	Lab	88 days	Mon 2/25/13	Wed 6/26/13
8	Office	75 days	Wed 3/27/13	Tue 7/9/13
9	**Structural Steel**	**57 days**	**Mon 8/19/13**	**Tue 11/5/13**
10	Lab	56 days	Mon 8/19/13	Mon 11/4/13
11	Office	30 days	Wed 9/25/13	Tue 11/5/13
12	**Concrete Slabs**	**32 days**	**Wed 10/9/13**	**Thu 11/21/13**
13	Lab	27 days	Wed 10/9/13	Thu 11/14/13
14	Office	13 days	Tue 11/5/13	Thu 11/21/13
15	**Building Enclosure**	**133 days**	**Fri 11/22/13**	**Tue 5/27/14**
16	Lab	133 days	Fri 11/22/13	Tue 5/27/14
17	Office	101 days	Mon 11/25/13	Mon 4/14/14
18	Elevators	55 days	Wed 3/5/14	Tue 5/20/14
19	**MEP R-I & Finishes**	**269 days**	**Wed 11/13/13**	**Mon 11/24/14**
20	Level 0	269 days	Wed 11/13/13	Mon 11/24/14
21	Mezzanine	246 days	Mon 11/18/13	Mon 10/27/14
22	1st Floor - Lab	230 days	Mon 11/25/13	Fri 10/10/14
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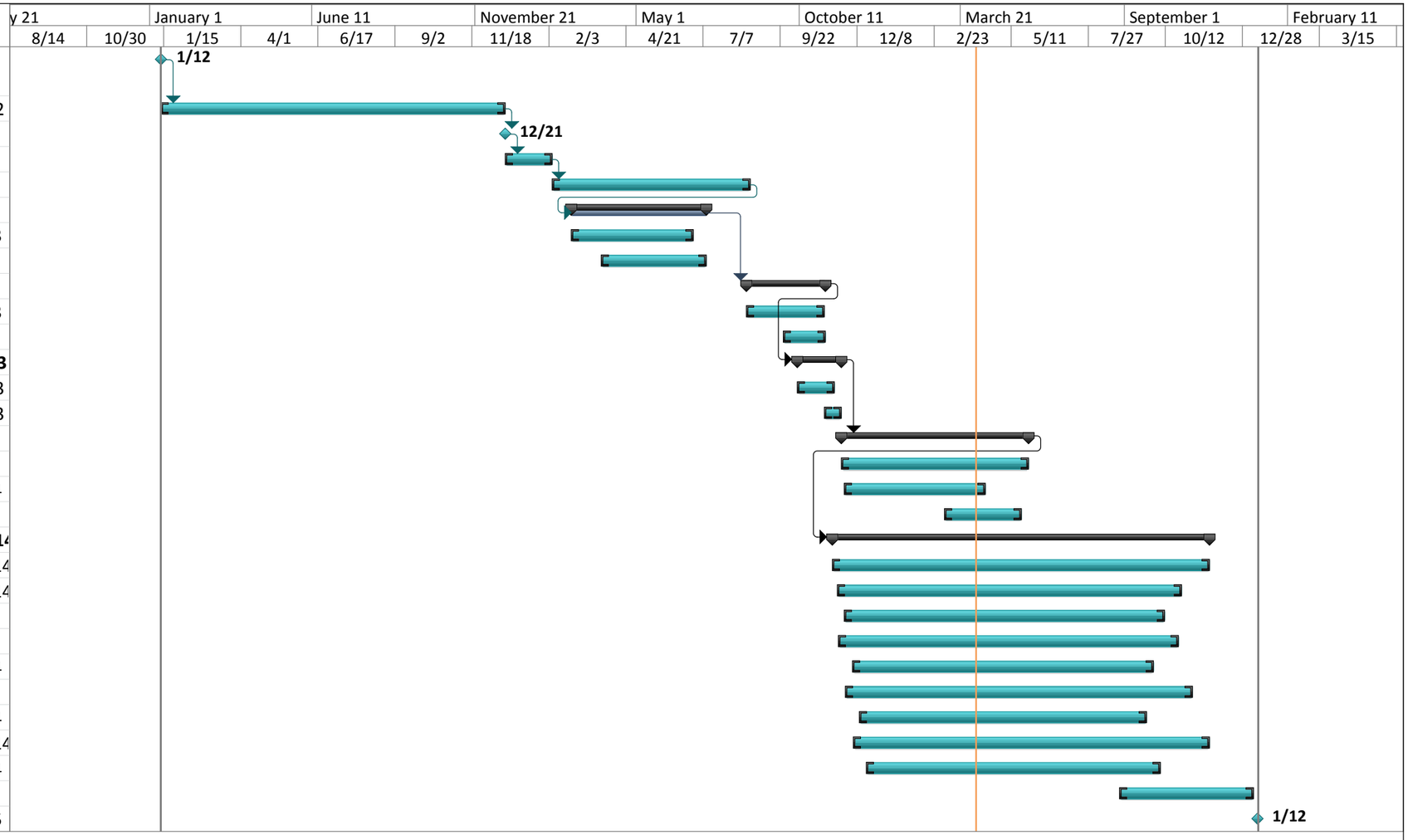
24	2nd Floor - Lab	215 days	Tue 12/3/13	Mon 9/29/14
25	2nd Floor - Office	249 days	Tue 11/26/13	Fri 11/7/14
26	3rd Floor - Lab	205 days	Tue 12/10/13	Mon 9/22/14
27	3rd Floor - Office	254 days	Wed 12/4/13	Mon 11/24/14
28	Penthouse	210 days	Tue 12/17/13	Mon 10/6/14
29	Testing & Commissioning	96 days	Wed 8/27/14	Wed 1/7/15
30	Occupancy	0 days	Mon 1/12/15	Mon 1/12/15

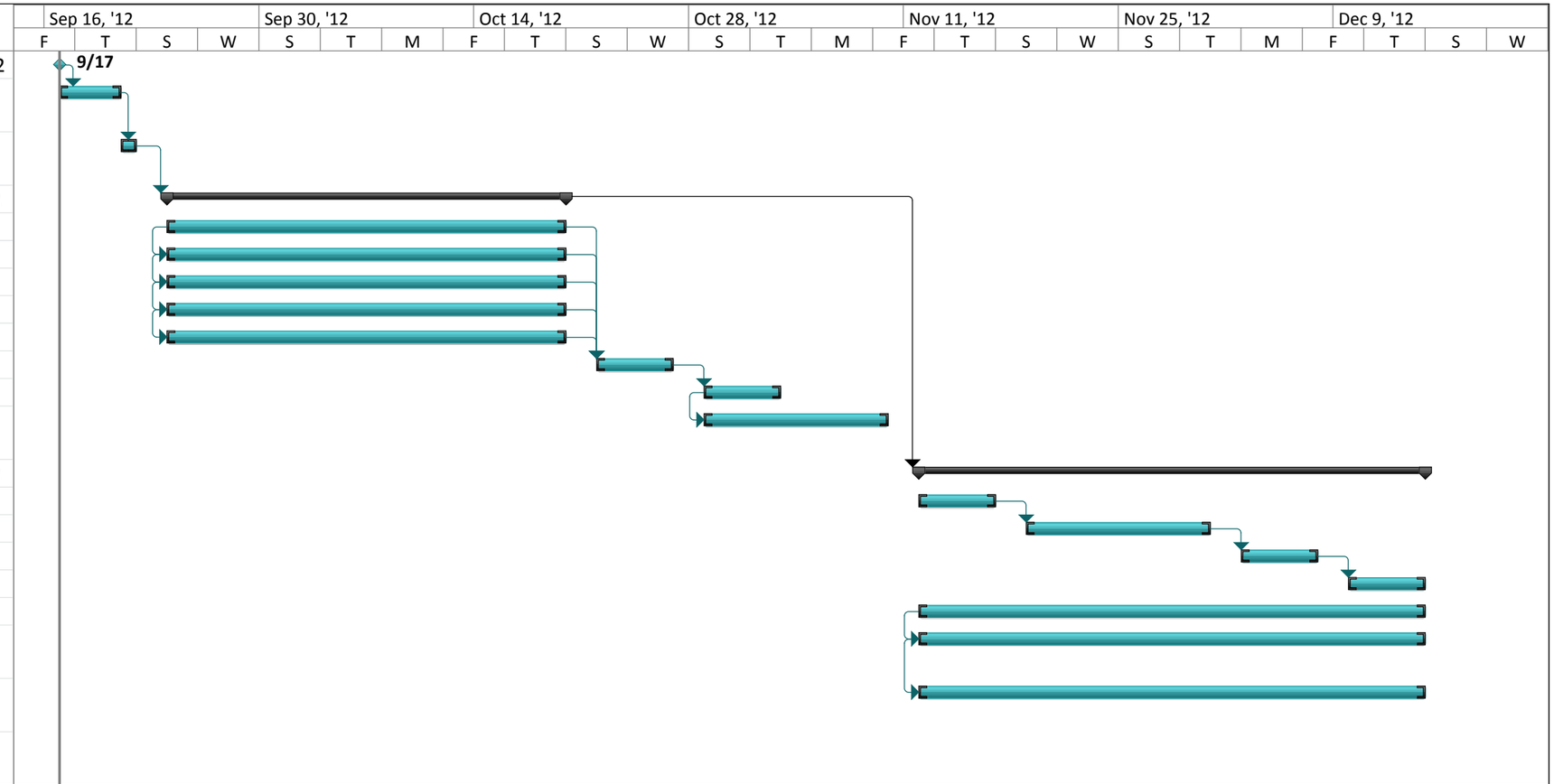


Project: Design Build Schedule.mp
Date: Sun 4/6/14

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline
Split	External Tasks	Inactive Summary	Manual Summary	Progress
Milestone	External Milestone	Manual Task	Start-only	
Summary	Inactive Task	Duration-only	Finish-only	

Appendix A.3 – Coordination Schedule

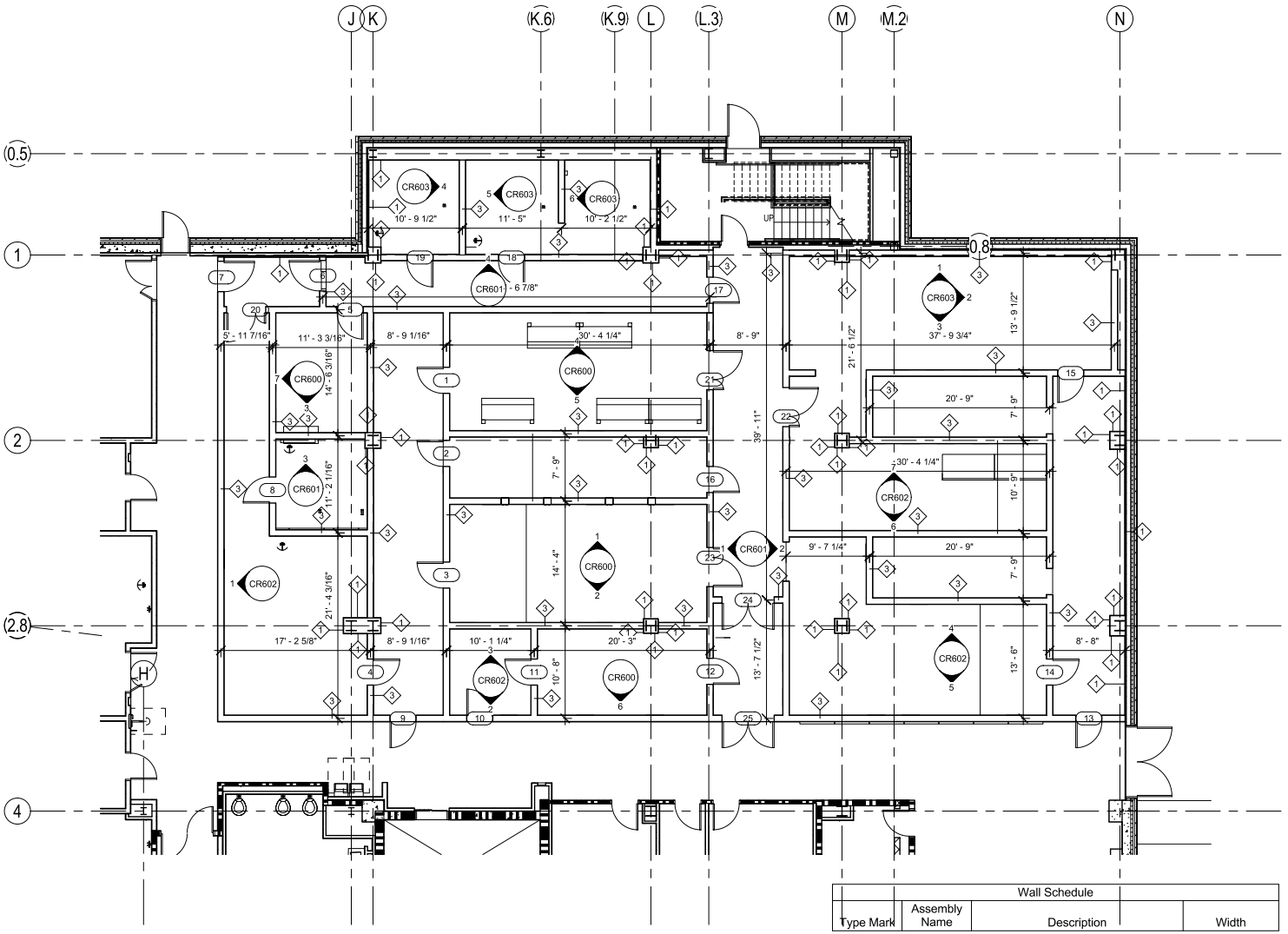
ID	Task Name	Duration	Start	Finish
1	Awarded UEB Project	0 days	Mon 9/17/12	Mon 9/17/12
2	Finalize Subcontractor Contracts	4 days	Mon 9/17/12	Thu 9/20/12
3	Preliminary Coordination Meeting	1 day	Fri 9/21/12	Fri 9/21/12
4	**3D Cooridnation Model**	**20 days**	**Mon 9/24/12**	**Fri 10/19/12**
5	Mechanical Model	4 wks	Mon 9/24/12	Fri 10/19/12
6	Electrical Model	4 wks	Mon 9/24/12	Fri 10/19/12
7	Plumbing Model	4 wks	Mon 9/24/12	Fri 10/19/12
8	Structural Model	4 wks	Mon 9/24/12	Fri 10/19/12
9	Clean Room Model	4 wks	Mon 9/24/12	Fri 10/19/12
10	Combine Models	5 days	Mon 10/22/12	Fri 10/26/12
11	Run Clash Detection	5 days	Mon 10/29/12	Fri 11/2/12
12	Clash Detection Meeting(s)	10 days	Mon 10/29/12	Fri 11/9/12
13	**Clean Room Coordination**	**25 days?**	**Mon 11/12/12**	**Fri 12/14/12**
14	CR Ceiling Grid Hangars	5 days	Mon 11/12/12	Fri 11/16/12
15	MEP Transitions	10 days	Mon 11/19/12	Fri 11/30/12
16	Mechanical Fittings	5 days	Mon 12/3/12	Fri 12/7/12
17	Electrical Equipment	5 days	Mon 12/10/12	Fri 12/14/12
18	Clash Fixes	25 days	Mon 11/12/12	Fri 12/14/12
19	Designer Coordination on Potential RFIs	25 days	Mon 11/12/12	Fri 12/14/12
20	Determine Long Lead items	25 days	Mon 11/12/12	Fri 12/14/12
21				



Project: Coordination Schedule
Date: Tue 3/18/14

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Appendix A.4 – Clean Room Plan



Wall Schedule			
Type Mark	Assembly Name	Description	Width
1		Interior Cleanroom Furring	0' - 0 1/4"
3		Interior Cleanroom Partition with RA	0' - 9"

1 Level 0
1/8" = 1'-0"

PRELIMINARY

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Evansdale Drive
Morganton, WV 26505

11/27/2012 LOUVER REVISIONS

DRAWN: JS CHECK: SAK

SCALE: 1/8" = 1'-0"

Cleanroom Floor Plan

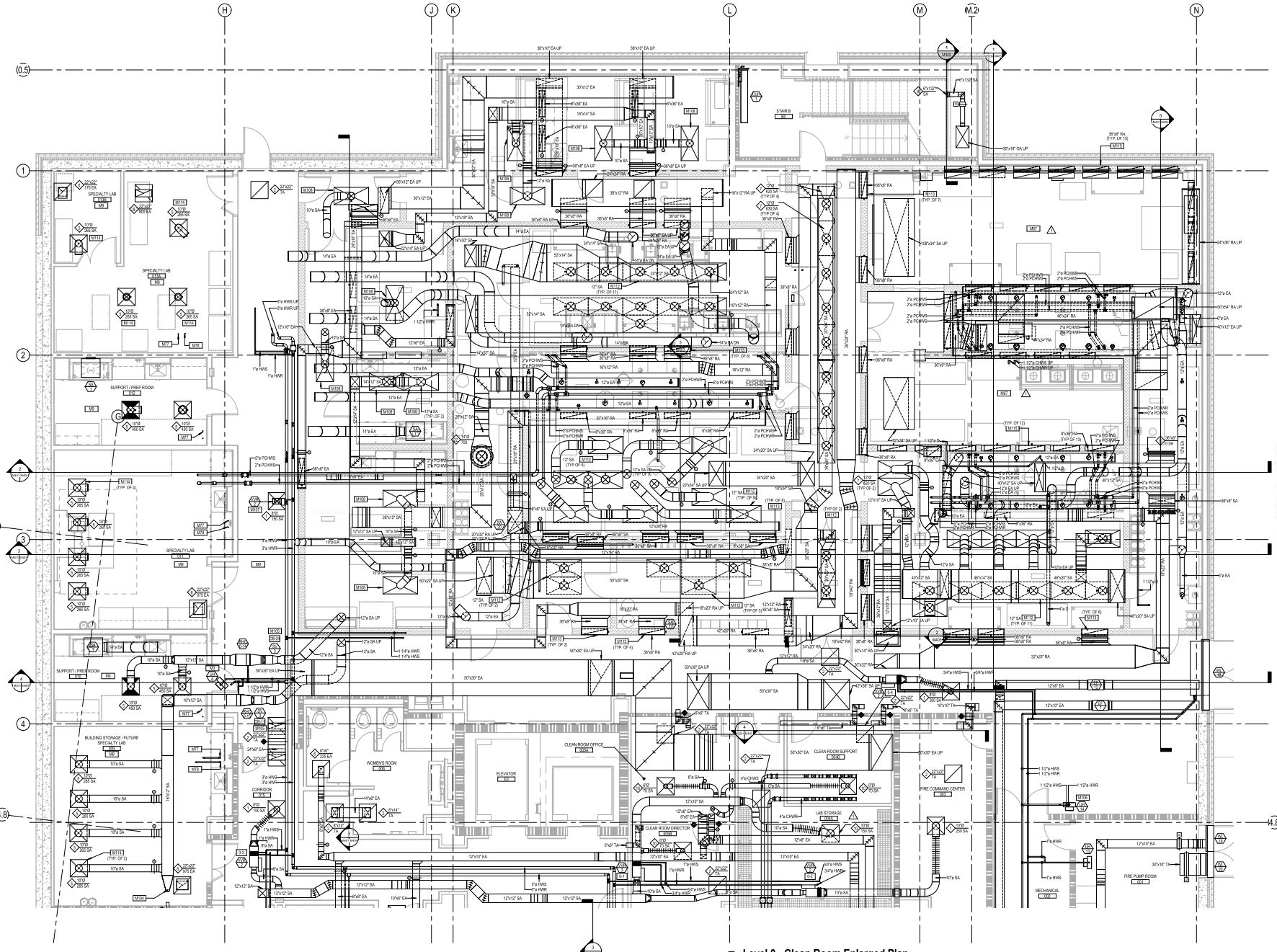
SHEET:

CR200a

PROJECT #: 12141

12/18/2012 4:22:52 PM C:\Users\grieke\Documents\12141 - WVU_Hodess - Interior Central_grieke.rvt

Appendix A.5 – Clean Room Mechanical Plan



1 M401 — Level 0 - Clean Room Enlarged Plan
1/4" = 1'-0"

GENERAL NOTES

GENERAL NOTES APPLY TO ALL SHEETS IN THE SERIES THAT THEY ARE ON. EACH SERIES OF SHEETS WILL START OVER AT NOTE 1.

1. CLEAN ROOM HEPA FILTERS BY CLEAN ROOM MFR. DIV 23 TO PROVIDE HARD CONNECTION
2. CLEAN ROOM FAN FILTER UNITS BY CLEAN ROOM MFR. DIV 23 TO PROVIDE FLEX CONNECTION

KEY NOTES

KEY NOTES ARE NUMBERED SEQUENTIALLY FROM M1 TO THE LAST KEY NOTE. THEY ARE PROJECT SPECIFIC. REFER TO M002 FOR THE ENTIRE LIST OF ALL KEY NOTES. ONLY THE KEY NOTES USED ON A SPECIFIC SHEET WILL BE LISTED ON THAT SHEET.

M3	Mount unit heater high above ductwork. Create a large enough space between the air valves to allow a tall enough ladder to be placed for servicing the unit heater. The intent of the unit heater is to heat the large volume above the ceiling.
M9	The area above the ceiling is a "double" height space. Refer to M0030b for continuation of work.
M67	Plenum by clean room mfr. Coordinate SA duct connection.
M77	Process Chilled Water drop. Refer to the process chilled water termination detail on the M000 series drawings.
M78	Coordinate the exact location of the drop during the fitout phase of the project based on the final room layout.
M104	Refer to M2030 for continuation
M105	Refer to M402 for the terminal balance schedule information associated with this valve. The laboratory information was kept together on one sheet.
M106	Locate unit below the ceiling.
M107	Locate this air terminal box in the vertical with the controller ported in the accessible direction
M108	Fan Filter module provided by the clean room contractor. Provide final connection to the equipment. There shall be a flexible connection between the unit and the ductwork. Refer to M603a for the fan filter module CFM. The mechanical contractor shall set the flow rate.
M112	HEPA filter provided by clean room contractor. Provide final connection and volume damper / Young Regulator. Balance each HEPA filter so that each filter has the same air flow.
M113	Provide duct connection to the top of the clean room for the ducted return from the clean room. Provide a volume damper / Young Regulator as shown / as required to evenly balance the flow between all of the room grilles for each room.
M114	Throw shall be set up for the vertical pattern
M115	Provide duct connection to the top of the clean room for the ducted return from the clean room.

TERMINAL BALANCE SCHEDULE

Zone/Room Numbers	Control Sequence	Box/Valve Type		Box Inlet Size	CFM Max.	CFM Min. Occ.	CFM Min. Unocc.
004A, 004B, 005A, 005B	5.1	VAR	3	0-1	430	100	100
003	3.5	VAR	2	0-2	250	50	50
015	3.5	VAR	2	0-3	150	150	150
CORRIDOR	3.5	VAR	2	0-4	200	200	200

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CONSULTANTS:

SEAL:

SEAL:

KEY PLAN:

PROJECT TITLE:

Advanced Engineering Research Building

WEST VIRGINIA UNIVERSITY PROJECT NO:
20110258

PROJECT LOCATION:
West Virginia University
Evansdale Drive
Morgantown, WV 26505

Revisions		
No.	Date	Description
1	11/7/2012	ADDENDUM #3

DRAWING TITLE

LEVEL 0 - CLEAN ROOM ENLARGED PLAN

ISSUE DATE: 10/16/12

DESIGN BY: Designer | APPROVED BY: Approver

SCALE: As indicated | REV LEVEL:

DRAWING NUMBER:

M401

STANTEC PROJECT NO.
218010157

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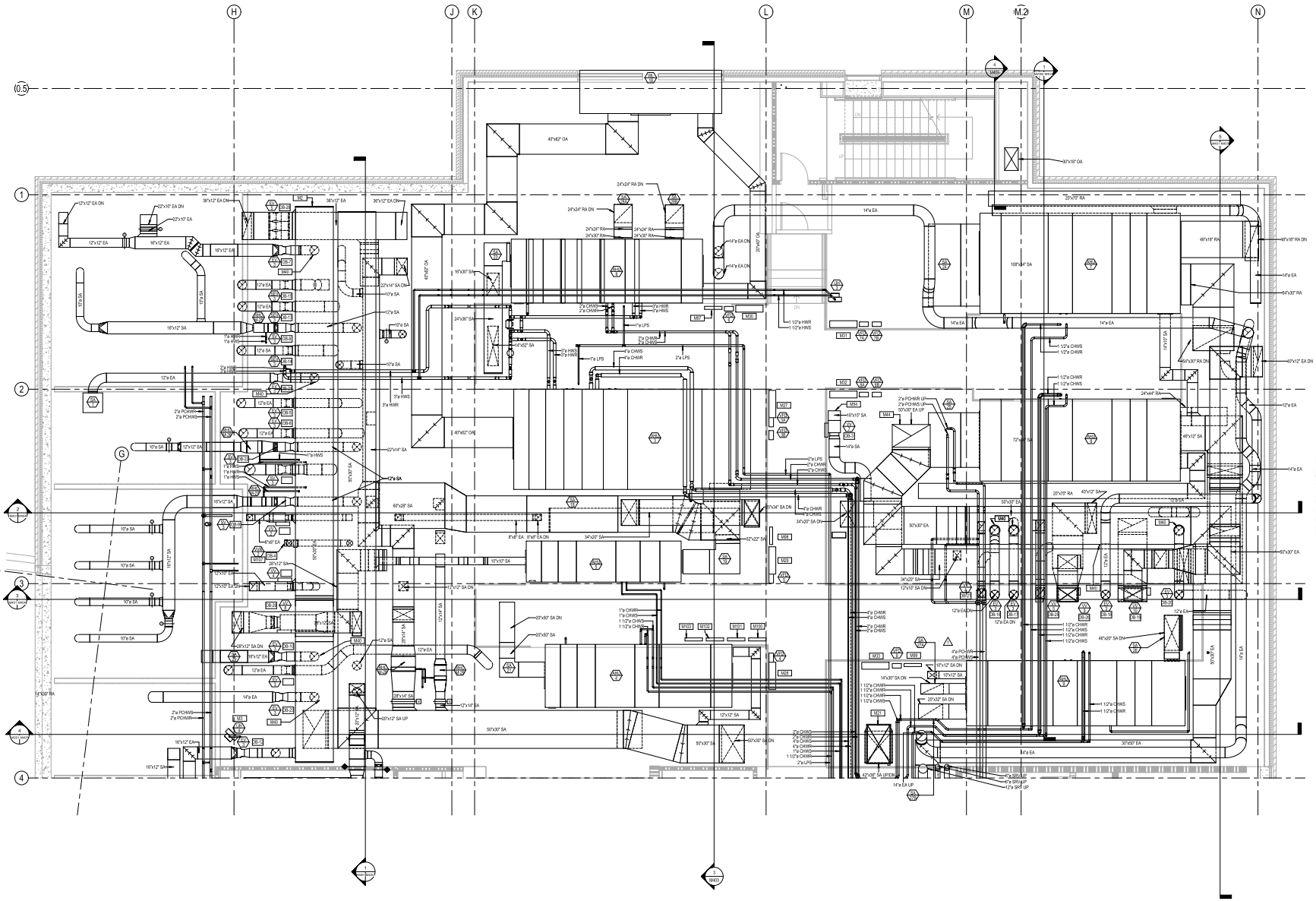
Appendix A.6 – Mezzanine Mechanical Plan



LEVEL 0 MEZZANINE - CLEAN ROOM ENLARGED PLAN

1/4" = 1'-0"

GENERAL NOTES

GENERAL NOTES APPLY TO ALL SHEETS IN THE SERIES THAT THEY ARE ON. EACH SERIES OF SHEETS WILL START OVER AT NOTE 1.

1. GENERAL NOTE 1.
2. GENERAL NOTE 2.

KEY NOTES

KEY NOTES ARE NUMBERED SEQUENTIALLY FROM MY TO THE LAST KEY NOTE. THEY ARE PROJECT SPECIFIC. REFER TO M002 FOR THE ENTIRE LIST OF ALL KEY NOTES. ONLY THE KEY NOTES USED ON A SPECIFIC SHEET WILL BE LISTED ON THAT SHEET.

M2	End of Stainless Steel Ductwork main.
M3	Mount unit heater high above ductwork. Create a large enough space between the air valves to allow a tall enough ladder to be placed for servicing the unit heater. The intent of the unit heater is to heat the large volume above the ceiling.
M21	Penetrate the bottom of the architectural shaft enclosure that is located below the LV1 slab. Provide a fire-smoke damper at penetration, coordinate with GC for required opening.
M27	Locate the AHU-3 controller here along wall
M28	Locate the AHU-4 controller here along wall
M30	Locate the AHU-5 controller here along wall
M31	Locate the AHU-6 controller here along wall
M32	Locate the AHU-7 controller here along wall
M33	Locate the AHU-8 controller here along wall
M40	Galvanized duct connection to a S.S exhaust main.
M44	(not used)
M54	Provide birds screen cover over open end of duct
M57	All volume dampers associated with AHU-6 shall have Young Regulator cable controls for remote balancing. Terminate each cable here.
M58	All volume dampers associated with AHU-5 shall have Young Regulator cable controls for remote balancing. Terminate each cable here.
M59	All volume dampers associated with AHU-8 shall have Young Regulator cable controls for remote balancing. Terminate each cable here.
M100	All volume dampers associated with Gowning Airlock shall have Young Regulator cable controls for remote balancing. Terminate each cable here.
M101	All volume dampers associated with Gowning shall have Young Regulator cable controls for remote balancing. Terminate each cable here.
M102	All volume dampers associated with Equipment Airlock shall have Young Regulator cable controls for remote balancing. Terminate each cable here.
M103	All volume dampers associated with Class 1000 Clean Corridor shall have Young Regulator cable controls for remote balancing. Terminate each cable here.
M107	Locate the air terminal box in the vertical with the controller pointed in the accessible direction.

TERMINAL BALANCE SCHEDULE

Zone/Room Numbers	Control Sequence	Box/Valve Type	Box/ Valve #	CFM Max.	CFM Min. Occ.	CFM Min. Unocc.
M03	4.5	VV	3	OB-1	385	105	105
M09	4.5	VV	3	OB-2	300	100	100
M02	3.5	VV	7	OB-3	1500	1500	1500
CORRIDOR	3.5	VVR	2	OB-4	160	150	150
006J	4.5	EV	3	OB-5	700	700	700
006J	4.5	EV	3	OB-6	700	700	700
013A, 013B	4.2	EV	3	OB-7	975	435	265
013A, 013B	4.2	SV	3	OB-8	1050	510	340
011	4.2	SV	3	OB-9	1050	485	325
011	4.2	EV	3	OB-10	975	410	250
009	4.2	SV	3	OB-11	1050	353	240
009	4.2	EV	3	OB-12	975	280	165
0001	4.5	SEV	3	OB-13	950	950	950
0001	4.5	SEV	3	OB-14	950	950	950
0001	4.5	SEX	3	OB-15	950	950	950
CHASE	4.5	EV	3	OB-16	700	700	700
CHASE	4.5	EV	3	OB-17	700	700	700

Zone/Room Numbers	Control Sequence	Box/Valve Type	Box/ Valve #	CFM Max.	CFM Min. Occ.	CFM Min. Unocc.
CHASE	4.5	EV	3	OB-18	700	700	700
CHASE	4.5	VV	10	OB-19	3500	3500	3500
CHASE	4.5	EV	3	OB-20	700	700	700
012	4.3	EV	3	OB-21	300	300	300
012	4.3	SV	3	OB-22	625	225	225
010	4.3	EV	3	OB-23	825	300	300
010	4.3	SV	3	OB-24	825	225	225
CHASE	4.5	VV	5	OB-25	690	0	0
CHASE	4.5	VV	9	OB-26	3200	3200	3200
SERVICE	4.5	VV	4	OB-27	0	0	0
CHASE/PLENUM							
006H	4.5	EV	5	OB-28	4180	4180	4180
		VV	8	OB-29	1900	0	0

LABORATORY REQUIREMENTS

ROOM NUMBER	+/-%	OFFSET	MINIMUM OCCUPIED EXHAUST	MINIMUM UNOCCUPIED EXHAUST
009	+	75	305	240
010	-	75	900	390
011	+	75	485	325
012	-	75	900	390
013A	+	75	910	340

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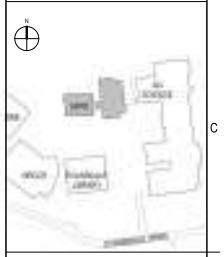

PROJECT TITLE:

Advanced Engineering Research Building

WEST VIRGINIA UNIVERSITY PROJECT NO:
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Revisions		
No.	Date	Description
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DRAWING TITLE

LEVEL 0 MEZZANINE-CLEAN ROOM ENLARGED PLAN

ISSUE DATE: 10/16/12

DESIGN BY: Designer | APPROVED BY: Approver

SCALE: As indicated | REV LEVEL:

DRAWING NUMBER:

M402

STANTEC PROJECT NO.
218010157

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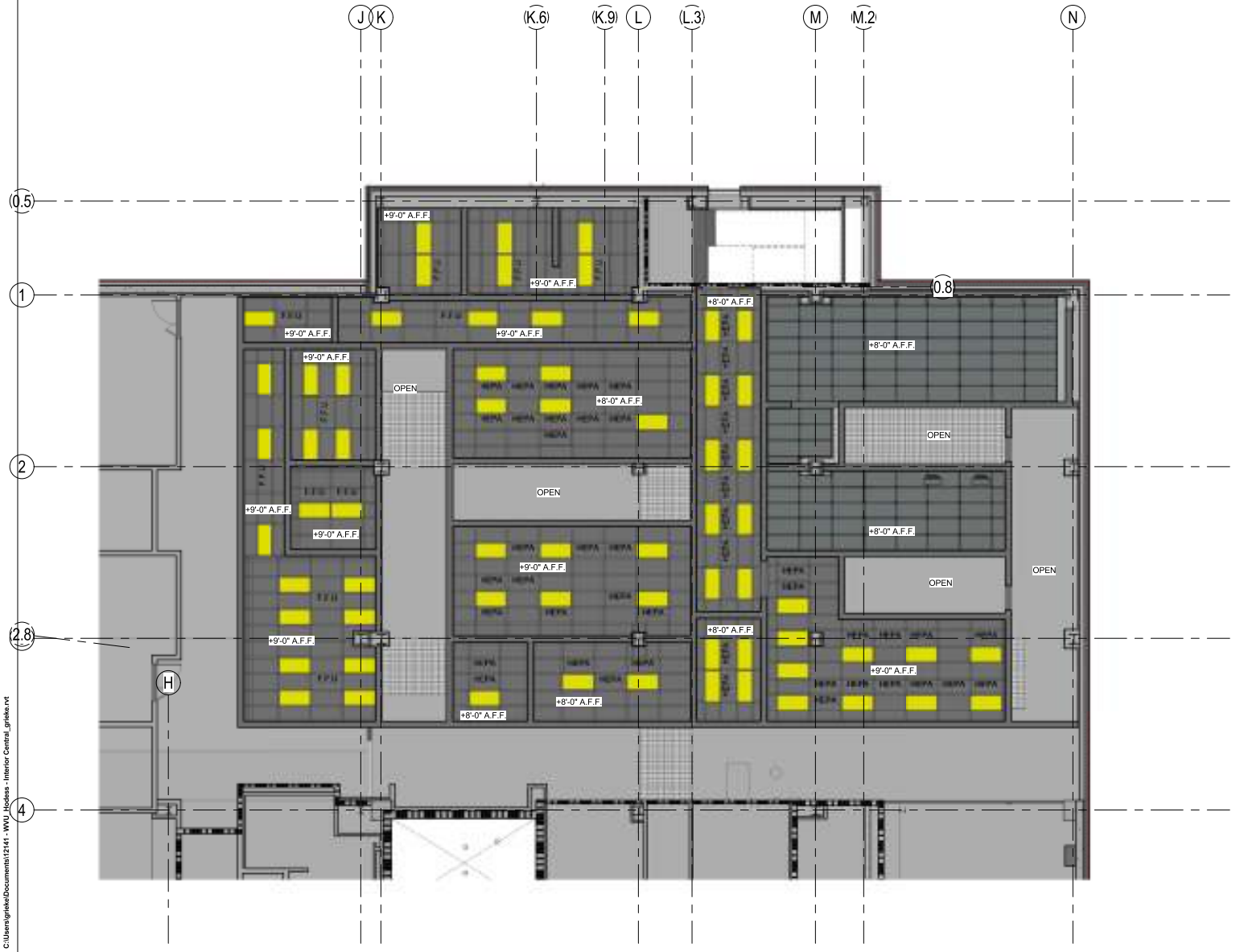
Appendix A.7 – Clean Room Lighting Plan



1 Level 0
1/8" = 1'-0"

PRELIMINARY

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11/27/2012 LOUVER REVISIONS

DRAWN: JS CHECK: SAK

SCALE: 1/8" = 1'-0"

Cleanroom Reflected Ceiling Plan

SHEET:

CR300a

PROJECT #: 12141

Appendix A.8 – Air-Handling Unit Details

AIR HANDLING UNIT 1, 2, 3 SCHEDULE

MARK		LOCATION	SERVICE	CAPACITY (CFM) SA	CAPACITY (CFM) DESIGN OA	MAX. VEL. FPM	ESP (IN. W.G.) SUPPLY	ESP (IN. W.G.) RETURN	SUPPLY FAN	PRE-FILTER	FINAL FILTER	COOLING COIL	HEATING COIL	SOUND POWER Db 63	125	250	500	1000	2000	4000	8000	MANUFACTURER	MODEL	REMARKS
AHU	1	PENTHOUSE	LV1-LV3	42700	25435	450	2.75	1.25	SF-1	PF-1	FF-1	CC-1	HC-1	89	95	88	100	96	90	85	82	TIM	CUSTOM	1,2,3,4,5,6,7,8,9,10,11,12,13,14
AHU	2	PENTHOUSE	LV1-LV3	42700	25435	450	2.75	1.25	SF-2	PF-2	FF-2	CC-2	HC-2	89	95	88	100	96	90	85	82	TIM	CUSTOM	1,2,3,4,5,6,7,8,9,10,11,12,13,14
AHU	3	LV1-LV3	LV0 / CLEAN RM	23700	23700	485	2.05	0.00	SF-3	PF-3	FF-3	CC-3	HC-3	90	94	83	97	97	95	91	86	TIM	CUSTOM	1,2,3,4,5,6,7,8,9,10,11,13,14

1. Manufacturer and model are basis of design.
2. The fan power levels are at the discharge of the unit.
3. The external pressure drop includes all pressure drop except for the pressure drop inside of the unit from the duct inlet connection to the duct outlet connection.
4. All access doors shall be a minimum of 24" wide and 72" tall.
5. Refer to the "500" series sheet for all applicable / required details to be used in the construction of the units.
6. All penetration through the custom AHU shall be made in the factory by the custom AHU mfr. The mechanical contractor shall coordinate all of the final sizes with the mfr prior to the submittal drawings. The mechanical contractor shall be responsible for the final sealing of the unit per the mfr requirements.
7. The unit mfr shall provide a junction box on the interior (SR) and the exterior of the unit for each section for control wiring. Conduit shall connect each J-box. The size of the box and conduit shall be coordinated with the controls contractor. The 600 series drawings should be used to estimate the sizes.
8. Each unit should include a section light. All lights shall be wired together to a single switch in the middle of the unit on the exterior side of the unit. For AHU-1 and AHU-2, there shall be a second switch on the other side of the unit for the fan sections that are isolated from the rest of the access doors.
9. Units have a steam humidifier. Each humidifier shall be insulated with a short absorption manifold. The steam pressure shall be 10 PSIG. AHU-1 and AHU-2 shall be sized for a leaving air set point of 53° F DB and 0.00802 lb/lb with an entering temperature of 53° F DB and 0.0015 lb/lb. AHU-3 shall be sized for a leaving air set point of 50° F and 0.0052246 lb/lb with an entering temperature of 50° F and 0.0004988 lb/lb.
10. Coordinate lug configurations with conductor sizes and quantities indicated on electrical drawings prior to ordering.
11. The unit shall have a UV light after the Cooling Coil.
12. The unit shall be constructed to allow for the unit to run with 1 fan while the other fan is isolated for repair/service.
13. Coordinate the location of all duct connections with the final coordination drawings before fabrication.
14. Provide all control dampers as shown on the M600 series drawings that are located inside of the unit.

AHU 1, 2, 3 FAN SCHEDULE (NORMAL)

MARK		SERVICE	LOCATION	TYPE AND ARRANGEMENT	CFM	S.P. IN W.G.	FAN RPM	BHP	MOTOR HP	MOTOR VOLTS	MOTOR PHASE	WHEEL TYPE	WHEEL DIA	MANUFACTURER	MODEL	REMARKS
SF	1	AHU-1	PENTHOUSE	DIRECT DRIVE	23700	7.00	1993	37.5	50	460	3	PLENUM	30"	GREENHECK	30-QEP	1,2,3,4,5,6
SF	2	AHU-2	PENTHOUSE	DIRECT DRIVE	23700	7.00	1993	37.5	50	460	3	PLENUM	30"	GREENHECK	30-QEP	1,2,3,4,5,6
SF	3	AHU-3	AHU-3	DIRECT DRIVE	11850	6.00	2380	16.9	25	460	3	PLENUM	22"	GREENHECK	22-QEP	1,2,3,4,5

1. Manufacturer and model are basis of design.
2. 2 Fans per AHU. The CFM, BHP, and HP flow rate is per fan. Fans shall be identified as "a", "b", etc.
3. The fans are direct drive plenum fans
4. Fans performance does not include fan system affect re-rating. The custom AHU mfr shall adjust the fan size to account for system affect caused by the fan configuration.
5. Each fan shall have a dedicated VFD.
6. The fan is sized based on 47,500 per unit (for redundancy) with the corresponding initial pressure drop.

AHU 1, 2, 3 COOLING COIL SCHEDULE

MARK		LOCATION	CFM	MBH SENSIBLE	MBH TOTAL	AIR TEMPERATURE (°F) E.D.B.	AIR TEMPERATURE (°F) E.W.B.	AIR TEMPERATURE (°F) L.D.B.	AIR TEMPERATURE (°F) L.W.B.	MAX. FACE VELOCITY	WATER (°F) E.W.T.	WATER (°F) L.W.T.	GPM	WATER P.D. FT. W.G.	MAX. AIR P.D. IN. W.G.	MAX. ROWS	REMARKS
CC	1	AHU-1	42700	1,610	2,293	87.3	69.5	52.5	52.3	450	44	60	285.0	5.80	0.94	8	1,2,3,4
CC	2	AHU-2	42700	1,610	2,293	87.3	69.5	52.5	52.3	450	44	60	285.0	5.80	0.94	8	1,2,3,4
CC	3	AHU-3	23700	1,005	1,799	89.0	72.0	48.0	47.3	450	44	60	225.0	13.10	1.33	6	1,2,3

1. The cooling coil shall be selected based on achieving the design leaving air temperature.
2. The coil shall be a split coil and only require half of the width of the unit for coil pull area.
3. The coil shall be designed for a face pull and the coil shall be removed from the unit through the access door. The corresponding access door shall be of sufficient height.
4. The coil is sized based on the heat recovery not working.

AHU 1, 2, 3 HEATING COIL SCHEDULE

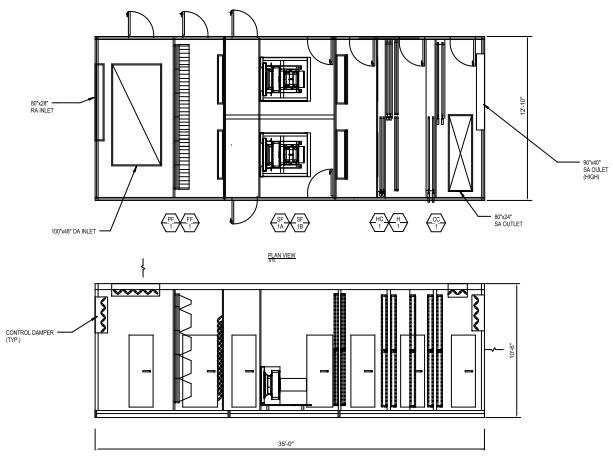
MARK		LOCATION	CFM	COIL CAPACITY MBH	AIR TEMPERATURE (°F) E.D.B.	AIR TEMPERATURE (°F) L.D.B.	MAX. FACE VELOCITY	GPM	WATER TEMPERATURE (°F) E.W.T.	WATER TEMPERATURE (°F) L.W.T.	AIR P.D. IN. W.G.	WATER P.D. FT. W.G.	MAX. ROWS	REMARKS
HC	1	AHU-1	27000	1,023	18	53	450	54.0	200	160	0.04	1.61	2	1,2,3,4,5
HC	2	AHU-2	27000	1,023	18	53	450	54.0	200	160	0.04	1.61	2	1,2,3,4,5
HC	3	AHU-3	23700	1,142	4	56	450	57.1	200	180	0.07	10.37	2	1,2,3,4

1. The heating coil shall be selected based on achieving the design leaving air temperature.
2. The coil shall be a split coil and only require half of the width of the unit for coil pull area.
3. The coil shall be designed for a face pull and the coil shall be removed from the unit through the access door. The corresponding access door shall be of sufficient height.
4. Coil is sized based on heat recovery not working.
5. Coil pressure drop shall correspond to full AHU air flow.

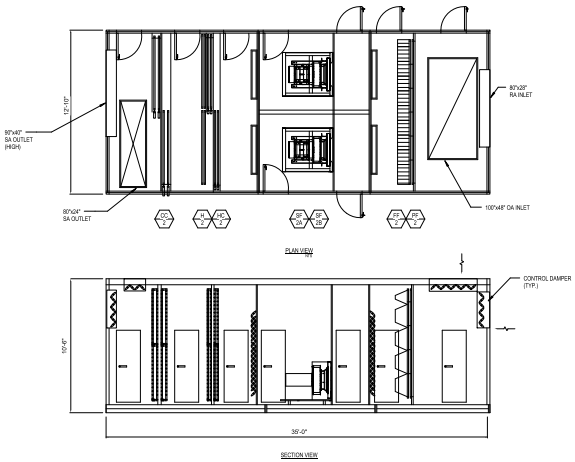
AHU 1, 2, 3 AIR FILTER SCHEDULE

MARK		SERVICE	TYPE	FILTER EFFICIENCY	CFM	MAX. AIR VELOCITY	INITIAL P.D. (IN. W.G.)	MANUFACTURER	MODEL	REMARKS
PF	1	AHU-1	RADIAL PLEATED	MERV-8	42700	450	0.23	FARR	30/30	1,2,3,4
PF	2	AHU-2	RADIAL PLEATED	MERV-8	42700	450	0.23	FARR	30/30	1,2,3,4
PF	3	AHU-3	RADIAL PLEATED	MERV-8	23700	450	0.19	FARR	30/30	1,2,3,4
FF	1	AHU-1	RIGID - HIGH EFFICIENCY	MERV-13	42700	450	0.49	FARR	RIGA-V	1,2,3,4
FF	2	AHU-2	RIGID - HIGH EFFICIENCY	MERV-13	42700	450	0.49	FARR	RIGA-V	1,2,3,4
FF	3	AHU-3	RIGID - HIGH EFFICIENCY	MERV-13	23700	450	0.45	FARR	RIGA-V	1,2,3,4

1. Manufacturer and model are basis of design.
2. A dirty filter allowance of twice the clean pressure drop shall be used as the filter pressure drop when calculating the internal pressure drop of the unit.
3. Provide a magnehelic differential pressure gauge for each filter bank on the exterior of the unit.
4. Match the filter area to the cross section of the unit to maximize the amount of filter area.



1 AHU 1 PLAN AND ELEVATION VIEWS
NTS



2 AHU 2 PLAN AND ELEVATION VIEWS
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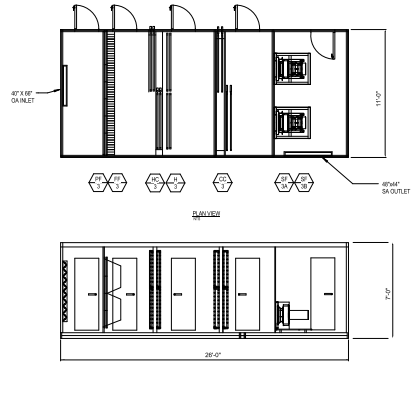

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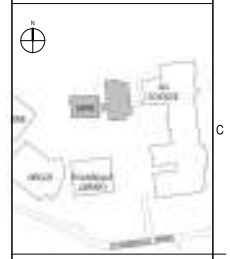

PROJECT TITLE:

Advanced Engineering Research Building

WEST VIRGINIA UNIVERSITY PROJECT NO:
20110258

PROJECT LOCATION:

West Virginia University
Evansdale Drive
Morgantown, WV 26505

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DRAWING TITLE

AHU SCHEDULES - SHEET 1

ISSUE DATE: 10/16/12

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M701A

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AIR HANDLING UNIT 4, 5, 6 SCHEDULE

MARK		LOCATION	SERVICE	CAPACITY (CFM) SA	CAPACITY (CFM) DESIGN OA	MAX. VEL FPM	ESP (IN. W.G.) SUPPLY	ESP (IN. W.G.) RETURN	SUPPLY FAN	PRE-FILTER	FINAL FILTER	COOLING COIL	HEATING COIL	SOUND POWER Db 63	125	250	500	1000	2000	4000	8000	MANUFACTURER	MODEL	REMARKS
AHU	4	LV 0 MEZZANINE	AIR LOCK CLASS 5, SOWMING CLASS, EQUIPMENT ENTRY CLASS, CLEAN ROOM CORRIDOR CLASS	11500	520	450	1.66	0.75	SF-4	PF-4	FF-4	CC-4		84	88	89	87	83	78	74	72	TMI	CUSTOM	1,2,3,4,5,6,7,8,10,12,13
AHU	5	LV 0 MEZZANINE	DEPOSITION CLASS	4440	300	450	1.82	0.50	SF-5	PF-5	FF-5	CC-5		83	82	80	88	82	81	76	76	TMI	CUSTOM	1,2,3,4,5,6,7,8,10,12,13
AHU	6	LV 0 MEZZANINE	WET PROCESS CLASS	7500	5100	450	2.12	1.00	SF-6	PF-6	FF-6	CC-6	HC-4	88	91	95	96	92	87	81	78	TMI	CUSTOM	1,2,3,4,5,6,7,8,9,10,11,12,13

1. Manufacturer and model are basis of design.
2. The fan power levels are at the discharge of the unit.
3. The external pressure drop includes all pressure drop except for the pressure drop inside of the unit from the duct inlet connection to the duct outlet connection.
4. All access doors shall be a minimum of 24" wide and 72" tall (or as tall as possible given the height of the unit).
5. Refer to the "500" series sheet for all applicable / required details to be used in the construction of the units.
6. All penetration through the custom AHU shall be made in the factory by the custom AHU mfr. The mechanical contractor shall coordinate all of the final sizes with the mfr prior to the submittal drawings. The mechanical contractor shall be responsible for the final sealing of the unit per the mfr requirements.
7. The unit mfr shall provide a junction box on the interior (IR) and the exterior of the unit for each section for control wiring. Conduit shall connect each J-box. The size of the box and conduit shall be coordinated with the controls contractor. The 800 series drawings should be used to estimate the sizes.
8. Each unit should include a section light. All lights shall be wired together to a single switch in the middle of the unit on the exterior side of the unit.
9. This unit shall have a steam humidifier. The humidifier shall be insulated with a short absorption manifold. The steam pressure shall be 10 PSI. AHU-6 shall be sized for a leaving air set point of 65° F and 0.007517 lb/lb with an entering temperature of 37.70° F DB and 0.004177 lb/lb.
10. Coordinate lug configurations with conductor sizes and quantities indicated on electrical drawings prior to ordering.
11. Provide bypass damper over HC-4B and CC-4.
12. The AHU air flow set point (MBS drawings) will determine the actual supply air flow.
13. Provide UV lights down stream of the cooling coil.

AHU 4, 5, 6 FAN SCHEDULE (NORMAL)

MARK		SERVICE	LOCATION	TYPE AND ARRANGEMENT	CFM	S.P. IN W.G.	FAN RPM	BHP	MOTOR HP	MOTOR VOLTS	MOTOR PHASE	WHEEL TYPE	WHEEL DIA.	MANUFACTURER	MODEL	REMARKS
SF	4	AHU-4	AHU-4	DIRECT DRIVE	11500	4.25	1804	10.8	20	460	3	PLENUM	24"	GREENHECK	24-QEP	1,3,4,5
SF	5	AHU-5	AHU-5	DIRECT DRIVE	4440	4.50	2631	4.2	7.5	460	3	PLENUM	18"	GREENHECK	18-QEP	1,3,4,5
SF	6	AHU-6	AHU-6	DIRECT DRIVE	7500	6.20	3060	11.9	15	460	3	PLENUM	18"	GREENHECK	18-QEP	1,3,4,5

1. Manufacturer and model are basis of design.
2. 2 Fans per AHU. The CFM, BHP, and HP flow rate is per fan. Fans shall be identified as "A", "B", etc.
3. The fans are direct drive plenum fans.
4. Fans performance does not include fan system affect de-rating. The custom AHU mfr shall adjust the fan size to account for system affect caused by the fan configuration.
5. Each fan shall have a dedicated VFD.

AHU 4, 5, 6 AIR FILTER SCHEDULE

MARK	Unit Mark	SERVICE	TYPE	FILTER EFFICIENCY	CFM	MAX. AIR VELOCITY	INITIAL P.D. (IN. W.G.)	MANUFACTURER	MODEL	REMARKS
PF	4	AHU-4	RADIAL PLEATED	MERV-8	11500	450	0.21	FARR	30/30	1,2,3,4
FF	4	AHU-4	RIGID - HIGH EFFICIENCY	MERV-13	11500	450	0.47	FARR	RGA-V	1,2,3,4
PF	5	AHU-5	RADIAL PLEATED	MERV-8	4440	450	0.21	FARR	30/30	1,2,3,4
FF	5	AHU-5	RIGID - HIGH EFFICIENCY	MERV-13	4440	450	0.47	FARR	RGA-V	1,2,3,4
PF	6A	AHU-6	RADIAL PLEATED	MERV-8	5100	450	0.28	FARR	30/30	1,2,3,4
FF	6A	AHU-6	RIGID - HIGH EFFICIENCY	MERV-13	7500	450	0.47	FARR	RGA-V	1,2,3,4
FF	6B	AHU-6	RIGID - HIGH EFFICIENCY	MERV-13	2340	450	0.47	FARR	RGA-V	1,2,3,4
PF	6B	AHU-6	RADIAL PLEATED	MERV-13	2340	450	0.21	FARR	30/30	1,2,3,4
PF	6C	AHU-6	RADIAL PLEATED	MERV-8	3296	450	0.21	FARR	30/30	1,2,3,4

1. Manufacturer and model are basis of design.
2. A dirty filter allowance of twice the clean pressure drop shall be used as the filter pressure drop when calculating the internal pressure drop of the unit.
3. Provide a magnehelic differential pressure gauge for each filter bank on the exterior of the unit.
4. Match the filter area to the cross section of the unit to maximize the amount of filter area.

AHU 4,5, 6 COOLING COIL SCHEDULE

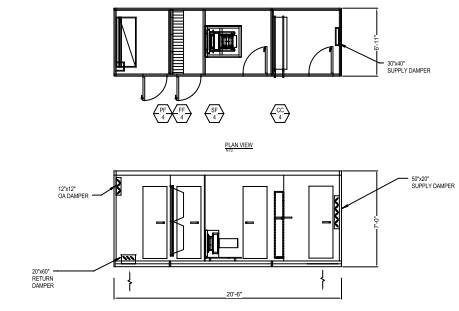
MARK		LOCATION	CFM	MBH SENSIBLE	MBH TOTAL	AIR TEMPERATURE (°F) E.D.B.	AIR TEMPERATURE (°F) E.W.B.	AIR TEMPERATURE (°F) L.D.B.	AIR TEMPERATURE (°F) L.W.B.	MAX. FACE VELOCITY	WATER (°F) E.W.T.	WATER (°F) L.W.T.	GPM	WATER P.D. FT. W.G.	MAX. AIR P.D. IN. W.G.	MAX. ROWS	REMARKS
CC	4	AHU-4	11500	27.6	28.5	69.7	57.4	67.5	56.5	450	44	60	4.3	2.70	0.06	6	1,3
CC	5	AHU-5	4440	20.6	29.4	70.4	57.6	64.1	55.1	450	44	60	3.8	6.34	0.12	6	1,3
CC	6	AHU-6	5100	232.4	490.2	89.0	72.5	47.0	46.5	450	44	60	50.0	10.50	0.35	6	1,3

1. The cooling coil shall be selected based on achieving the design leaving air temperature.
2. The coil shall be a split coil and only require half of the width of the unit for coil pull area.
3. The coil shall be designed for a face pull and the coil shall be removed from the unit through the access door. The corresponding access door shall be of sufficient height.

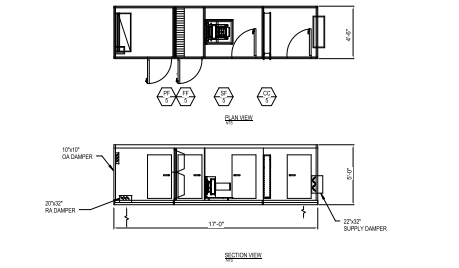
AHU 6 HEATING COIL SCHEDULE

MARK		LOCATION	CFM	COIL CAPACITY MBH	AIR TEMPERATURE (°F) E.D.B.	AIR TEMPERATURE (°F) L.D.B.	MAX. FACE VELOCITY	GPM	WATER TEMPERATURE (°F) E.W.T.	WATER TEMPERATURE (°F) L.W.T.	AIR P.D. IN. W.G.	WATER P.D. FT. W.G.	MAX. ROWS	REMARKS
HC	4A	AHU-6	7500	326.5	22.7	65	450	16.3	200	160	0.07	2.68	2	1,3,5
HC	4B	AHU-6	5100	99.6	47	65	450	5.0	200	160	0.04	0.78	1	1,3

1. The heating coil shall be selected based on achieving the design leaving air temperature.
2. The coil shall be a split coil and only require half of the width of the unit for coil pull area.
3. The coil shall be designed for a face pull and the coil shall be removed from the unit through the access door. The corresponding access door shall be of sufficient height.
4. Coil is sized based on heat recovery not working.
5. Coil pressure drop shall correspond to full AHU air flow.



4 AHU 4 PLAN AND ELEVATION VIEWS
NTS



5 AHU 5 PLAN AND ELEVATION VIEWS
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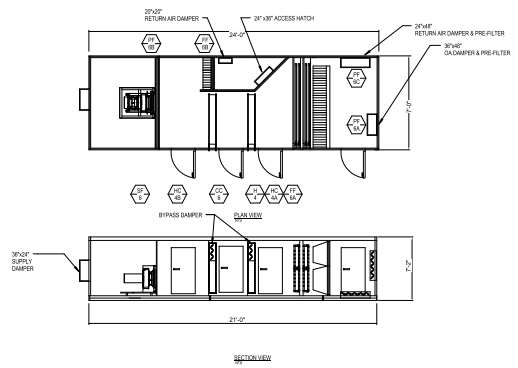


6 AHU 6 PLAN AND ELEVATION VIEWS
NTS

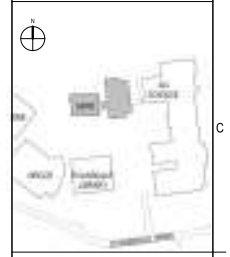
Stantec
400 Morgan Center
101 East Diamond Street
Butler, PA 16001
TEL: 724.285.4761
FAX: 724.285.6815
www.stantec.com

CONSULTANTS:

SEAL:

SEAL:

KEY PLAN:



PROJECT TITLE:

Advanced Engineering Research Building

WEST VIRGINIA UNIVERSITY PROJECT NO:
20110258

PROJECT LOCATION:

West Virginia University
Evansdale Drive
Morgantown, WV 26505

Revisions		
No.	Date	Description
1	11/7/2012	ADDENDUM #3

DRAWING TITLE

AHU SCHEDULES - SHEET 2

ISSUE DATE: 10/16/12

DESIGN BY: Designer | APPROVED BY: Approver

SCALE: As indicated | REV LEVEL:

DRAWING NUMBER:

M701B

STANTEC PROJECT NO.
218010157

12/19/2012 11:00:27 AM TBLOCK-C.dwgx

AIR HANDLING UNIT 7, 8, 9 SCHEDULE

MARK		LOCATION	SERVICE	CAPACITY (CFM) SA	CAPACITY (CFM) DESIGN OA	MAX. VEL FPM	ESP (IN. W.G.) SUPPLY	ESP (IN. W.G.) RETURN	SUPPLY FAN	PRE-FILTER	FINAL FILTER	COOLING COIL	HEATING COIL	SOUND POWER Db 63	125	250	500	1000	2000	4000	8000	MANUFACTURER	MODEL	REMARKS
AHU	7	LV-I MEZZANINE	STEPPERVALIGNER PHOTOLITHOGRAPHY	31000	7500	450	2.00	0.05	SF-7	PF-7	PF-7	CC-7		83	87	91	89	95	85	83	80	TMI	CUSTOM	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16
AHU	8	LV-I MEZZANINE	PHOTOLITHOGRAPHY CLASS 100	23660	3300	450	2.15	0.01	SF-8	PF-8	PF-8	CC-8		91	91	85	95	95	93	90	87	TMI	CUSTOM	1,2,3,4,5,6,7,8,9,10,11,12,13,15,16
AHU	9	LV-I MEZZANINE	ASSEMBLY CLASS 100	8840	955	450	1.66	0.66	SF-9	PF-9	PF-9	CC-9		88	87	87	92	93	87	82	78	TMI	CUSTOM	1,2,3,4,5,6,7,8,9,11,12,13,16

1. Manufacturer and model are basis of design.
2. The fan power levels are at the discharge of the unit.
3. The external pressure drop includes all pressure drop except for the pressure drop inside of the unit from the duct inlet connection to the duct outlet connection.
4. All access doors shall be a minimum of 24" wide and 72" tall.
5. Refer to the "5000" series sheet for all applicable / required details to be used in the construction of the units.
6. All penetration through the custom AHU shall be made in the factory by the custom AHU mfr. The mechanical contractor shall coordinate all of the final sizes with the mfr prior to the submittal drawings. The mechanical contractor shall be responsible for the final sealing of the unit per the mfr requirements.
7. The unit mfr shall provide a junction box on the interior (SR) and the exterior of the unit for each section for control wiring. Conduit shall connect each J-box. The size of the box and conduit shall be coordinated with the controls contractor. The 800 series drawings should be used to estimate the sizes.
8. Each unit should include a section light. All lights shall be wired together to a single switch in the middle of the unit on the exterior side of the unit.
9. Coordinate lug configurations with conductor sizes and quantities indicated on electrical drawings prior to ordering.
10. Install the OA air flow stations inside of the RA plenum. Provide manual volume dampers into each return air duct.
11. The AHU air flow set point (MBS0 drawings) will determine the actual supply air flow. The AHUs have been designed to operate at the lower velocity.
12. Provide all control dampers (as shown on the MBS series drawings) that are located inside of the unit.
13. Coordinate the condensate drain location with the coordinated shop drawings. The drain location is critical to the drain piping fitting properly.
14. The AHU MPR shall provide the sound attenuator (SA-A) located with-in the unit. The attenuator shall comply with the sound attenuator specification and be equal to the VIBRO-ACOUSTICS MODEL PD-ULV. The size shall be 3 ft long and match the cross section of the unit. Provide the following dynamic insertion losses

HZ 63 125 250 500 1000 2000 4000
LOSS 7 7 13 17 11 9 6

15. The AHU MPR shall provide the sound attenuator (SA-B) located with-in the unit. The attenuator shall comply with the sound attenuator specification and be equal to the VIBRO-ACOUSTICS MODEL PD-ULV. The size shall be 3 ft long and match the cross section of the unit. Provide the following dynamic insertion losses

HZ 63 125 250 500 1000 2000 4000
LOSS 7 7 13 17 11 9 6

16. Provide UV lights down stream of the cooling coil.

AHU 7, 8, 9 FAN SCHEDULE (NORMAL)

MARK		SERVICE	LOCATION	TYPE AND ARRANGEMENT	CFM	S.P. IN. W.G.	FAN RPM	BHP	MOTOR HP	MOTOR VOLTS	MOTOR PHASE	WHEEL TYPE	WHEEL DIA.	MANUFACTURER	MODEL	REMARKS
SF	7	AHU-7	AHU-7	DIRECT DRIVE	15560	4.50	1780	16.5	25	460	3	PLENUM	27"	GREENHECK	27-QEP	1,2,3,4,5
SF	8	AHU-8	AHU-8	DIRECT DRIVE	11583	4.25	2230	13.2	20	460	3	PLENUM	22"	GREENHECK	22-QEP	1,2,3,4,5
SF	9	AHU-9	AHU-9	DIRECT DRIVE	8840	4.25	2230	13.2	20	460	3	PLENUM	22"	GREENHECK	22-QEP	1,3,4,5

1. Manufacturer and model are basis of design.
2. 2 Fans per unit. The CFM, BHP, and HP flow rate is per fan. Fans shall be identified as "A", "B", etc.
3. The fans are direct drive plenum fans
4. Fans performance does not include fan system affect re-rating. The custom AHU mfr shall adjust the fan size to account for system affect caused by the fan configuration.
5. Each fan shall have a dedicated VFD.

AHU 7, 8, 9 AIR FILTER SCHEDULE

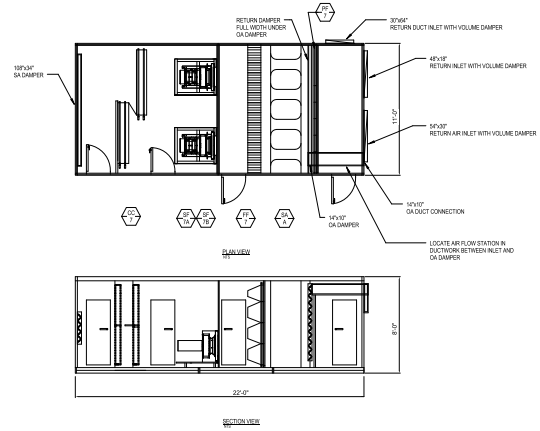
MARK		SERVICE	TYPE	FILTER EFFICIENCY	CFM	MAX. AIR VELOCITY	INITIAL P.D. (IN. W.G.)	MANUFACTURER	MODEL	REMARKS
PF	7	AHU-7	RADIAL PLEATED	MERV-8	31890	450	0.24	FARR	30/30	1,2,3,4,5,6,7
PF	8	AHU-8	RADIAL PLEATED	MERV-8	23660	450	0.21	FARR	30/30	1,2,3,4,5,6,7
PF	9	AHU-9	RADIAL PLEATED	MERV-8	8840	450	0.22	FARR	30/30	1,2,3,4,6,7
FF	7	AHU-7	RIGID - HIGH EFFICIENCY	MERV-13	31890	450	0.48	FARR	RGA-Y	1,2,3,4,6,7
FF	8	AHU-8	RIGID - HIGH EFFICIENCY	MERV-13	23660	450	0.42	FARR	RGA-Y	1,2,3,4,6,7
FF	9	AHU-9	RIGID - HIGH EFFICIENCY	MERV-13	8840	450	0.44	FARR	RGA-Y	1,2,3,4,6,7

1. Manufacturer and model are basis of design.
2. A dirty filter allowance of twice the clean pressure drop shall be used as the filter pressure drop when calculating the internal pressure drop of the unit.
3. Provide a magnehelic differential pressure gauge for each filter bank on the exterior of the unit.
4. Match the filter area to the cross section of the unit to maximize the amount of filter area.
5. Match the filter area to the cross section of the return air damper to maximize the amount of filter area.
6. After all commissioning, certification, balancing activities, and cleaning have been completed, the filters should be replaced with new filters.
7. After all commissioning, certification, balancing activities, and cleaning have been completed, pre filters should be removed and not replaced. The filters should instead be turned over to the owner for storage.

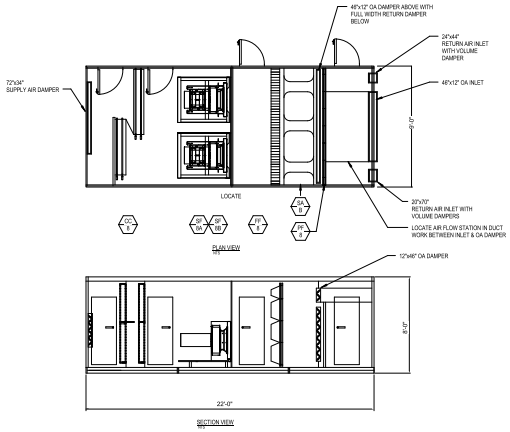
AHU 7, 8, 9 COOLING COIL SCHEDULE

MARK		LOCATION	CFM	MBH SENSIBLE	MBH TOTAL	AIR TEMPERATURE (°F) E.D.B.	E.W.B.	L.D.B.	L.W.B.	MAX. FACE VELOCITY	WATER (°F) E.W.T.	L.W.T.	GPM	WATER P.D. FT. H.G.	MAX. AIR P.D. IN. W.G.	MAX. ROWS	REMARKS
CC	7	AHU-7	31890	525,000.0	126,000	71.1	57.8	87.3	59.8	450	44	60	17.5	1.30	0.56	6	1,2,3
CC	8	AHU-8	23800	48,700.0	48,800	99.3	57.1	67.4	56.4	450	44	60	7.0	1.40	0.55	6	1,2,3
CC	9	AHU-9	8840	45.2	47	69.7	57.2	65.5	55.8	450	44	60	5.9	1.68	0.59	6	1,2,3

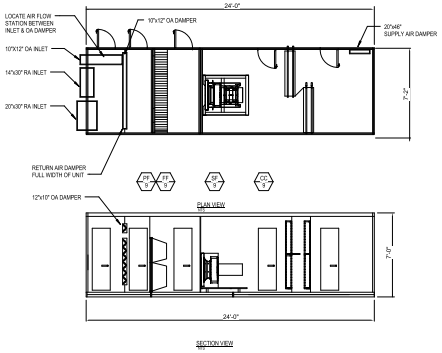
1. The cooling coil shall be selected based on achieving the design leaving air temperature.
2. The coil shall be a split coil and only require half of the width of the unit for coil pull area.
3. The coil shall be designed for a face pull and the coil shall be removed from the unit through the access door. The corresponding access door shall be of sufficient height.



7 AHU 7 PLAN AND ELEVATION VIEWS
NTS



5 AHU 8 PLANS AND ELEVATION VIEWS
NTS



6 AHU 9 PLANS AND ELEVATION VIEWS
NTS

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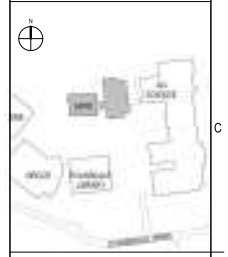
CONSULTANTS:

SEAL:

SEAL:

KEY PLAN:



PROJECT TITLE:

Advanced Engineering Research Building

WEST VIRGINIA UNIVERSITY PROJECT NO:
20110258

PROJECT LOCATION:

West Virginia University
Evansdale Drive
Morgantown, WV 26505

Revisions		
No.	Date	Description
1	11/7/2012	ADDENDUM #3

DRAWING TITLE

AHU SCHEDULES - SHEET 3

ISSUE DATE: 10/16/12

DESIGN BY: Designer	APPROVED BY: Approver
SCALE: As indicated	REV LEVEL:

DRAWING NUMBER:

M701C

STANTEC PROJECT NO.
218010157

12/19/2012 11:58:47 AM TBLOCK-C.dwg

Appendix A.9 – University Representative Interview

Q: ***Were there specific reasons for deciding to offer Hodess Construction a direct contract with the University?***

A: *Hodess was brought on much earlier than Massaro, during the design, for design coordination input. They aided the design team to make sure the Clean Room would be constructable and work out any grey areas early. We had a contract with Hodess for these services as well as the construction services and we had originally planned on transferring their contract to Massaro, but legally was more complicated, so we decided to keep the contract with Hodess.*

Q: ***What are the benefits of this arrangement for WVU?***

A: *The main benefit was having Hodess on board early. This way with their scope of work and the design, all of the little things were able to be sorted out early. As the owner, we want to have the project transfer smoothly from the design phase to construction, that way, the project could hopefully remain on time and budget and eliminate potential cost increases, etc. In terms of monies owed and everything, there isn't really anything different because we have Hodess and Massaro both under contract.*

Appendix A.10 – Massaro Project Manager Interview

Q: ***What are the advantages/disadvantages of having Hodess contracted directly to the University?***

A: *As with having anyone contracted to you there is money owed involved and we don't have to worry about that with Hodess. Also the Clean Room design is very tied to what the owner wants and less confusion on our part because there won't be any major changes later while we are building the thing. Even though Hodess is the Clean Room contractor, we are still responsible for quality of the entire building including the Clean Room, so nothing really changes there with the contract situation. Another disadvantage is there is less direct control for us as the GC over Hodess, but that is something that we work on with constant communication with Hodess.*

Q: ***When it comes to the MEP work for the clean room and surrounding area (Mezzanine, Level 0) do the MEP subs own all the work or does Hodess own that work inside the clean room?***

A: *Basically the MEP subs own all the work except for the terminations within the Clean Room. Hodess owns all HEPA filters, terminals, lights, etc. but the subcontractors own any above ceiling work and in the instance of the lights, the electrical subcontractor owns wiring and powering the lights, but not the fixtures themselves.*

Q: ***If Hodess does not own the MEP work in the clean room, what are the plans for coordinating that work with the MEP subs?***

A: *This was one of the main reasons we decided to create the 3D model of these systems because the coordination was going to be difficult and necessary. There were a lot of meetings and conversations between the different subs and Hodess and us in order to get everything worked out as much as possible. One of the big things we encountered was the hangars for the ceiling grid were clashing with duct and pipes so we all sat in a room and worked out the design to make sure everything fit.*

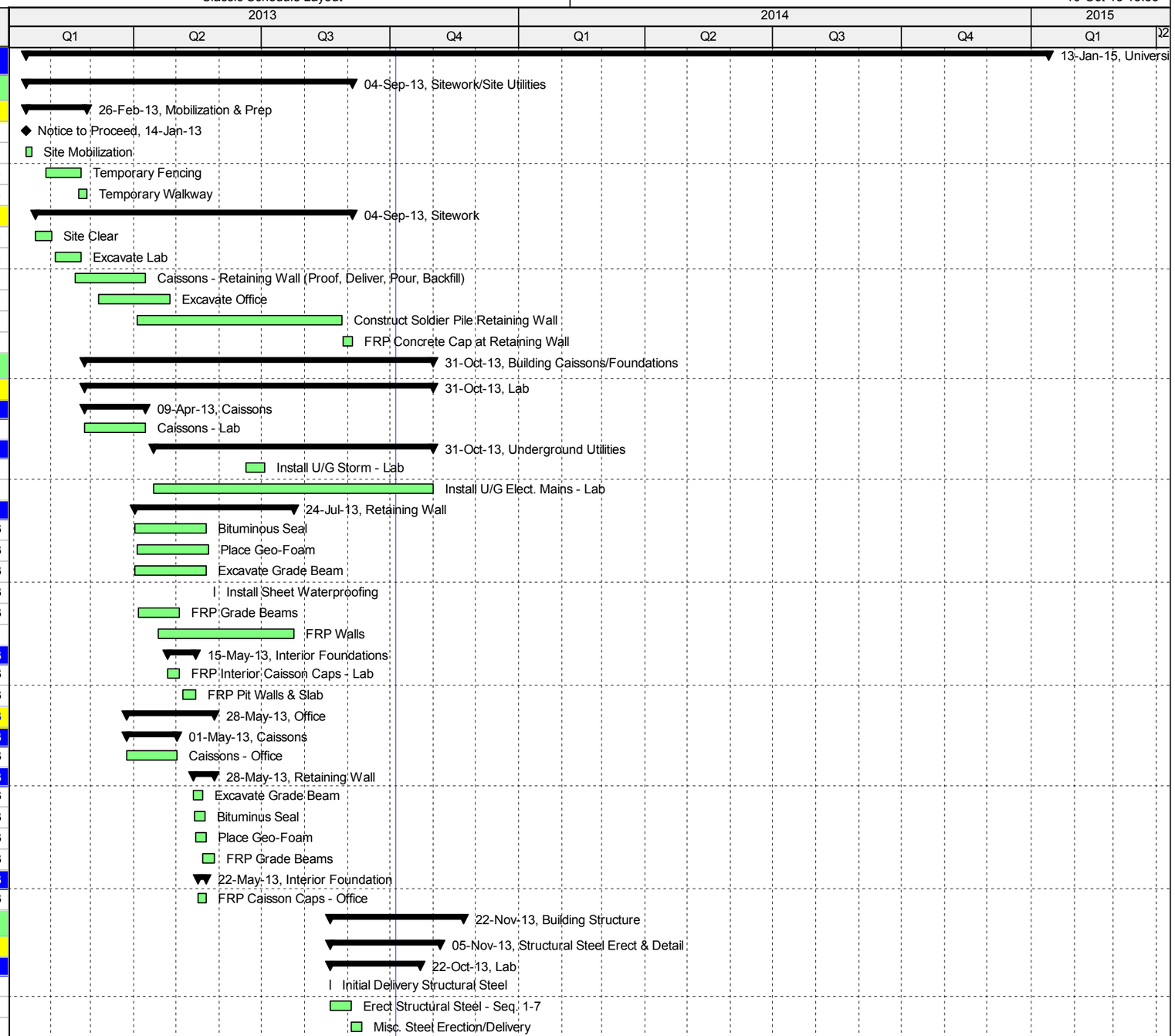
Q: ***How is Massaro affected in terms of RFIs and Submittals regarding the clean room, since the information, I assume, goes directly to Hodess?***

A: *We managed to take care of a lot of the questions and confusion early on so any RFIs were written when the problems were discovered during coordination, but there are some channels that we have to go through since certain questions pertained to Hodess and others were from the subs. I just hope that we can avoid any major RFIs at this point, but some are unavoidable.*

Appendix B – Analysis 2

Appendix B.1 – Original Project Schedule

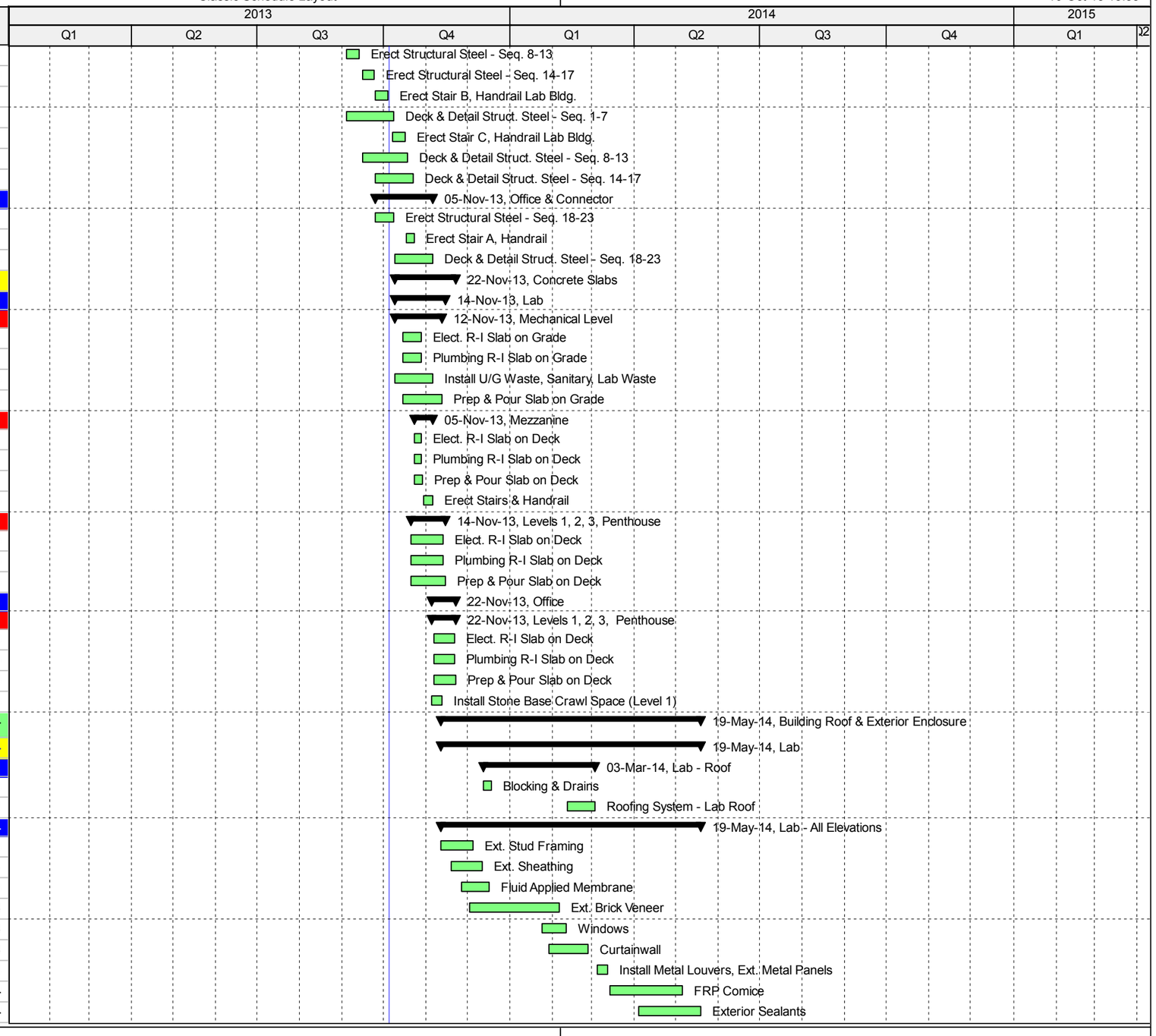
Activity ID	Activity Name	Original Duration	Start	Finish
University Engineering Building		517	14-Jan-13	13-Jan-15
Sitework/Site Utilities		165	14-Jan-13	04-Sep-13
Mobilization & Prep		32	14-Jan-13	26-Feb-13
A0100	Notice to Proceed	0	14-Jan-13	
A1000	Site Mobilization	5	14-Jan-13	18-Jan-13
A1010	Temporary Fencing	20	28-Jan-13	22-Feb-13
A1020	Temporary Walkway	4	21-Feb-13	26-Feb-13
Sitework		160	21-Jan-13	04-Sep-13
A1030	Site Clear	10	21-Jan-13	01-Feb-13
A1040	Excavate Lab	15	04-Feb-13	22-Feb-13
A1050	Caissons - Retaining Wall (Proof, Deliver, F	37	18-Feb-13	09-Apr-13
A1060	Excavate Office	37	07-Mar-13	26-Apr-13
A1070	Construct Soldier Pile Retaining Wall	103	03-Apr-13	27-Aug-13
A1080	FRP Concrete Cap at Retaining Wall	5	28-Aug-13	04-Sep-13
Building Caissons/Foundations		176	25-Feb-13	31-Oct-13
Lab		176	25-Feb-13	31-Oct-13
Caissons		32	25-Feb-13	09-Apr-13
A1090	Caissons - Lab	32	25-Feb-13	09-Apr-13
Underground Utilities		141	15-Apr-13	31-Oct-13
A1100	Install U/G Storm - Lab	10	20-Jun-13	03-Jul-13
A1110	Install U/G Elect. Mains - Lab	141	15-Apr-13	31-Oct-13
Retaining Wall		80	02-Apr-13	24-Jul-13
A1120	Bituminous Seal	37	02-Apr-13	22-May-13
A1130	Place Geo-Foam	38	03-Apr-13	24-May-13
A1140	Excavate Grade Beam	37	02-Apr-13	22-May-13
A1150	Install Sheet Waterproofing	1	28-May-13	28-May-13
A1160	FRP Grade Beams	22	04-Apr-13	03-May-13
A1170	FRP Walls	68	18-Apr-13	24-Jul-13
Interior Foundations		15	25-Apr-13	15-May-13
A1180	FRP Interior Caisson Caps - Lab	7	25-Apr-13	03-May-13
A1190	FRP Pit Walls & Slab	8	06-May-13	15-May-13
Office		44	27-Mar-13	28-May-13
Caissons		26	27-Mar-13	01-May-13
A1200	Caissons - Office	26	27-Mar-13	01-May-13
Retaining Wall		11	13-May-13	28-May-13
A1210	Excavate Grade Beam	6	13-May-13	20-May-13
A1220	Bituminus Seal	6	14-May-13	21-May-13
A1230	Place Geo-Foam	6	15-May-13	22-May-13
A1240	FRP Grade Beams	6	20-May-13	28-May-13
Interior Foundation		4	17-May-13	22-May-13
A1250	FRP Caisson Caps - Office	4	17-May-13	22-May-13
Building Structure		69	19-Aug-13	22-Nov-13
Structural Steel Erect & Detail		56	19-Aug-13	05-Nov-13
Lab		46	19-Aug-13	22-Oct-13
A1260	Initial Delivery Structural Steel	1	19-Aug-13	19-Aug-13
A1270	Erect Structural Steel - Seq. 1-7	11	19-Aug-13	03-Sep-13
A1280	Misc. Steel Erection/Delivery	6	03-Sep-13	10-Sep-13



Actual Level of Effort | Actual Work | Remaining Work | Critical Remaining Work | Milestone | summary

TASK filter: All Activities

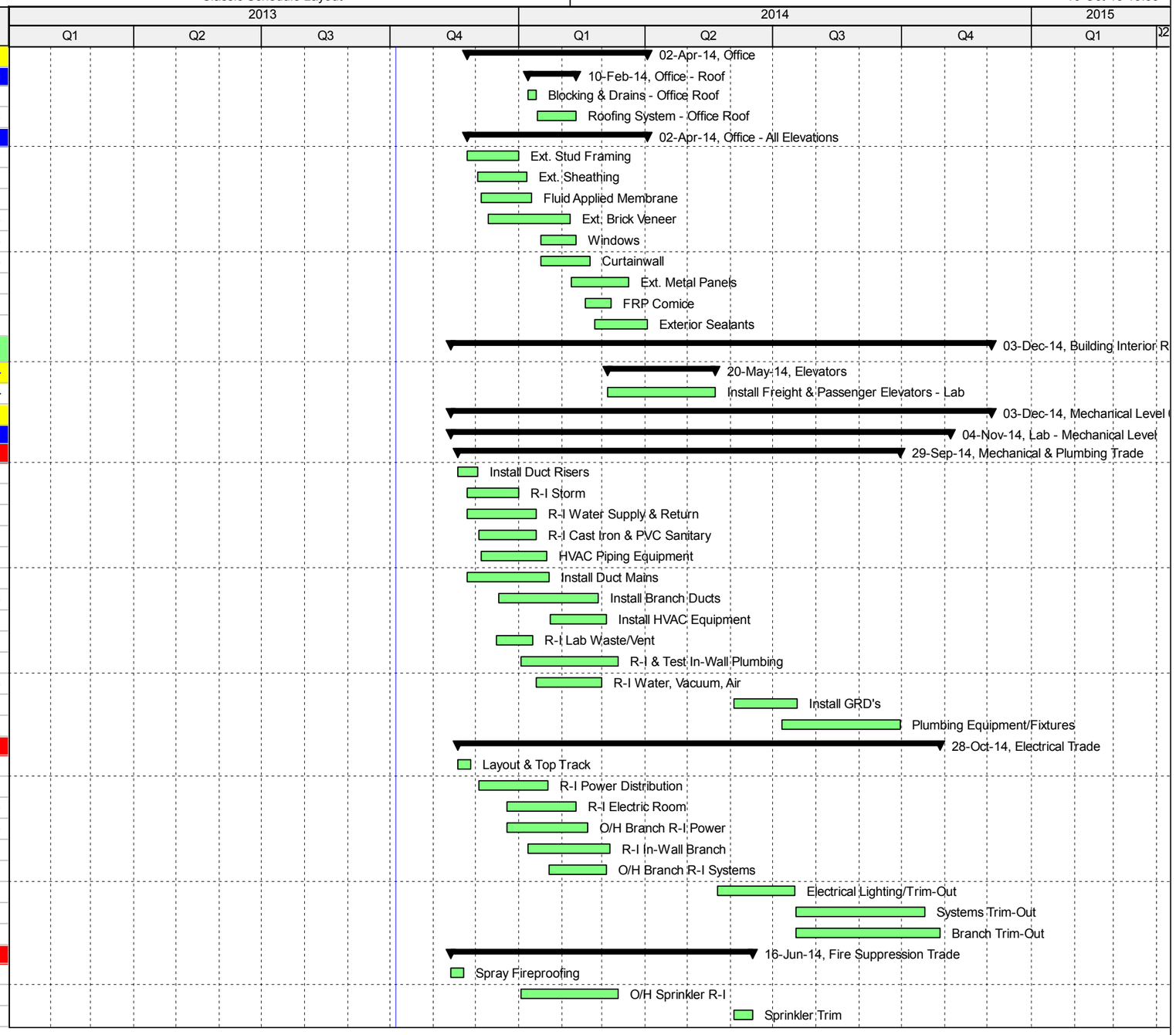
Activity ID	Activity Name	Original Duration	Start	Finish
A1290	Erect Structural Steel - Seq. 8-13	8	04-Sep-13	13-Sep-13
A1300	Erect Structural Steel - Seq. 14-17	7	16-Sep-13	24-Sep-13
A1310	Erect Stair B, Handrail Lab Bldg.	8	25-Sep-13	04-Oct-13
A1320	Deck & Detail Struct. Steel - Seq. 1-7	25	04-Sep-13	08-Oct-13
A1330	Erect Stair C, Handrail Lab Bldg.	8	07-Oct-13	16-Oct-13
A1340	Deck & Detail Struct. Steel - Seq. 8-13	25	16-Sep-13	18-Oct-13
A1350	Deck & Detail Struct. Steel - Seq. 14-17	20	25-Sep-13	22-Oct-13
Office & Connector		30	25-Sep-13	05-Nov-13
A1360	Erect Structural Steel - Seq. 18-23	10	25-Sep-13	08-Oct-13
A1370	Erect Stair A, Handrail	5	17-Oct-13	23-Oct-13
A1380	Deck & Detail Struct. Steel - Seq. 18-23	20	09-Oct-13	05-Nov-13
Concrete Slabs		33	09-Oct-13	22-Nov-13
Lab		27	09-Oct-13	14-Nov-13
Mechanical Level		25	09-Oct-13	12-Nov-13
A1390	Elect. R-I Slab on Grade	10	15-Oct-13	28-Oct-13
A1400	Plumbing R-I Slab on Grade	10	15-Oct-13	28-Oct-13
A1410	Install U/G Waste, Sanitary, Lab Waste	20	09-Oct-13	05-Nov-13
A1420	Prep & Pour Slab on Grade	21	15-Oct-13	12-Nov-13
Mezzanine		10	23-Oct-13	05-Nov-13
A1430	Elect. R-I Slab on Deck	4	23-Oct-13	28-Oct-13
A1440	Plumbing R-I Slab on Deck	4	23-Oct-13	28-Oct-13
A1450	Prep & Pour Slab on Deck	5	23-Oct-13	29-Oct-13
A1460	Erect Stairs & Handrail	5	30-Oct-13	05-Nov-13
Levels 1, 2, 3, Penthouse		19	21-Oct-13	14-Nov-13
A1470	Elect. R-I Slab on Deck	18	21-Oct-13	13-Nov-13
A1480	Plumbing R-I Slab on Deck	18	21-Oct-13	13-Nov-13
A1490	Prep & Pour Slab on Deck	19	21-Oct-13	14-Nov-13
Office		14	05-Nov-13	22-Nov-13
Levels 1, 2, 3, Penthouse		14	05-Nov-13	22-Nov-13
A1540	Elect. R-I Slab on Deck	12	06-Nov-13	21-Nov-13
A1550	Plumbing R-I Slab on Deck	12	06-Nov-13	21-Nov-13
A1560	Prep & Pour Slab on Deck	13	06-Nov-13	22-Nov-13
A1570	Install Stone Base Crawl Space (Level 1)	6	05-Nov-13	12-Nov-13
Building Roof & Exterior Enclosure		134	11-Nov-13	19-May-14
Lab		134	11-Nov-13	19-May-14
Lab - Roof		57	12-Dec-13	03-Mar-14
A1580	Blocking & Drains	5	12-Dec-13	18-Dec-13
A1590	Roofing System - Lab Roof	15	11-Feb-14	03-Mar-14
Lab - All Elevations		134	11-Nov-13	19-May-14
A1600	Ext. Stud Framing	17	11-Nov-13	04-Dec-13
A1610	Ext. Sheathing	16	19-Nov-13	11-Dec-13
A1620	Fluid Applied Membrane	14	26-Nov-13	16-Dec-13
A1630	Ext. Brick Veneer	47	02-Dec-13	05-Feb-14
A1640	Windows	12	24-Jan-14	10-Feb-14
A1650	Curtainwall	21	29-Jan-14	26-Feb-14
A1660	Install Metal Louvers, Ext. Metal Panels	6	05-Mar-14	12-Mar-14
A1670	FRP Cornice	37	14-Mar-14	05-May-14
A1680	Exterior Sealants	32	04-Apr-14	19-May-14



Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

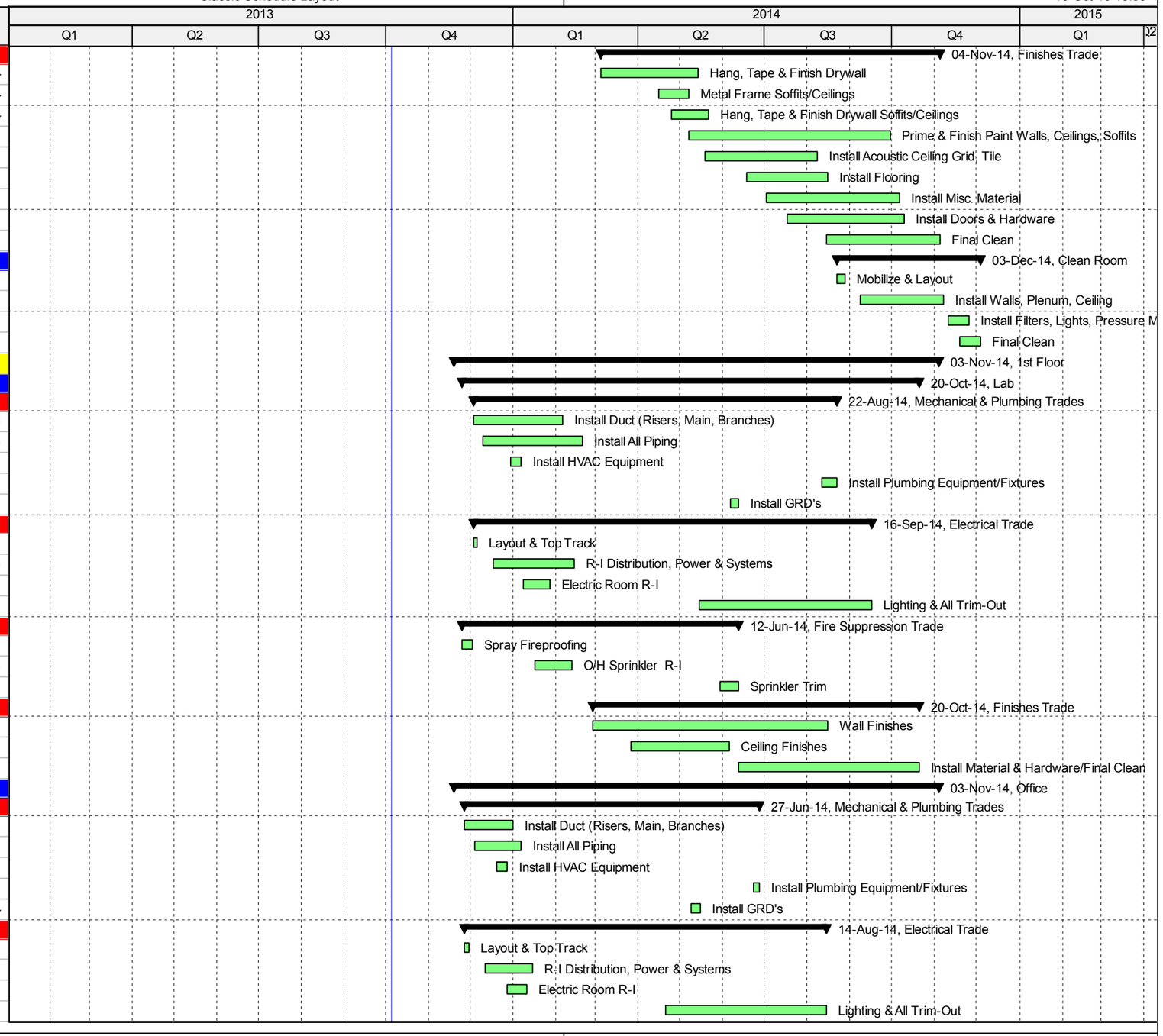
Activity ID	Activity Name	Original Duration	Start	Finish
Office		91	25-Nov-13	02-Apr-14
Office - Roof		25	07-Jan-14	10-Feb-14
A1690	Blocking & Drains - Office Roof	5	07-Jan-14	13-Jan-14
A1700	Roofing System - Office Roof	20	14-Jan-14	10-Feb-14
Office - All Elevations		91	25-Nov-13	02-Apr-14
A1710	Ext. Stud Framing	25	25-Nov-13	31-Dec-13
A1720	Ext. Sheathing	25	02-Dec-13	06-Jan-14
A1730	Fluid Applied Membrane	25	05-Dec-13	09-Jan-14
A1740	Ext. Brick Veneer	42	10-Dec-13	06-Feb-14
A1750	Windows	18	16-Jan-14	10-Feb-14
A1760	Curtainwall	26	16-Jan-14	20-Feb-14
A1770	Ext. Metal Panels	30	07-Feb-14	20-Mar-14
A1780	FRP Cornice	15	17-Feb-14	07-Mar-14
A1790	Exterior Sealants	28	24-Feb-14	02-Apr-14
Building Interior Rough-Ins Finishes		274	13-Nov-13	03-Dec-14
Elevators		55	05-Mar-14	20-May-14
A1800	Install Freight & Passenger Elevators - Lab	55	05-Mar-14	20-May-14
Mechanical Level 0 & Mezzanine		274	13-Nov-13	03-Dec-14
Lab - Mechanical Level		253	13-Nov-13	04-Nov-14
Mechanical & Plumbing Trade		224	18-Nov-13	29-Sep-14
A1810	Install Duct Risers	10	18-Nov-13	02-Dec-13
A1820	R-I Storm	25	25-Nov-13	31-Dec-13
A1830	R-I Water Supply & Return	34	25-Nov-13	13-Jan-14
A1840	R-I Cast Iron & PVC Sanitary	29	03-Dec-13	13-Jan-14
A1850	HVAC Piping Equipment	32	05-Dec-13	20-Jan-14
A1860	Install Duct Mains	41	25-Nov-13	22-Jan-14
A1870	Install Branch Ducts	51	17-Dec-13	26-Feb-14
A1880	Install HVAC Equipment	29	23-Jan-14	04-Mar-14
A1890	R-I Lab Waste/Vent	19	16-Dec-13	10-Jan-14
A1900	R-I & Test In-Wall Plumbing	50	02-Jan-14	12-Mar-14
A1910	R-I Water, Vacuum, Air	35	13-Jan-14	28-Feb-14
A1920	Install GRD's	34	03-Jun-14	18-Jul-14
A1930	Plumbing Equipment/Fixtures	61	07-Jul-14	29-Sep-14
Electrical Trade		245	18-Nov-13	28-Oct-14
A1940	Layout & Top Track	8	18-Nov-13	27-Nov-13
A1950	R-I Power Distribution	35	03-Dec-13	21-Jan-14
A1960	R-I Electric Room	35	23-Dec-13	10-Feb-14
A1970	O/H Branch R-I Power	41	23-Dec-13	18-Feb-14
A1980	R-I In-Wall Branch	43	07-Jan-14	06-Mar-14
A1990	O/H Branch R-I Systems	30	22-Jan-14	04-Mar-14
A2000	Electrical Lighting/Trim-Out	40	22-May-14	16-Jul-14
A2010	Systems Trim-Out	67	17-Jul-14	17-Oct-14
A2020	Branch Trim-Out	74	17-Jul-14	28-Oct-14
Fire Suppression Trade		152	13-Nov-13	16-Jun-14
A2030	Spray Fireproofing	8	13-Nov-13	22-Nov-13
A2040	O/H Sprinkler R-I	50	02-Jan-14	12-Mar-14
A2050	Sprinkler Trim	10	03-Jun-14	16-Jun-14



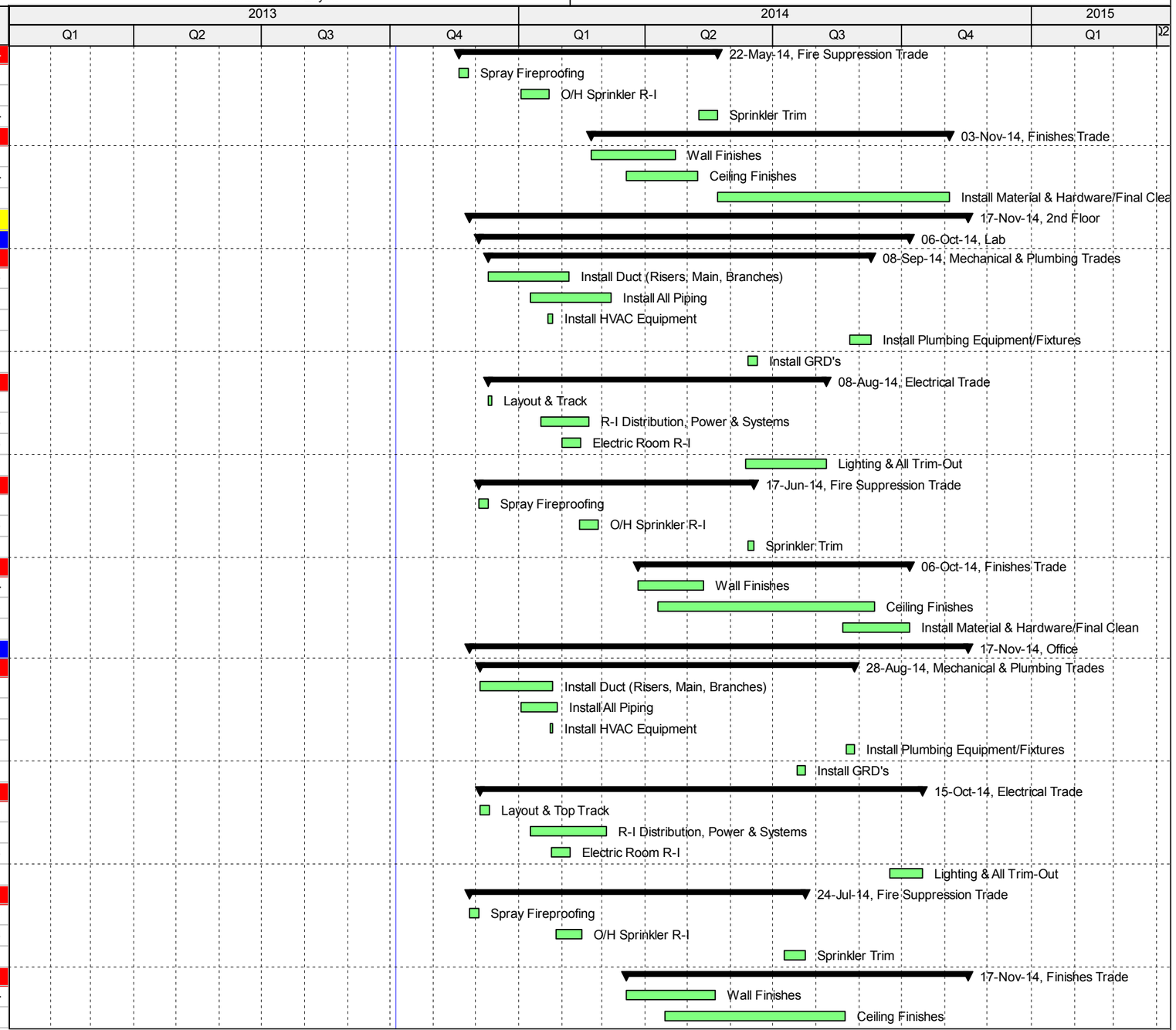
Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
Finishes Trade		175	05-Mar-14	04-Nov-14
A2060	Hang, Tape & Finish Drywall	51	05-Mar-14	14-May-14
A2070	Metal Frame Soffits/Ceilings	16	16-Apr-14	07-May-14
A2080	Hang, Tape & Finish Drywall Soffits/Ceilings	19	25-Apr-14	21-May-14
A2090	Prime & Finish Paint Walls, Ceilings, Soffits	104	07-May-14	29-Sep-14
A2100	Install Acoustic Ceiling Grid, Tile	60	19-May-14	08-Aug-14
A2110	Install Flooring	43	18-Jun-14	15-Aug-14
A2120	Install Misc. Material	69	02-Jul-14	06-Oct-14
A2130	Install Doors & Hardware	61	17-Jul-14	09-Oct-14
A2140	Final Clean	58	15-Aug-14	04-Nov-14
Clean Room		74	22-Aug-14	03-Dec-14
A2150	Mobilize & Layout	5	22-Aug-14	28-Aug-14
A2160	Install Walls, Plenum, Ceiling	45	08-Sep-14	07-Nov-14
A2170	Install Filters, Lights, Pressure Monitoring S	12	10-Nov-14	25-Nov-14
A2180	Final Clean	11	19-Nov-14	03-Dec-14
1st Floor		248	19-Nov-13	03-Nov-14
Lab		234	25-Nov-13	20-Oct-14
Mechanical & Plumbing Trades		188	03-Dec-13	22-Aug-14
A2190	Install Duct (Risers, Main, Branches)	46	03-Dec-13	05-Feb-14
A2200	Install All Piping	51	10-Dec-13	19-Feb-14
A2210	Install HVAC Equipment	6	30-Dec-13	06-Jan-14
A2220	Install Plumbing Equipment/Fixtures	10	11-Aug-14	22-Aug-14
A2230	Install GRD's	5	06-Jun-14	12-Jun-14
Electrical Trade		205	03-Dec-13	16-Sep-14
A2240	Layout & Top Track	3	03-Dec-13	05-Dec-13
A2250	R-I Distribution, Power & Systems	42	17-Dec-13	13-Feb-14
A2260	Electric Room R-I	14	08-Jan-14	27-Jan-14
A2270	Lighting & All Trim-Out	89	15-May-14	16-Sep-14
Fire Suppression Trade		142	25-Nov-13	12-Jun-14
A2280	Spray Fireproofing	5	25-Nov-13	02-Dec-13
A2290	O/H Sprinkler R-I	20	16-Jan-14	12-Feb-14
A2300	Sprinkler Trim	10	30-May-14	12-Jun-14
Finishes Trade		168	27-Feb-14	20-Oct-14
A2310	Wall Finishes	122	27-Feb-14	15-Aug-14
A2320	Ceiling Finishes	51	27-Mar-14	05-Jun-14
A2330	Install Material & Hardware/Final Clean	93	12-Jun-14	20-Oct-14
Office		248	19-Nov-13	03-Nov-14
Mechanical & Plumbing Trades		152	26-Nov-13	27-Jun-14
A2340	Install Duct (Risers, Main, Branches)	24	26-Nov-13	31-Dec-13
A2350	Install All Piping	23	04-Dec-13	06-Jan-14
A2360	Install HVAC Equipment	5	20-Dec-13	27-Dec-13
A2370	Install Plumbing Equipment/Fixtures	5	23-Jun-14	27-Jun-14
A2380	Install GRD's	5	09-May-14	15-May-14
Electrical Trade		186	26-Nov-13	14-Aug-14
A2390	Layout & Top Track	3	26-Nov-13	29-Nov-13
A2400	R-I Distribution, Power & Systems	24	11-Dec-13	14-Jan-14
A2410	Electric Room R-I	11	27-Dec-13	10-Jan-14
A2420	Lighting & All Trim-Out	84	21-Apr-14	14-Aug-14



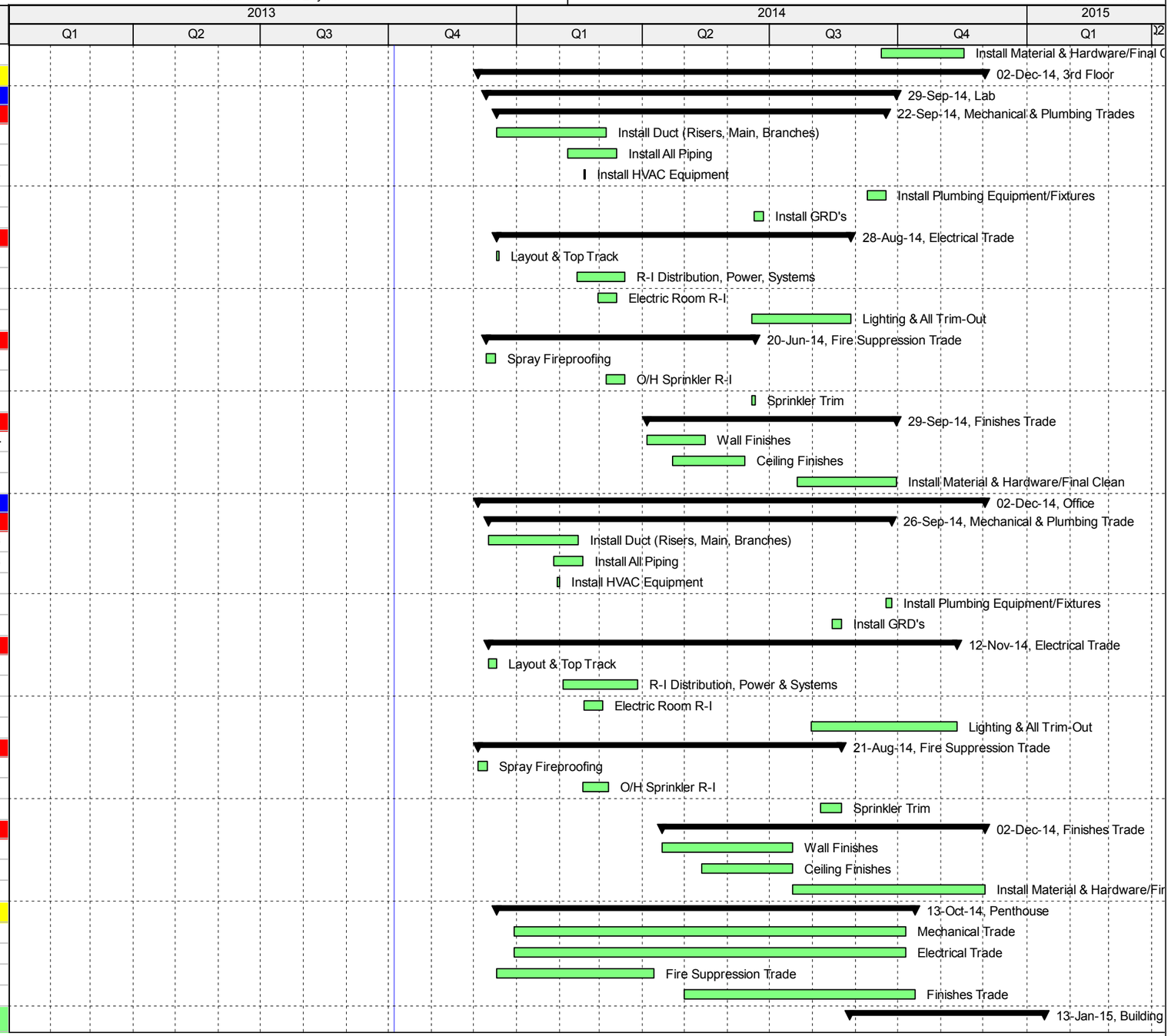
Activity ID	Activity Name	Original Duration	Start	Finish
Fire Suppression Trade		131	19-Nov-13	22-May-14
A2430	Spray Fireproofing	5	19-Nov-13	25-Nov-13
A2440	O/H Sprinkler R-I	15	02-Jan-14	22-Jan-14
A2450	Sprinkler Trim	10	09-May-14	22-May-14
Finishes Trade		182	21-Feb-14	03-Nov-14
A2460	Wall Finishes	43	21-Feb-14	22-Apr-14
A2470	Ceiling Finishes	38	18-Mar-14	08-May-14
A2480	Install Material & Hardware/Final Clean	118	22-May-14	03-Nov-14
2nd Floor		253	26-Nov-13	17-Nov-14
Lab		219	03-Dec-13	06-Oct-14
Mechanical & Plumbing Trades		194	10-Dec-13	08-Sep-14
A2490	Install Duct (Risers, Main, Branches)	41	10-Dec-13	05-Feb-14
A2500	Install All Piping	42	09-Jan-14	07-Mar-14
A2510	Install HVAC Equipment	4	21-Jan-14	24-Jan-14
A2520	Install Plumbing Equipment/Fixtures	11	25-Aug-14	08-Sep-14
A2530	Install GRD's	5	13-Jun-14	19-Jun-14
Electrical Trade		173	10-Dec-13	08-Aug-14
A2540	Layout & Track	3	10-Dec-13	12-Dec-13
A2550	R-I Distribution, Power & Systems	25	16-Jan-14	19-Feb-14
A2560	Electric Room R-I	10	31-Jan-14	13-Feb-14
A2570	Lighting & All Trim-Out	43	11-Jun-14	08-Aug-14
Fire Suppression Trade		140	03-Dec-13	17-Jun-14
A2580	Spray Fireproofing	5	03-Dec-13	09-Dec-13
A2590	O/H Sprinkler R-I	10	13-Feb-14	26-Feb-14
A2600	Sprinkler Trim	3	13-Jun-14	17-Jun-14
Finishes Trade		138	27-Mar-14	06-Oct-14
A2610	Wall Finishes	33	27-Mar-14	12-May-14
A2620	Ceiling Finishes	111	10-Apr-14	11-Sep-14
A2630	Install Material & Hardware/Final Clean	34	20-Aug-14	06-Oct-14
Office		253	26-Nov-13	17-Nov-14
Mechanical & Plumbing Trades		191	04-Dec-13	28-Aug-14
A2640	Install Duct (Risers, Main, Branches)	37	04-Dec-13	24-Jan-14
A2650	Install All Piping	19	02-Jan-14	28-Jan-14
A2660	Install HVAC Equipment	2	23-Jan-14	24-Jan-14
A2670	Install Plumbing Equipment/Fixtures	5	22-Aug-14	28-Aug-14
A2680	Install GRD's	5	18-Jul-14	24-Jul-14
Electrical Trade		225	04-Dec-13	15-Oct-14
A2690	Layout & Top Track	5	04-Dec-13	10-Dec-13
A2700	R-I Distribution, Power & Systems	39	09-Jan-14	04-Mar-14
A2710	Electric Room R-I	10	24-Jan-14	06-Feb-14
A2720	Lighting & All Trim-Out	18	22-Sep-14	15-Oct-14
Fire Suppression Trade		171	26-Nov-13	24-Jul-14
A2730	Spray Fireproofing	5	26-Nov-13	03-Dec-13
A2740	O/H Sprinkler R-I	15	27-Jan-14	14-Feb-14
A2750	Sprinkler Trim	12	09-Jul-14	24-Jul-14
Finishes Trade		175	18-Mar-14	17-Nov-14
A2760	Wall Finishes	46	18-Mar-14	20-May-14
A2770	Ceiling Finishes	93	15-Apr-14	21-Aug-14



Actual Level of Effort | Remaining Work | Milestone
Actual Work | Critical Remaining Work | summary

TASK filter: All Activities

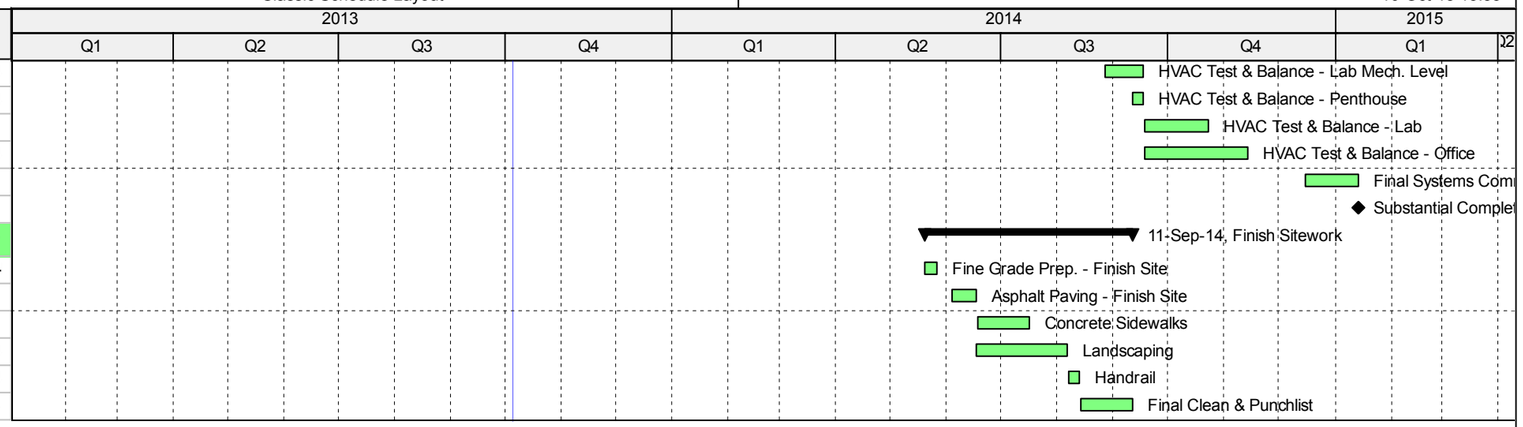
Activity ID	Activity Name	Original Duration	Start	Finish
A2780	Install Material & Hardware/Final Clean	42	19-Sep-14	17-Nov-14
3rd Floor		259	04-Dec-13	02-Dec-14
Lab		209	10-Dec-13	29-Sep-14
Mechanical & Plumbing Trades		199	17-Dec-13	22-Sep-14
A2790	Install Duct (Risers, Main, Branches)	56	17-Dec-13	05-Mar-14
A2800	Install All Piping	26	06-Feb-14	13-Mar-14
A2810	Install HVAC Equipment	1	18-Feb-14	18-Feb-14
A2820	Install Plumbing Equipment/Fixtures	10	09-Sep-14	22-Sep-14
A2830	Install GRD's	5	20-Jun-14	26-Jun-14
Electrical Trade		182	17-Dec-13	28-Aug-14
A2840	Layout & Top Track	3	17-Dec-13	19-Dec-13
A2850	R-I Distribution, Power, Systems	25	13-Feb-14	19-Mar-14
A2860	Electric Room R-I	10	28-Feb-14	13-Mar-14
A2870	Lighting & All Trim-Out	52	18-Jun-14	28-Aug-14
Fire Suppression Trade		138	10-Dec-13	20-Jun-14
A2880	Spray Fireproofing	5	10-Dec-13	16-Dec-13
A2890	O/H Sprinkler R-I	10	06-Mar-14	19-Mar-14
A2900	Sprinkler Trim	3	18-Jun-14	20-Jun-14
Finishes Trade		127	04-Apr-14	29-Sep-14
A2910	Wall Finishes	30	04-Apr-14	15-May-14
A2920	Ceiling Finishes	39	22-Apr-14	13-Jun-14
A2930	Install Material & Hardware/Final Clean	51	21-Jul-14	29-Sep-14
Office		259	04-Dec-13	02-Dec-14
Mechanical & Plumbing Trade		207	11-Dec-13	26-Sep-14
A2940	Install Duct (Risers, Main, Branches)	46	11-Dec-13	13-Feb-14
A2950	Install All Piping	16	27-Jan-14	17-Feb-14
A2960	Install HVAC Equipment	2	30-Jan-14	31-Jan-14
A2970	Install Plumbing Equipment/Fixtures	5	22-Sep-14	26-Sep-14
A2980	Install GRD's	5	15-Aug-14	21-Aug-14
Electrical Trade		240	11-Dec-13	12-Nov-14
A2990	Layout & Top Track	5	11-Dec-13	17-Dec-13
A3000	R-I Distribution, Power & Systems	40	03-Feb-14	28-Mar-14
A3010	Electric Room R-I	10	18-Feb-14	03-Mar-14
A3020	Lighting & All Trim-Out	75	31-Jul-14	12-Nov-14
Fire Suppression Trade		186	04-Dec-13	21-Aug-14
A3030	Spray Fireproofing	5	04-Dec-13	10-Dec-13
A3040	O/H Sprinkler R-I	15	17-Feb-14	07-Mar-14
A3050	Sprinkler Trim	12	06-Aug-14	21-Aug-14
Finishes Trade		166	15-Apr-14	02-Dec-14
A3060	Wall Finishes	68	15-Apr-14	17-Jul-14
A3070	Ceiling Finishes	48	13-May-14	17-Jul-14
A3080	Install Material & Hardware/Final Clean	99	17-Jul-14	02-Dec-14
Penthouse		214	17-Dec-13	13-Oct-14
A3090	Mechanical Trade	201	30-Dec-13	06-Oct-14
A3100	Electrical Trade	201	30-Dec-13	06-Oct-14
A3110	Fire Suppression Trade	81	17-Dec-13	09-Apr-14
A3120	Finishes Trade	118	01-May-14	13-Oct-14
Building Systems Start-Up Testing & Com		100	27-Aug-14	13-Jan-15



Actual Level of Effort | Actual Work | Remaining Work | Critical Remaining Work | Milestone | summary

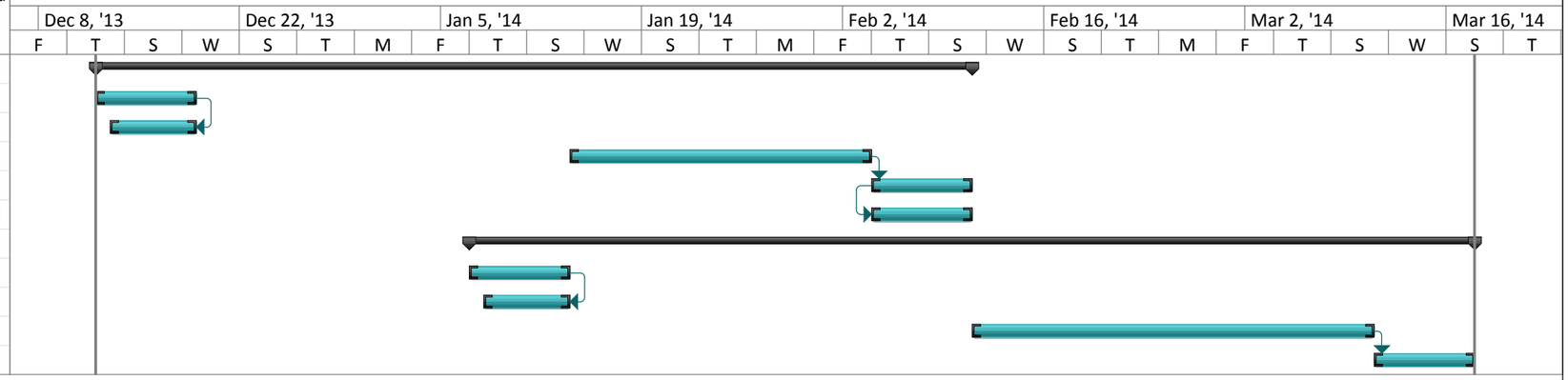
TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
A3130	HVAC Test & Balance - Lab Mech. Level	16	27-Aug-14	17-Sep-14
A3140	HVAC Test & Balance - Penthouse	5	11-Sep-14	17-Sep-14
A3150	HVAC Test & Balance - Lab	26	18-Sep-14	23-Oct-14
A3160	HVAC Test & Balance - Office	41	18-Sep-14	13-Nov-14
A3170	Final Systems Commissioning	22	15-Dec-14	13-Jan-15
A3240	Substantial Completion	0		13-Jan-15
Finish Sitework		83	20-May-14	11-Sep-14
A3180	Fine Grade Prep. - Finish Site	5	20-May-14	26-May-14
A3190	Asphalt Paving - Finish Site	10	04-Jun-14	17-Jun-14
A3200	Concrete Sidewalks	21	18-Jun-14	16-Jul-14
A3210	Landscaping	37	17-Jun-14	06-Aug-14
A3220	Handrail	5	07-Aug-14	13-Aug-14
A3230	Final Clean & Punchlist	21	14-Aug-14	11-Sep-14



Appendix B.2 – Re-Sequenced Fully-Adhered Schedule

ID	Task Name	Duration	Start	Finish	Pred
1	**Lab - Fully Adhered TPO**	**43 days**	**Thu 12/12/13**	**Mon 2/10/14**	
2	Roof Blocking - Lab	5 days	Thu 12/12/13	Wed 12/18/13	
3	Roof Drains - Lab	4 days	Fri 12/13/13	Wed 12/18/13	2FF
4	Roofing System - Lab	15 days	Tue 1/14/14	Mon 2/3/14	
5	Lightning Protection - Lab	5 days	Tue 2/4/14	Mon 2/10/14	4
6	Install Roof Crane	5 days	Tue 2/4/14	Mon 2/10/14	5SS
7	**Office - Fully Adhered TPO**	**50 days**	**Tue 1/7/14**	**Mon 3/17/14**	
8	Roof Blocking - Office	5 days	Tue 1/7/14	Mon 1/13/14	
9	Roof Drains - Office	4 days	Wed 1/8/14	Mon 1/13/14	8FF
10	Roofing System - Office	20 days	Tue 2/11/14	Mon 3/10/14	
11	Lightning Protection - Office	5 days	Tue 3/11/14	Mon 3/17/14	10

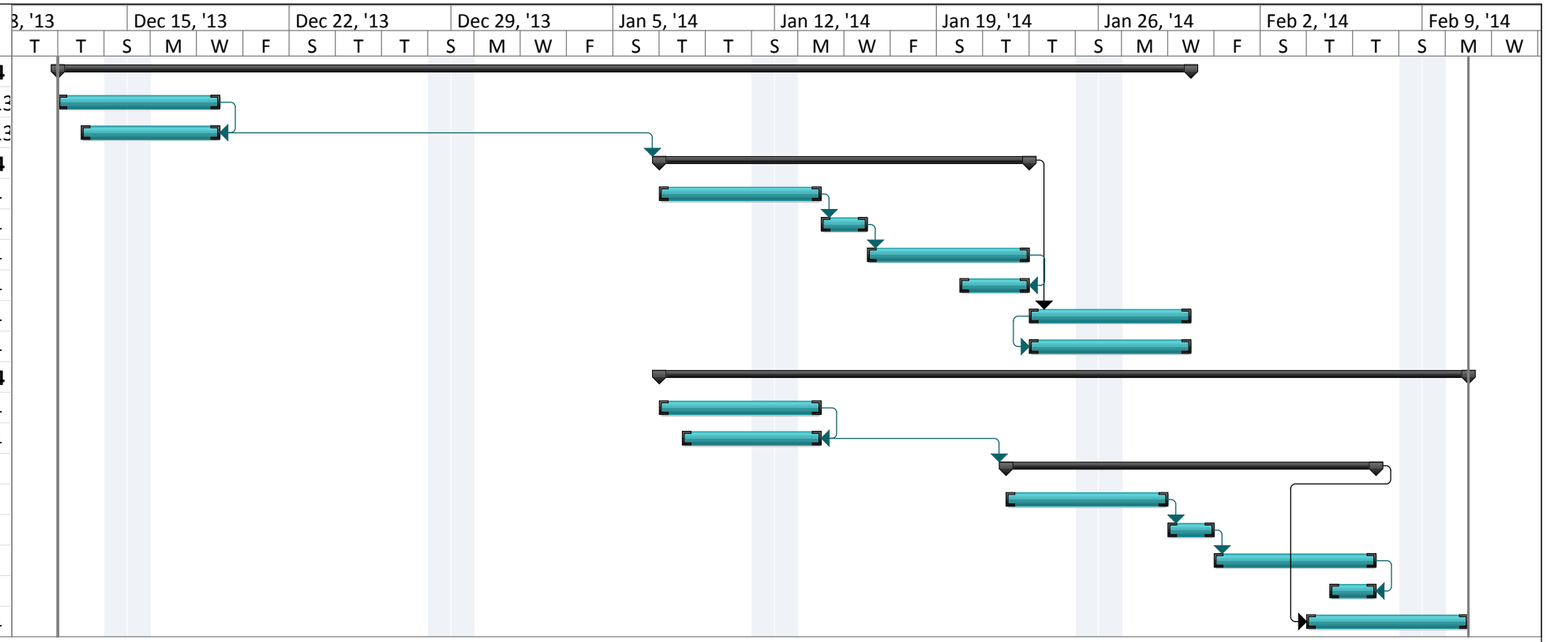


Project: Fully Adhered TPO Reseq
Date: Sun 4/6/14

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Appendix B.3 – InvisiWeld Schedule

ID	Task Name	Duration	Start	Finish
1	**Lab - InvisiWeld Roof**	**35 days**	**Thu 12/12/13**	**Wed 1/29/14**
2	Roof Blocking - Lab	5 days	Thu 12/12/13	Wed 12/18/13
3	Roof Drains - Lab	4 days	Fri 12/13/13	Wed 12/18/13
4	**Roof System**	**12 days**	**Tue 1/7/14**	**Wed 1/22/14**
5	Insulation & Cover Board Install	5 days	Tue 1/7/14	Mon 1/13/14
6	InvisiWeld Plates Install	2 days	Tue 1/14/14	Wed 1/15/14
7	Membrane Install	5 days	Thu 1/16/14	Wed 1/22/14
8	Plate Welds	3 days	Mon 1/20/14	Wed 1/22/14
9	Lightning Protection	5 days	Thu 1/23/14	Wed 1/29/14
10	Install Roof Crane	5 days	Thu 1/23/14	Wed 1/29/14
11	**Office - InvisiWeld Roof**	**25 days**	**Tue 1/7/14**	**Mon 2/10/14**
12	Roof Blocking - Lab	5 days	Tue 1/7/14	Mon 1/13/14
13	Roof Drains - Lab	4 days	Wed 1/8/14	Mon 1/13/14
14	**Roof System**	**12 days**	**Wed 1/22/14**	**Thu 2/6/14**
15	Insulation & Cover Board Install	5 days	Wed 1/22/14	Tue 1/28/14
16	InvisiWeld Plates Install	2 days	Wed 1/29/14	Thu 1/30/14
17	Membrane Install	5 days	Fri 1/31/14	Thu 2/6/14
18	Plate Welds	2 days	Wed 2/5/14	Thu 2/6/14
19	Lightning Protection	5 days	Tue 2/4/14	Mon 2/10/14

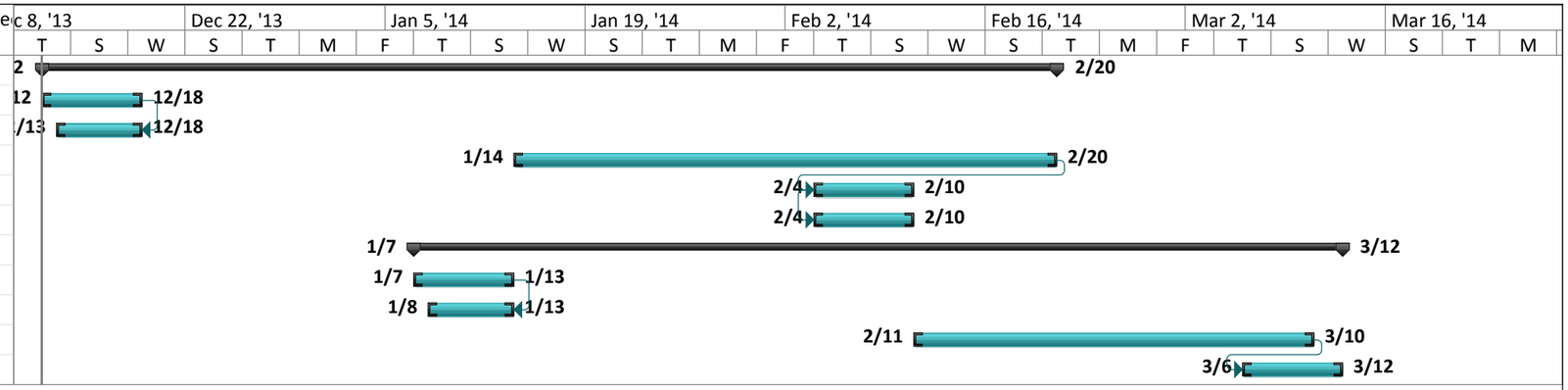


Project: InvisiWeld Schedule.mpp
Date: Sun 4/6/14

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline			
Split	External Tasks	Inactive Summary	Manual Summary	Progress			
Milestone	External Milestone	Manual Task	Start-only				
Summary	Inactive Task	Duration-only	Finish-only				

Appendix B.4 – Built-Up Roof Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Lab - Built-Up Roof**	**51 days**	**Thu 12/12/13**	**Thu 2/20/14**	
2	Roof Blocking - Lab	5 days	Thu 12/12/13	Wed 12/18/13	
3	Roof Drains - Lab	4 days	Fri 12/13/13	Wed 12/18/13	2FF
4	Roofing System - Lab	28 days	Tue 1/14/14	Thu 2/20/14	
5	Lightning Protection - Lab	5 days	Tue 2/4/14	Mon 2/10/14	4
6	Install Roof Crane	5 days	Tue 2/4/14	Mon 2/10/14	5SS
7	**Office - Built-Up Roof**	**47 days**	**Tue 1/7/14**	**Wed 3/12/14**	
8	Roof Blocking - Office	5 days	Tue 1/7/14	Mon 1/13/14	
9	Roof Drains - Office	4 days	Wed 1/8/14	Mon 1/13/14	8FF
10	Roofing System - Office	20 days	Tue 2/11/14	Mon 3/10/14	
11	Lightning Protection - Office	5 days	Thu 3/6/14	Wed 3/12/14	10



Project: BUR Schedule.mpp
Date: Sun 4/6/14

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Appendix B.5 – Original General Conditions Estimate

ORIGINAL GENERAL CONDITIONS ESTIMATE			
Item	Unit	Cost/Unit	Total Cost
01-101 Superintendent (month)	24	$9,200.00	$220,800.00
01-103 Field Engineer (month)	24	$6,000.00	$144,000.00
01-105 Foreman (month)	24	$6,000.00	$144,000.00
01-106 Project Manager (month)	24	$9,900.00	$237,600.00
01-107 Material Handling (month)	24	$1,000.00	$24,000.00
01-109 Project Engineer (month)	24	$6,200.00	$148,800.00
01-117 Field - Training (month)	24	$120.00	$2,880.00
01-151 Superintendent Per Diem (month)	24	$1,000.00	$24,000.00
01-154 Vehicle Reimbursements (month)	24	$1,000.00	$24,000.00
01-202 Bonds	LS	0.5%*TC	$215,000.00
01-203 B & O Tax	LS	0.018%*TC	$77,400.00
01-204 Builders Risk Insurance	LS	0.24%*TC	$103,200.00
01-210 Blueprinting	24	0.05%*TC	$21,500.00
01-211 CPM Schedule	LS	0.05%*TC	$21,500.00
01-212 Office Supplies (month)	24	$125.00	$3,000.00
01-213 Postage (month)	24	$125.00	$3,000.00
01-214 Office Trailer (month)	24	$430.00	$10,320.00
01-215 Drinking Water (month)	24	$75.00	$1,800.00
01-218 Project Signs	LS	$2,500.00	$2,500.00
01-221 Safety	LS	$2,000.00	$2,000.00
01-223 Clean Up	LS	$15,000.00	$15,000.00
01-224 Temporary Partitions (ea.)	7	$175.00	$1,225.00
01-226 Final Clean (month)	1	$1,000.00	$1,000.00
01-229 Project Photos (month)	24	$1,575.00	$37,800.00
01-231 Architects Office (month)	24	$250.00	$6,000.00
01-232 Snow Removal/Street Sweeping (month)	24	$400.00	$9,600.00

Item	Unit	Cost/Unit	Total Cost
01-234 Street Repair (month)	24	$300.00	$7,200.00
01-303 Dumpsters (5) (month)	24	$175.00	$4,200.00
01-304 Hoist (month)	12	$2,000.00	$24,000.00
01-306 Small Tools	LS	$1,000.00	$1,000.00
01-404 Special Testing	LS	$5,000.00	$5,000.00
01-406 Other Testing	LS	$5,000.00	$5,000.00
01-501 Temporary Electric (month)	24	$150.00	$3,600.00
01-502 Temporary Phone (month)	24	$85.00	$2,040.00
01-504 Temporary Water (month)	24	$70.00	$1,680.00
01-505 Temporary Toilet Facilities (month)	24	$55.00	$1,320.00
01-506 Temporary Heat (month)	10	$230.00	$2,300.00
01-507 Temp. Weather Protection (month)	24	$150.00	$3,600.00
01-509 Barricades (ea.)	10	$390.00	$3,900.00
01-511 Temporary Stairs/Ramps (ea.)	12	$100.00	$1,200.00
01-512 Temporary Fencing (LF)	1504	$25.00	$37,600.00
01-515 Internet Service (month)	24	$100.00	$2,400.00
01-519 Rodent & Pest Control (month)	24	$120.00	$2,880.00
TOTAL			$1,610,845.00
TOTAL CONSTRUCTION COSTS * 6%			$1,962,000.00
COST DIFFERENCE			$351,155.00
% DIFFERENCE			17.90

Appendix B.6 – Revised General Conditions Estimate

REVISED GENERAL CONDITIONS ESTIMATE			
Item	Unit	Cost/Unit	Total Cost
01-101 Superintendent (month)	24	$9,200.00	$220,800.00
01-103 Field Engineer (month)	24	$6,000.00	$144,000.00
01-105 Foreman (month)	24	$6,000.00	$144,000.00
01-106 Project Manager (month)	24	$9,900.00	$237,600.00
01-107 Material Handling (month)	24	$1,000.00	$24,000.00
01-109 Project Engineer (month)	24	$6,200.00	$148,800.00
01-117 Field - Training (month)	24	$120.00	$2,880.00
01-151 Superintendent Per Diem (month)	24	$1,000.00	$24,000.00
01-154 Vehicle Reimbursements (month)	24	$1,000.00	$24,000.00
01-202 Bonds	LS	0.5%*TC	$215,000.00
01-203 B & O Tax	LS	0.018%*TC	$77,400.00
01-204 Builders Risk Insurance	LS	0.24%*TC	$103,200.00
01-210 Blueprinting	24	0.05%*TC	$21,500.00
01-211 CPM Schedule	LS	0.05%*TC	$21,500.00
01-212 Office Supplies (month)	24	$125.00	$3,000.00
01-213 Postage (month)	24	$125.00	$3,000.00
01-214 Office Trailer (month)	24	$430.00	$10,320.00
01-215 Drinking Water (month)	24	$75.00	$1,800.00
01-218 Project Signs	LS	$2,500.00	$2,500.00
01-221 Safety	LS	$2,000.00	$2,000.00
01-223 Clean Up	LS	$15,000.00	$15,000.00
01-224 Temporary Partitions (ea.)	7	$175.00	$1,225.00
01-226 Final Clean (month)	1	$1,000.00	$1,000.00
01-229 Project Photos (month)	24	$1,575.00	$37,800.00
01-231 Architects Office (month)	24	$250.00	$6,000.00
01-232 Snow Removal/Street Sweeping (month)	24	$400.00	$9,600.00

Item	Unit	Cost/Unit	Total Cost
01-234 Street Repair (month)	24	$300.00	$7,200.00
01-303 Dumpsters (5) (month)	24	$175.00	$4,200.00
01-304 Hoist (month)	12	$2,000.00	$24,000.00
01-306 Small Tools	LS	$1,000.00	$1,000.00
01-404 Special Testing	LS	$5,000.00	$5,000.00
01-406 Other Testing	LS	$5,000.00	$5,000.00
01-501 Temporary Electric (month)	24	$150.00	$3,600.00
01-502 Temporary Phone (month)	24	$85.00	$2,040.00
01-504 Temporary Water (month)	24	$70.00	$1,680.00
01-505 Temporary Toilet Facilities (month)	24	$55.00	$1,320.00
01-506 Temporary Heat (month)	10	$500.00	$5,000.00
01-507 Temp. Weather Protection (month)	24	$150.00	$3,600.00
01-508 Temp. Enclosure (month)	10	$500.00	$5,000.00
01-509 Barricades (ea.)	10	$390.00	$3,900.00
01-511 Temporary Stairs/Ramps (ea.)	12	$100.00	$1,200.00
01-512 Temporary Fencing (LF)	1504	$25.00	$37,600.00
01-515 Internet Service (month)	24	$100.00	$2,400.00
01-519 Rodent & Pest Control (month)	24	$120.00	$2,880.00
TOTAL			$1,618,545.00
TOTAL CONSTRUCTION COSTS * 6%			$1,962,000.00
COST DIFFERENCE			$343,455.00
% DIFFERENCE			17.51

Appendix B.7 – Weather Underground Data

Weather History for [redacted]

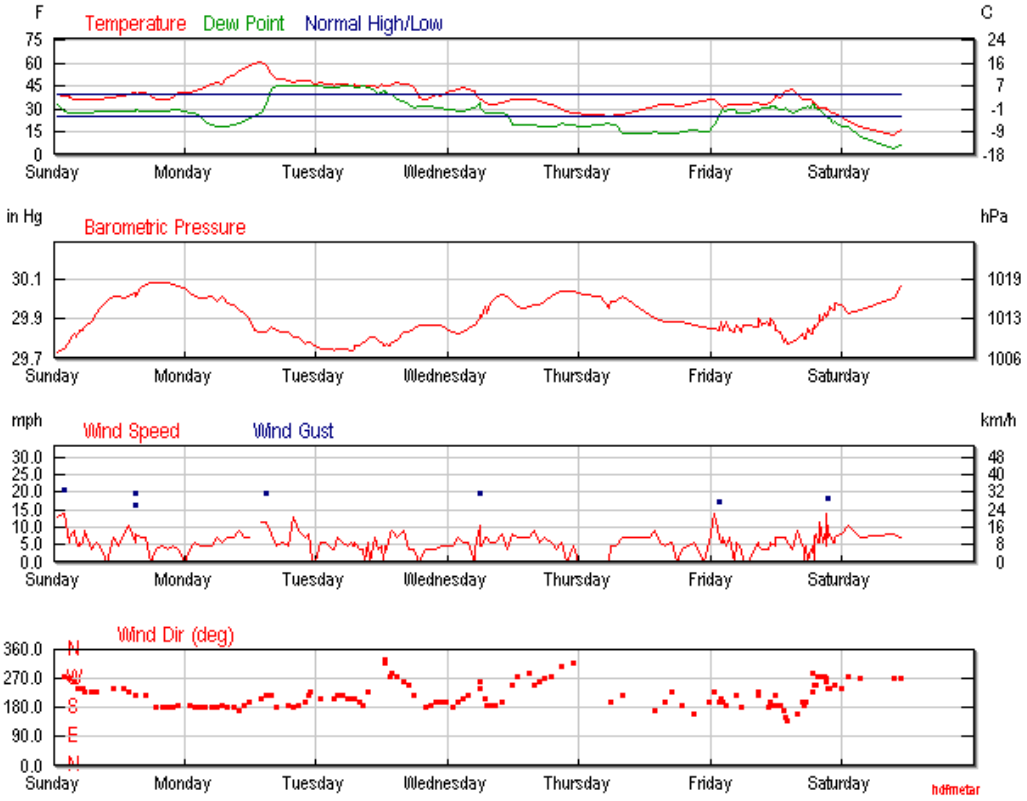
Week of January 12, 2014 through January 18, 2014

Week of January 12, 2014 through January 18, 2014

« Previous Week | January | 14 | 2014 | View | Next Week »

Daily | Weekly | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**61** °F	**42** °F	**24** °F	
Mean Temperature	**50** °F	**35** °F	**19** °F	
Min Temperature	**39** °F	**28** °F	**13** °F	
Degree Days				
Heating Degree Days (base 65)	46	30	15	207
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**45** °F	**25** °F	**3** °F	
Precipitation				
Precipitation	**0.21** in	**0.08** in	**0.00** in	**0.50** in
Snow depth	-	-	-	-
Wind				
Wind	**17** mph	**6** mph	**0** mph	
Gust Wind	**26** mph	**19** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.08** in	**29.90** in	**29.73** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Jan	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
12	41	38	34	32	28	26	76	70	64	30.08	29.94	29.73	10	10	10	14	6	22	0.00	
13	61	50	39	45	31	17	93	59	25	30.03	29.89	29.76	10	10	8	17	7	26	0.21	Rain
14	48	42	35	45	39	29	100	80	60	29.87	29.79	29.74	10	9	3	12	4	20	0.19	Rain
15	43	35	26	34	24	17	82	67	51	30.04	29.95	29.82	10	10	4	9	5	20	0.01	Rain , Snow
16	36	30	24	19	15	13	81	62	43	30.02	29.92	29.85	10	10	10	9	4	17	0.00	
17	43	34	24	32	28	17	92	66	40	29.98	29.86	29.77	10	6	0	14	6	23	0.09	Fog , Rain , Snow
18	24	19	13	18	9	3	61	61	61	30.06	29.98	29.93	10	9	6	13	7	18	T	

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Weather History for [redacted]

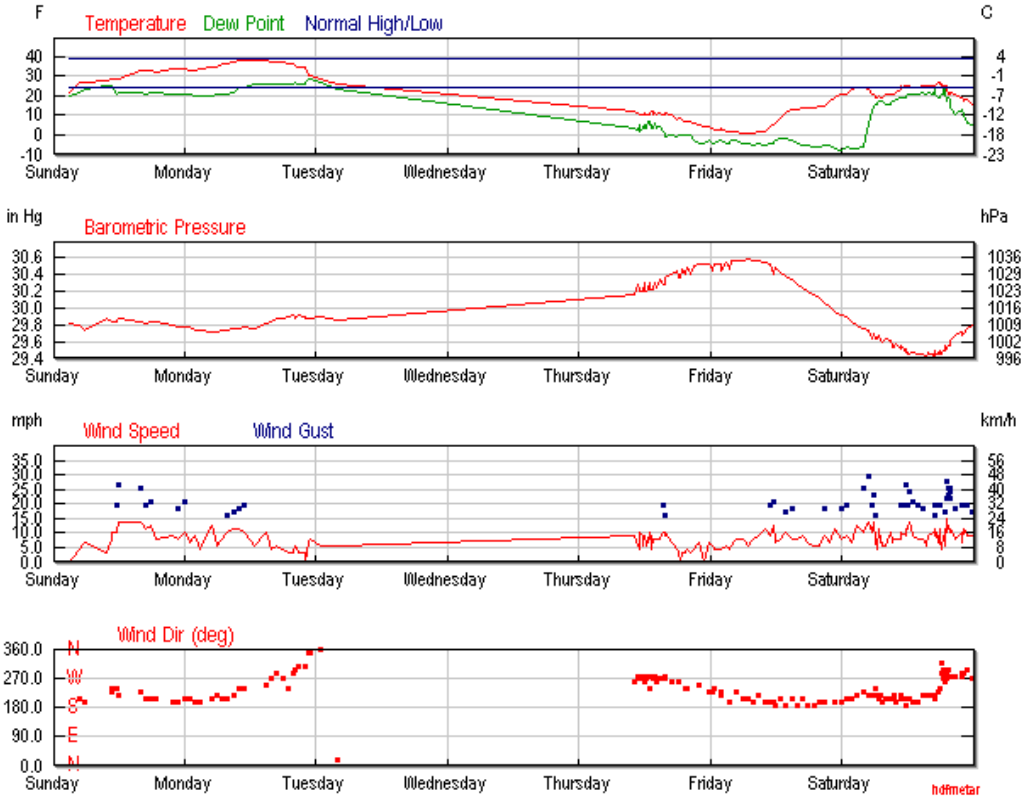
Week of January 19, 2014 through January 25, 2014

Week of January 19, 2014 through January 25, 2014

« Previous Week | January | 21 | 2014 | View | Next Week »

Daily | **Weekly** | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**38** °F	**27** °F	**12** °F	
Mean Temperature	**36** °F	**22** °F	**8** °F	
Min Temperature	**33** °F	**16** °F	**1** °F	
Degree Days				
Heating Degree Days (base 65)	57	43	29	259
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**28** °F	**14** °F	**-8** °F	
Precipitation				
Precipitation	**0.08** in	**0.02** in	**0.00** in	**0.11** in
Snow depth	-	-	-	-
Wind				
Wind	**21** mph	**8** mph	**0** mph	
Gust Wind	**35** mph	**19** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.58** in	**29.96** in	**29.42** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Jan	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
19	34	27	19	25	22	20	92	77	61	29.87	29.82	29.74	10	9	2	17	8	29	0.02	Snow
20	38	36	33	28	24	20	70	61	52	29.91	29.81	29.72	10	10	9	13	7	21	0.00	
21	29	28	26	27	25	23	92	88	84	29.90	29.88	29.85	10	6	2	6	6	-	0.01	Snow
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
23	12	8	4	7	2	-4	83	73	63	30.53	30.32	30.17	10	5	0	13	6	22	T	Snow
24	21	11	1	-2	-4	-8	87	59	31	30.58	30.37	29.91	10	9	3	15	8	23	0.00	
25	26	21	16	23	16	-7	92	59	25	29.89	29.57	29.42	10	4	0	21	10	35	0.08	Fog , Snow

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Weather History for [redacted]

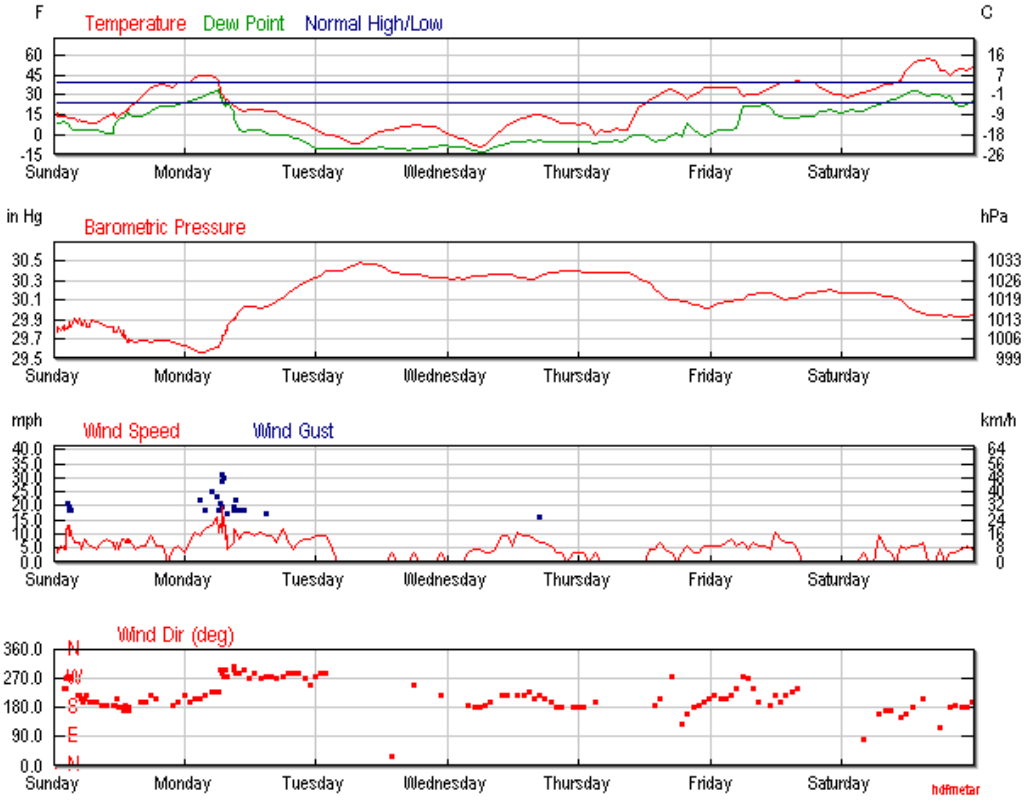
Week of January 26, 2014 through February 1, 2014

Week of January 26, 2014 through February 1, 2014

« Previous Week | January 28 2014 View | Next Week »

Daily | **Weekly** | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**57** °F	**34** °F	**7** °F	
Mean Temperature	**43** °F	**21** °F	**-1** °F	
Min Temperature	**29** °F	**7** °F	**-9** °F	
Degree Days				
Heating Degree Days (base 65)	66	44	22	309
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**34** °F	**6** °F	**-13** °F	
Precipitation				
Precipitation	**0.08** in	**0.02** in	**0.00** in	**0.15** in
Snow depth	-	-	-	-
Wind				
Wind	**20** mph	**4** mph	**0** mph	
Gust Wind	**31** mph	**19** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.49** in	**30.12** in	**29.57** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Jan	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
26	40	24	8	24	10	1	88	68	47	29.91	29.78	29.63	10	6	0	15	7	24	0.08	Fog , Snow
27	45	25	4	34	13	-11	92	70	47	30.33	29.90	29.57	10	7	0	20	9	31	0.07	Fog , Rain , Snow
28	7	-1	-9	-8	-10	-12	83	64	45	30.49	30.40	30.33	10	10	10	12	1	21	0.00	
29	15	3	-9	-4	-7	-13	83	62	40	30.41	30.36	30.32	10	10	10	14	5	20	0.00	
30	36	17	-2	8	-2	-7	79	50	20	30.39	30.24	30.02	10	10	5	10	2	16	0.00	
31	41	35	29	23	14	2	75	49	22	30.20	30.14	30.05	10	10	8	13	4	20	0.00	
2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Feb	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
1	57	43	28	33	25	17	69	51	32	30.18	30.05	29.93	10	10	10	9	3	15	0.00	

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Weather History for [redacted]

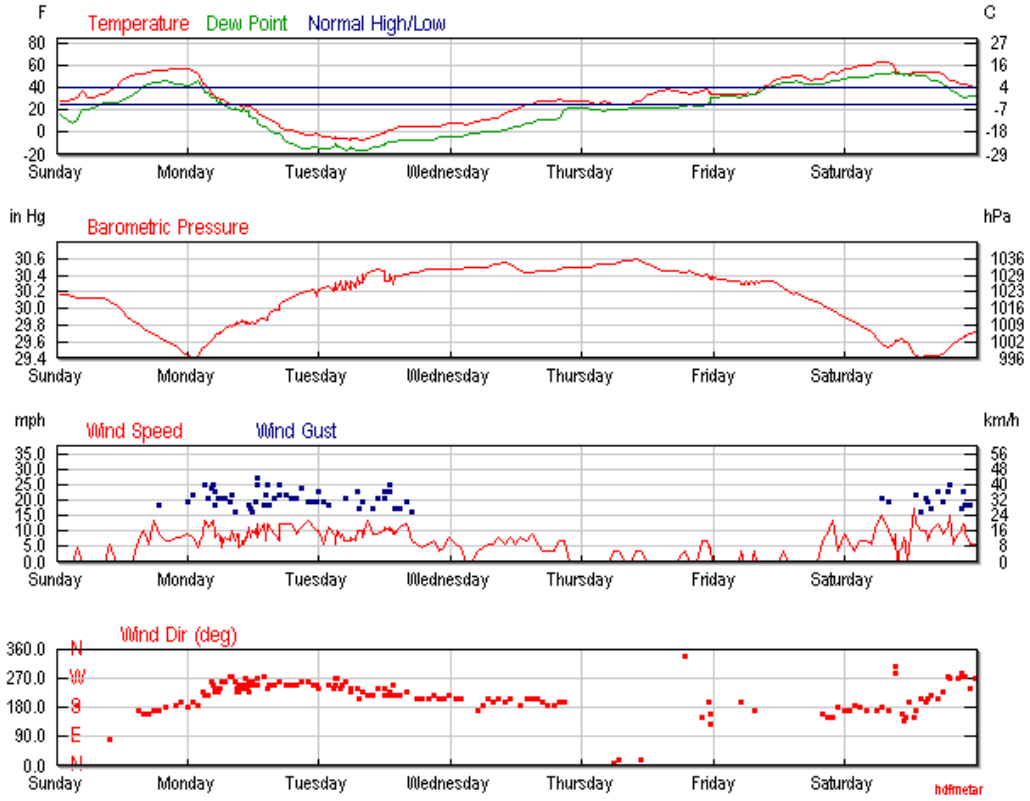
Week of January 5, 2014 through January 11, 2014

Week of January 5, 2014 through January 11, 2014

« Previous Week | January 7 2014 View | Next Week »

Daily | **Weekly** | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**64** °F	**44** °F	**7** °F	
Mean Temperature	**52** °F	**30** °F	**0** °F	
Min Temperature	**40** °F	**17** °F	**-7** °F	
Degree Days				
Heating Degree Days (base 65)	65	35	13	242
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	2	0	0	2
Dew Point				
Dew Point	**53** °F	**21** °F	**-17** °F	
Precipitation				
Precipitation	**0.51** in	**0.16** in	**0.00** in	**0.79** in
Snow depth	-	-	-	-
Wind				
Wind	**18** mph	**5** mph	**0** mph	
Gust Wind	**35** mph	**20** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.59** in	**30.12** in	**29.41** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Jan	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
5	56	40	24	45	30	8	75	59	42	30.16	29.89	29.44	10	10	10	17	4	24	T	
6	57	27	-4	45	15	-15	92	74	56	30.22	29.83	29.41	10	5	1	17	10	35	0.22	Rain , Snow
7	7	0	-7	-4	-12	-17	75	66	56	30.48	30.35	30.21	10	8	2	18	8	26	0.00	
8	29	18	6	21	6	-4	81	64	46	30.55	30.49	30.43	10	10	7	12	5	23	T	Snow
9	38	31	24	31	23	18	88	70	52	30.59	30.48	30.35	10	9	2	9	1	13	0.01	Snow
10	57	45	33	47	38	30	100	86	71	30.35	30.22	29.91	10	9	2	17	2	21	0.05	Rain
11	64	52	40	53	46	30	100	81	62	29.86	29.60	29.42	10	8	2	18	8	26	0.51	Rain

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Weather History for [redacted]

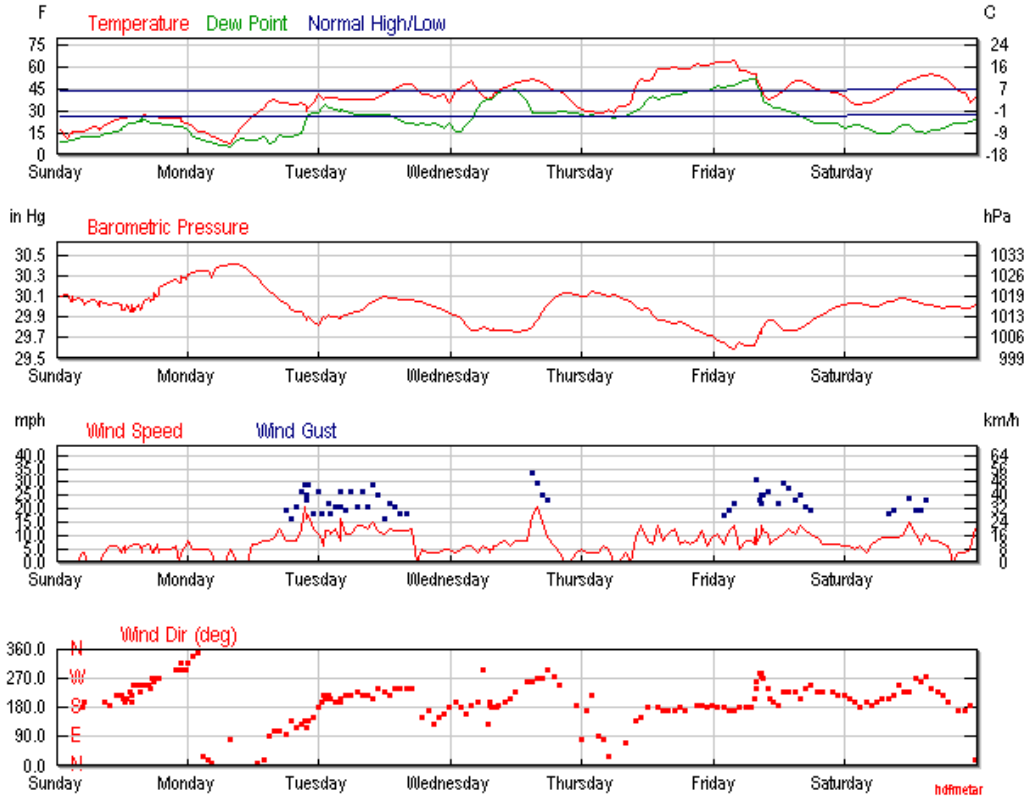
Week of February 16, 2014 through February 22, 2014

Week of February 16, 2014 through February 22, 2014

« Previous Week February 18 2014 View Next Week »

Daily Weekly Monthly Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**64** °F	**50** °F	**27** °F	
Mean Temperature	**51** °F	**38** °F	**19** °F	
Min Temperature	**38** °F	**26** °F	**8** °F	
Degree Days				
Heating Degree Days (base 65)	46	27	14	186
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**53** °F	**26** °F	**5** °F	
Precipitation				
Precipitation	**0.25** in	**0.08** in	**0.00** in	**0.54** in
Snow depth	-	-	-	-
Wind				
Wind	**22** mph	**7** mph	**0** mph	
Gust Wind	**40** mph	**23** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.43** in	**29.98** in	**29.59** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Feb	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
16	27	19	11	25	18	9	92	80	67	30.32	30.08	29.95	10	6	1	12	4	16	0.02	Snow
17	41	25	8	29	13	5	91	60	29	30.43	30.17	29.83	10	8	2	22	6	32	0.03	Rain , Snow
18	48	42	35	34	26	18	85	60	34	30.10	29.99	29.87	10	10	7	21	10	30	0.01	Rain
19	53	42	31	45	33	16	0	0	0	30.14	29.88	29.76	10	9	2	21	7	40	0.17	Rain
20	62	45	27	45	35	25	92	68	44	30.15	29.95	29.72	10	10	8	16	7	24	0.06	Rain
21	64	51	38	53	36	18	89	64	38	30.03	29.78	29.59	10	9	2	20	9	31	0.25	Rain
22	56	45	34	24	18	14	59	40	20	30.09	30.03	29.99	10	10	10	18	7	28	0.00	

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Weather History for [redacted]

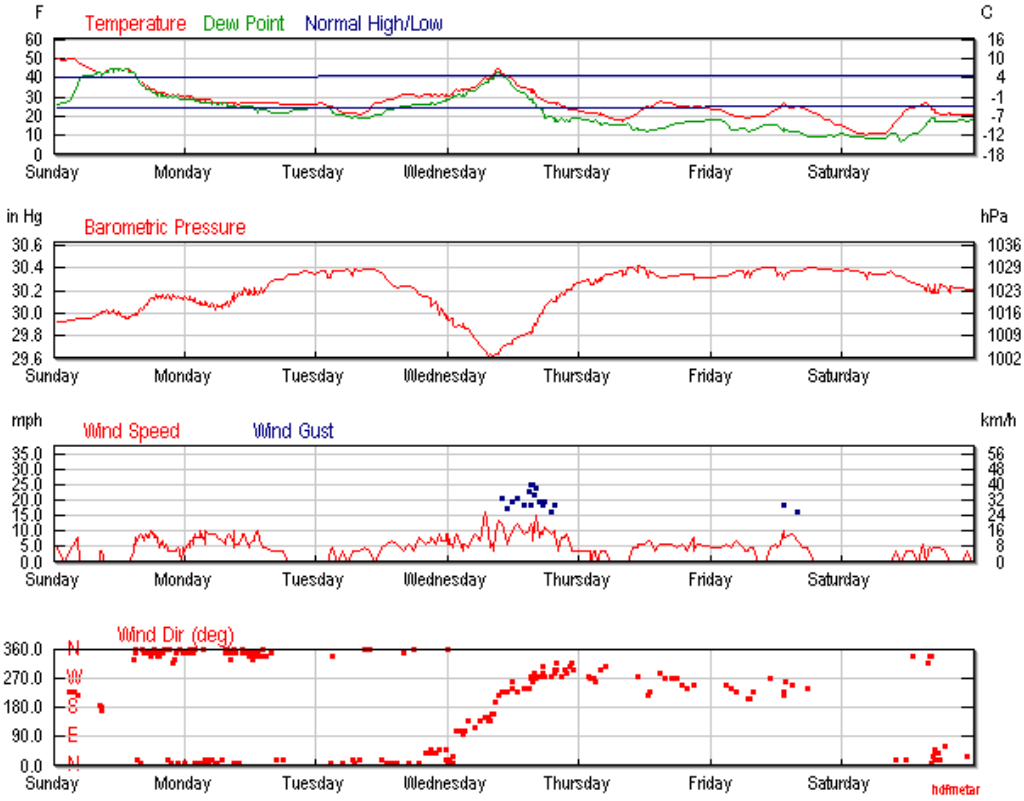
Week of February 2, 2014 through February 8, 2014

Week of February 2, 2014 through February 8, 2014

« Previous Week February 4 2014 View Next Week »

Daily Weekly Monthly Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**51** °F	**34** °F	**26** °F	
Mean Temperature	**41** °F	**27** °F	**18** °F	
Min Temperature	**30** °F	**20** °F	**10** °F	
Degree Days				
Heating Degree Days (base 65)	47	38	24	264
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**45** °F	**23** °F	**7** °F	
Precipitation				
Precipitation	**0.72** in	**0.37** in	**0.01** in	**1.87** in
Snow depth	-	-	-	-
Wind				
Wind	**16** mph	**5** mph	**0** mph	
Gust Wind	**23** mph	**20** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.42** in	**30.19** in	**29.61** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Feb	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
2	51	41	30	45	37	26	100	68	35	30.17	30.04	29.93	10	3	0	13	4	16	0.45	Fog , Rain , Snow
3	30	28	26	29	25	21	100	91	81	30.37	30.16	30.03	10	3	0	13	5	18	0.72	Fog , Snow
4	32	27	21	28	24	19	100	89	78	30.39	30.25	29.96	10	7	2	10	4	16	0.12	Rain
5	45	34	23	43	29	18	100	85	69	30.25	29.90	29.61	10	6	0	16	9	23	0.57	Fog , Rain , Snow
6	29	23	17	18	16	12	92	73	53	30.42	30.33	30.25	10	8	2	9	4	15	0.01	Snow
7	26	20	14	18	13	9	84	69	54	30.40	30.36	30.30	10	8	4	12	4	21	T	Snow
8	26	18	10	19	14	7	92	73	54	30.39	30.27	30.18	10	7	1	7	2	9	T	Snow

Comma Delimited File

Weather History for [redacted]

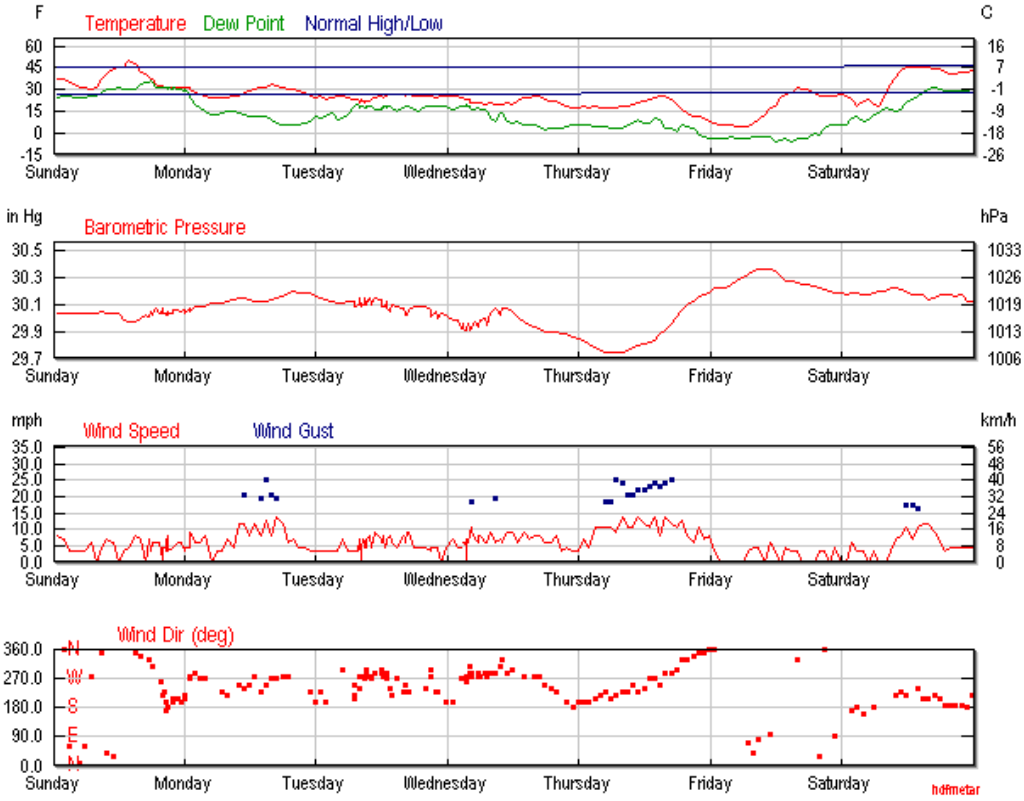
Week of February 23, 2014 through March 1, 2014

Week of February 23, 2014 through March 1, 2014

« Previous Week | February 25 2014 View | Next Week »

Daily | **Weekly** | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**51** °F	**35** °F	**25** °F	
Mean Temperature	**40** °F	**26** °F	**17** °F	
Min Temperature	**29** °F	**17** °F	**3** °F	
Degree Days				
Heating Degree Days (base 65)	48	39	25	272
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**36** °F	**14** °F	**-6** °F	
Precipitation				
Precipitation	**0.20** in	**0.04** in	**0.00** in	**0.24** in
Snow depth	-	-	-	-
Wind				
Wind	**20** mph	**6** mph	**0** mph	
Gust Wind	**31** mph	**20** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.36** in	**30.08** in	**29.74** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Feb	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
23	51	40	29	36	30	24	100	73	46	30.07	30.03	29.97	10	7	1	12	4	19	0.20	Rain , Snow
24	34	29	23	30	13	6	92	62	32	30.20	30.13	30.03	10	10	10	16	7	26	0.00	
25	28	25	22	20	17	9	84	67	50	30.15	30.09	30.00	10	6	0	12	5	17	0.03	Fog , Snow
26	26	21	16	20	12	2	88	64	39	30.07	29.95	29.85	10	6	0	13	7	22	0.01	Fog , Snow
27	25	17	8	10	4	-4	67	54	40	30.19	29.90	29.74	10	10	7	20	10	31	T	
28	32	18	3	6	-2	-6	76	49	22	30.36	30.27	30.19	10	10	10	8	2	11	0.00	
2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Mar	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
1	46	33	19	31	21	5	77	55	33	30.22	30.18	30.12	10	10	10	15	5	23	0.00	

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Weather History for [redacted]

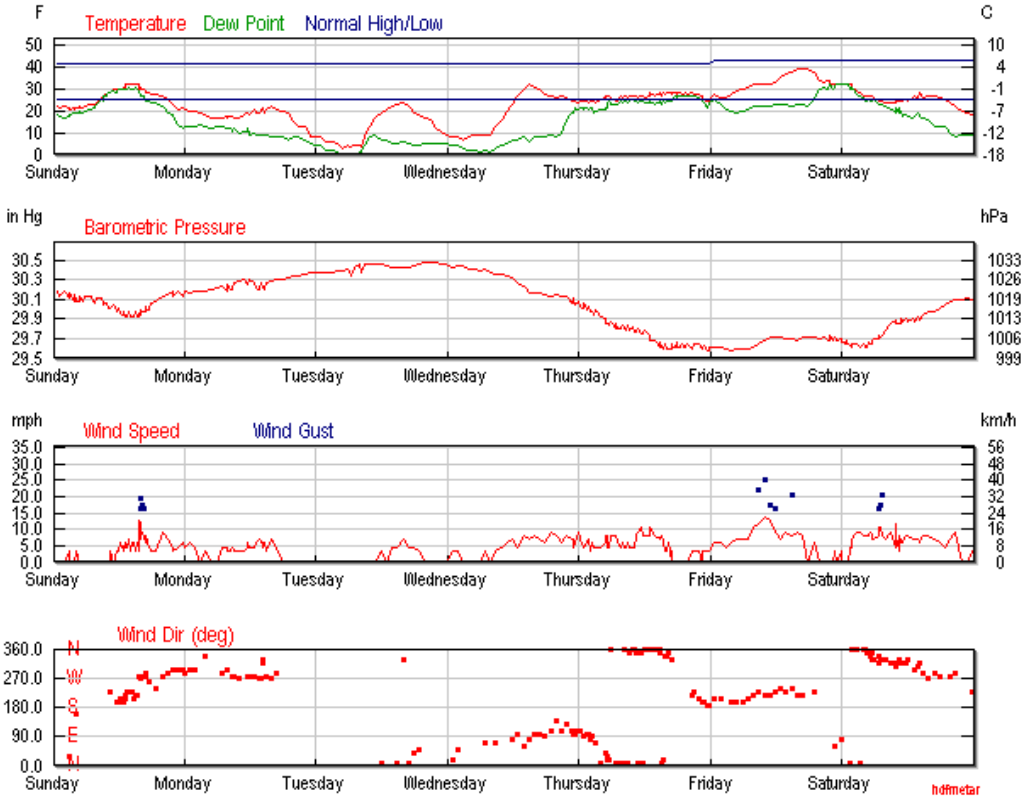
Week of February 9, 2014 through February 15, 2014

Week of February 9, 2014 through February 15, 2014

« Previous Week | February | 11 | 2014 | View | Next Week »

Daily | **Weekly** | Monthly | Custom

	Max	Avg	Min	Sum
Temperature				
Max Temperature	**40** °F	**30** °F	**23** °F	
Mean Temperature	**33** °F	**23** °F	**13** °F	
Min Temperature	**25** °F	**14** °F	**2** °F	
Degree Days				
Heating Degree Days (base 65)	52	42	32	296
Cooling Degree Days (base 65)	0	0	0	0
Growing Degree Days (base 50)	0	0	0	0
Dew Point				
Dew Point	**32** °F	**17** °F	**0** °F	
Precipitation				
Precipitation	**0.27** in	**0.14** in	**0.00** in	**0.70** in
Snow depth	-	-	-	-
Wind				
Wind	**16** mph	**4** mph	**0** mph	
Gust Wind	**30** mph	**18** mph	**16** mph	
Sea Level Pressure				
Sea Level Pressure	**30.48** in	**30.03** in	**29.58** in	



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Daily Weather History & Observations

2014	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Feb	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
9	32	27	21	31	25	12	100	86	71	30.19	30.04	29.92	10	4	0	13	3	20	0.12	Fog , Snow
10	23	15	6	14	10	4	84	70	56	30.38	30.26	30.17	10	8	1	8	3	14	T	Snow
11	24	13	2	9	4	0	91	68	45	30.48	30.43	30.34	10	8	4	7	1	9	0.00	
12	32	19	6	21	9	1	88	61	33	30.45	30.25	30.05	10	8	1	13	5	18	T	Snow
13	30	27	23	27	24	19	100	91	81	30.06	29.75	29.58	10	2	0	13	5	17	0.27	Fog , Snow
14	40	33	25	32	25	19	100	74	48	29.73	29.67	29.58	10	8	0	16	6	30	0.05	Fog , Snow
15	32	25	17	32	22	8	100	78	55	30.11	29.81	29.61	10	4	0	13	6	22	0.26	Fog , Snow

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Appendix B.8 – Fully Adhered TPO Firestone Literature

I.S.O.Spray™ S Adhesive

Item Description	Item Number
Part A: 55 gal (208 L) Drum 48.5 gal (184 L)	W56RACIASD
Part A: 15 gal (57 L) Drum 14 gal (53 L)	W56RACIASP
Part B: 55 gal (208 L) Drum 48.5 gal (184 L)	W56RACIBSD
Part B: 15 gal (57 L) Drum 14 gal (53 L)	W56RACIBSP

Product Information

Description:

Firestone I.S.O.Spray™ S Adhesive is a two-part polyurethane adhesive, mixed and dispensed from a heated high-pressure spray or bead-extruding system to anchor acceptable roof insulation to acceptable substrates, to adhere multiple layers of insulation, or to adhere fleece backed UltraPly™ TPO XR membrane.

Product Packaging

Container Size:	Weight per Drum:	Drums per Pallet:
Part A in 15 gal (57 L) Drum	145 lb (66 kg)	9
Part B in 15 gal (57 L) Drum	130 lb (59 kg)	9
Part A in 55 gal (208 L) Drum	500 lb (227 kg)	4
Part A in 55 gal (208 L) Drum	450 lb (204 kg)	4

Method of Application for Insulation Attachment:

1. Install only as much roof insulation as can be covered and made watertight during the workday.
2. Substrates to receive I.S.O.Spray S Adhesive shall be above 40 °F (4.4 °C) clean, smooth, dry, free of sharp edges, loose and foreign materials, oil, grease, and other contaminates.
3. Prepare the insulation by laying out and planning insulation placement. Trim or cut insulation as necessary to fit around penetrations. Insulation placement will immediately follow dispensing of I.S.O.Spray S Adhesive. This step is critical for tapered insulation systems.
4. Dispense I.S.O.Spray S Adhesive on the substrate as follows:
    a. Spray Application: Full spray coverage 1/8" to 1/4" thick (3.2 to 6.4 mm).
    b. Bead Application: 3/4" to 1" wide 6" or 12" centered beads (19.1 to 25.4 mm wide 152.4 or 304.8 mm centered beads).
    NOTE: Closer bead spacing may be required at building corners and edges, depending on wind zone.
5. If the I.S.O.Spray S Adhesive does not rise, stop dispensing. Troubleshooting is required to determine why the adhesive is not rising.
6. Immediately set the insulation boards (maximum size: 4' x 4' [1.2 m x 1.2 m]) after dispensing the I.S.O.Spray S Adhesive.
7. Immediately after setting the insulation board, weight each board, using full pails of Bonding Adhesive or other available source of weight that will not damage the roof insulation. This ensures full contact and adhesion during set-up time. Set-up time will vary depending on ambient conditions.
8. Performance of I.S.O.Spray S Adhesive should be periodically monitored during the workday to verify that sufficient rise, adhesion, and full bonding is occurring.
9. Do not attempt to apply I.S.O.Spray S Adhesive when unfavorable conditions exist.

I.S.O.Spray™ S Adhesive

Method of Application for UltraPly TPO XR Membrane Attachment:

1. Install only as much UltraPly TPO XR Membrane as can be completed and made watertight during the workday.
2. Substrates to receive I.S.O.Spray S Adhesive shall be above 40 °F (4.4 °C), clean, smooth, dry, free of sharp edges, loose and foreign materials, oil, grease, and other contaminates.
3. Starting at the highest roof elevation, unroll and position UltraPly TPO XR Membrane. Position membrane panels so the laps will be completed in “shingle fashion”, and not “buck” water.
4. Fold the properly positioned membrane panels back to expose the substrate to receive I.S.O.Spray S Adhesive.
5. Dispense I.S.O.Spray S Adhesive on the substrate as follows:
    a. Spray Application: Full spray coverage 1/8" to 1/4" thick (3.2 to 6.4 mm).
    b. Bead Application: 3/4" to 1" wide 6" or 12" centered beads (19.1 to 25.4 mm wide 152.4 or 304.8 mm centered beads).
    Note: Closer bead spacing may be required at building corners and edges depending on wind zone.
    c. **Do not apply I.S.O.Spray S Adhesive to UltraPly TPO XR Membrane.** Keep lap areas of UltraPly TPO XR Membrane clean and free of I.S.O.Spray S Adhesive. Remove any I.S.O.Spray S Adhesive that contaminates lap areas.
6. If the I.S.O.Spray S Adhesive does not rise, stop dispensing. Troubleshooting is required to determine why the adhesive is not rising.
7. I.S.O.Spray S Adhesive shall rise (within 1 to 2 minutes). Mate the UltraPly TPO XR Membrane into the freshly applied adhesive.
8. Using a roller (such as linoleum roller) to ensure proper adhesion, roll the freshly mated UltraPly TPO XR Membrane.
9. Performance of I.S.O.Spray S Adhesive should be periodically monitored during the workday to verify that sufficient rise, adhesion, and full bonding is occurring.
10. Do not attempt to apply I.S.O.Spray S Adhesive when unfavorable conditions exist.

Acceptable Substrates

Substrate	Insulation Attachment?	TPO XR Attachment?	Notes
Structural Concrete (New)	Yes	No	Newly poured decks must be sufficiently cured to allow adhesion to the substrate surface. Cure times vary. A roof consultant, structural engineer, or concrete industry professional may be contacted to perform moisture tests if readiness of concrete is in question.
Structural Concrete (Existing)	Yes	Yes	Positive adhesion test required.
Steel	Yes	No	New steel decks may require cleaning to remove processing oils.
Gypsum Decks	Yes	Yes	
Cementitious Woodfiber	Yes	Yes	
Modified Bitumen Roofs	Yes	Yes	
Plywood and OSB	Yes	Yes	
SBS Base Sheets	Yes	Yes	
Lightweight Concrete	No	Yes	Acceptable lightweight concrete substrates include cellular or air-entrained concrete. Lightweight concrete substrates with aggregate (such as perlite or vermiculite) are not acceptable.

I.S.O.Spray™ S Adhesive

Acceptable Substrates (Continued)

Existing Asphalt B.U.R.	Yes	Yes	Existing substrates containing residual asphalt must be cleaned and scraped as smooth as possible.
ISO 95+™ GL Insulation, ISOGard™ HD Cover Board, RESISTA™ Insulation, FiberTop Woodfiber, DensDeck® and DensDeck® Prime, Expanded Polystyrene (EPS), Extruded Polystyrene (XPS), Polyiso Insulation, Woodfiber	Yes	Yes	
Existing Singly-Ply Roofs, Coal Tar Pitch, Fiberglass Insulation, Perlite Insulation	No	No	These substrates are not acceptable as an immediate substrate for this product.

DensDeck is a registered Trademark of Georgia-Pacific.

Storage:

- Do not allow I.S.O.Spray S Adhesive to freeze.
- Store in original, unopened containers between 65 °F and 85 °F (18.3 °C and 29.4 °C).
- Keep bungs on drums tightly closed during storage.
- Do not store in direct sunlight.
- Do not expose to moisture.
- For optimum results, rotate stock to ensure stored material has not exceeded the shelf life.

Shelf Life:

- Shelf life of six to nine (6 to 9) months can be expected when stored in original, unopened containers at temperatures between 65 °F and 85 °F (18.3 °C and 29.4 °C) and kept out of sunlight.
- Drums indicate a “use before” date.

Coverage Rate:

- Spray Application: Coverage rates will vary by substrate from 60 to 95 ft^2/gal (1.5 to 2.3 m^2/L).
- Bead Application: Coverage rates of 3/4" to 1" (19.1 to 25.4 mm) beads will vary by bead spacing:
    - 4" (102 mm) o.c. bead spacing will achieve coverage of 60 to 90 ft^2/gal (1.5 to 2.2 m^2/L)
    - 6" (152.4 mm) o.c. bead spacing will achieve coverage of 90 to 120 ft^2/gal (2.2 to 2.9 m^2/L)
    - 12" (305 mm) o.c. bead spacing will achieve coverage of 170 to 190 ft^2/gal (4.2 to 4.7 m^2/L)

Precautions:

1. Review applicable Material Safety Data Sheets (MSDS) prior to use or handling.
2. Personnel who are sensitive or allergic to isocyanate or polyurethane should not work with I.S.O.Spray S Adhesive.
3. Review method of application with spray equipment supplier prior to use.
4. Review spray equipment prior to use. Ensure that all is in good working order: generator, air compressor, mix/meter/dispense spray unit, transfer pumps, heated hoses, spray gun, etc. Ground spray unit per dispensing equipment manufacturer’s requirements.
5. Avoid contact with eyes and skin. Use gloves and safety glasses with side shields when handling or dispensing I.S.O.Spray S Adhesive. Wash thoroughly after handling.
6. Avoid breathing of vapors. Wear respirators, long sleeves and long pants.

I.S.O.Spray™ S Adhesive

Precautions (Continued):

7. Protect all areas subject to overspray of the I.S.O.Spray S Adhesive. This includes, but is not limited to: cars parked adjacent to the building receiving the I.S.O.Spray S Adhesive, air intakes/exhausts on the building, roof-mounted HVAC units, roof drains, access hatches and windows/skylights accessible to the roof, and any other item or personnel which may be downwind from spraying the I.S.O.Spray S Adhesive. There will be days that the wind conditions, as well as temperature conditions, prevent the use of I.S.O.Spray S Adhesive. Do not attempt to spray I.S.O.Spray S Adhesive when the wind speed exceeds 15 mph (24 km/h). This can be estimated by observing a flag. When a flag is windblown to the extent that it flies approximately “straight out”, the wind is too extreme to use I.S.O.Spray S Adhesive on that particular workday.
8. Begin dispensing I.S.O.Spray S Adhesive only when Part A and B pre-heaters have reached 135 to 145 °F (57 to 63 °C) in the mix/meter/dispense unit. Maintain 135 to 145 °F (57 to 63 °C) throughout the heated hoses.
9. When used for insulation attachment, it is imperative that freshly installed insulation is continuously weighted until such time as the I.S.O.Spray S Adhesive sets up and the board is held in place by the adhesive.
10. Freshly installed UltraPly TPO XR Membrane shall be rolled immediately after mating to ensure proper adhesion.
11. Use caution when removing drum bungs as contents may develop pressure. Loosen bungs 3/4" (19.1 mm), and allow gas to escape before completely removing bungs.
12. Do not burn or torch-cut empty drums. Empty B component drums can be reconditioned at drum re-conditioners. Empty A (or B) component drums should be disposed of in accordance with local, state, and federal regulations.

LEED® Information:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location (Part A): New Martinsville, WV; Baytown, TX
Manufacturing Location (Part B): Elwood, IL

Physical Properties

Property	Typical Performance
Color:	Part A: Light Brown Part B: Light Brown
Mix Ration of A:B:	1:1 by Volume
Specific Gravity at 77 °F (25 °C):	Part A: 1.24 Part B: 1.10
Viscosity at 77 °F (25 °C) Part A/Part B:	150 to 250 cps using RVT #2 spindle at 30 RPM
V.O.C. Content:	Part A: 0 lb/gal (0 g/L) Part B: 0.9 lb/gal (108 g/L)

Please contact your Firestone Roof Systems Advisor at 1-800-428-4511 for further information.

This sheet is meant to highlight Firestone products and specifications and is subject to change without notice. Firestone takes responsibility for furnishing quality materials which meet published Firestone product specifications. Neither Firestone nor its representatives practice architecture. Firestone offers no opinion on and expressly disclaims any responsibility for the soundness of any structure. Firestone accepts no liability for structural failure or resultant damages. Consult a competent structural engineer prior to installation if the structural soundness or structural ability to properly support a planned installation is in question. No Firestone representative is authorized to vary this disclaimer.

TECHNICAL INFORMATION SHEET

Single-Ply LVOC Bonding Adhesive

TIS # 822

ITEM NUMBER: W56358705L

Description:

Firestone Single-Ply LVOC Bonding Adhesive is a bonding adhesive designed for bonding RubberGard™ EPDM, FormFlash™ or UltraPly™ TPO membranes and flashings to wood, metal, masonry and other acceptable substrates.

Method of Application:

1. Surfaces to receive Firestone Single-Ply LVOC Bonding Adhesive must be clean, smooth, dry, and free of sharp edges, loose and foreign materials, oil, grease, and other contaminants. Sweep the mating surface of the membrane with a stiff broom to remove excess dusting agent, if present, and remove other contaminants from the mating surface.
2. Stir the adhesive thoroughly before and during use, achieving a uniform mix with no sediment on the bottom and no marbling evident.
3. Apply adhesive at about the same time to both the membrane and the substrate to allow approximately the same flash-off time.
4. Apply by rolling the adhesive evenly on mating surfaces, avoiding globs or puddles.
5. As an option, spray on adhesive and then roll out uniformly and evenly with a solvent-resistant paint roller. **Care must be taken not to apply Firestone Single-Ply LVOC Bonding Adhesive over any area that is to be later cleaned and spliced to another sheet or flashing.**
6. Allow adhesive to flash off until tacky. Touch the adhesive surface with a clean, dry finger to be certain that the adhesive does not stick or string. Push down and forward on the adhesive at an angle to ensure that the adhesive is ready throughout its thickness. If either motion exposes wet or stringy adhesive when the finger is lifted, then it is not ready for mating. Flash off time may vary significantly depending on ambient air conditions.
7. Starting at the fold, roll the adhesive coated portion of the sheet into the adhesive coated substrate slowly and evenly so as to minimize wrinkles. To ensure mating of the membrane to substrate, broom the top of the mated membrane with a stiff push broom immediately after mating membrane to substrate.

Storage:

- Store in original unopened containers at temperatures between 60 °F (15.6 °C) and 80 °F (26.7 °C) until ready for use.
- For optimum results, rotate your stock to ensure stored material has not exceeded the shelf life of one year.
- Shelf life of one year can be expected if stored in original sealed container at temperatures between 60 °F (15.6 °C) and 80 °F (26.7 °C). If exposed to lower temperatures, restore to room temperature prior to use.
- Shelf life will be shortened if exposed to elevated temperatures. Rotate stock to insure stored material will not go beyond the shelf life of one year.

Precautions:

- Review Material Safety Data Sheet prior to use.
- Flammable. Keep away from fire and open flame and other possible ignition sources during storage and use. Do not smoke when using.
- Harmful or fatal if swallowed.
- Avoid prolonged inhalation.
- Avoid prolonged contact with skin. Gloves should be worn (OSHA approved).
- Avoid eye contact by wearing safety goggles with side shields.
- Thinning is not allowed.
- Do not use for splicing.
- Do not use with UltraPly TPO XR membranes.
- Use only in well ventilated areas.
- Cover tightly when not in use.
- Recommended cleaner is Toluene (while fluid).

Compliance:

Post Consumer Recycled Content:	0%
Pre Consumer Recycled Content:	0%
Manufacturing Location:	South Bend, IN

FM APPROVED

CLASSIFIED C UL US

TECHNICAL INFORMATION SHEET

Packaging:	
Unit:	5 Gallon (19 L)
Coverage:	45-60 ft²/gal (1.10 – 1.47 m²/L) shall be obtained depending on the substrate. Some surfaces are more uneven and porous and will result in a lower coverage rate while smooth, non-porous substrates may result in higher coverage rates. Rates are based on roller application to both mating surfaces. When sprayed and back-rolled, the rate may be slightly higher than when rolled only.
Weight:	≈40 lb (20.4 kg)
Units Per Pallet:	45

Physical Properties:	*Minimum Performance*
Base:	Polychloroprene Rubber
Color:	Yellow
Solvents:	Acetone; Tert-butyl Acetate; Ethyl Acetate
Solids:	22%
Viscosity:	3300-3800 Centipiose, R.V.F. Brookfield, #3 Spindle @ 10 RPM
Weight:	7.45 ±0.15 lb/gal (0.893 ±0.018 kg/L)
Specific Gravity:	0.875 to 0.911
V.O.C. Content:	< 250 g/L (When tert-butyl Acetate is considered VOC exempt.)

Approved Power Equipment:

Graco Spray Equipment:

287975 30:1 Xtreme® pneumatic pump with Air Assisted Airless package, (1000 psi operating pressure)
Hopper and pump mounted to Heavy Duty Cart, 287884, 288347 Hopper Kit, 222695 Agitator to be mounted by customer, 249133, 249256, 249180 Air Cap for G40 Applicator (800 psi min. fluid atomization; air pressure 80 psi)
GG4321, GG4421 tips

Garlock 2120 Commander Sprayer

18 hp Kohler Engine, 4500 psi Rating, Pump Displacement 45:1, GPM Rating: up to 5 gpm, ½" x 100' hose, 2" Intake pipe with screen 5 or 55 gal drum containers, Graco Spray Tips: .019 to .025 diameter hose (26000 psi operating pressure)

Garlock Twin Gun Airless Sprayer

6.5 hp Honda Engine, 3000 psi Rating, Pump Displacement 30:1, GPM Rating: up to 1 ½ gpm, Up to 400' of single ½" diameter hose, Up to 200' of dual ½" diameter hose, ½" Intake pipe with screen, 5 or 55 gal drum containers, Bulk tank containers, Graco Spray Tips: .019 to .025 diameter hose (1850 psi operating pressure)

Please Contact your Firestone Roof Systems Advisor at 1-800-428-4511 for further information.

UltraPly™ TPO Platinum™ Membrane

Item Description	Item Number
1 Roll	Various

Product Information

Description:

Firestone UltraPly™ TPO Platinum™ membrane is a flexible, 0.080" (2.03 mm) thick, Thermoplastic Polyolefin (TPO) roofing membrane. It is reinforced with a polyester, weft-inserted scrim. This heat weldable TPO Platinum membrane is available in 0.080" (2.03 mm) thickness and widths up to 12' 4" (3.8 m). Firestone Platinum TPO is available in white, tan and gray. This reflective membrane is suitable for a variety of low-slope applications.

Method of Application:

1. Substrates must be clean, dry, smooth, and free of sharp edges, fins, loose or foreign materials, oil, grease, and other materials that may damage the membrane.
2. All roughened surfaces that can damage the membrane shall be repaired as specified to offer a smooth substrate.
3. All surface voids greater than 1/4" (6.3 mm) wide shall be properly filled with an acceptable fill material.
4. Firestone UltraPly TPO Platinum membrane is installed as continuous roofing or waterproofing layer on the roof. Rolls are overlapped (side laps and end laps) prior to the heat welding of the seam areas.
5. Install the UltraPly TPO Platinum Roofing System in accordance with current Firestone UltraPly TPO Platinum membrane specifications, details and workmanship requirements.

Storage:

- Store away from sources of punctures and physical damage.
- Assure that structural decking will support the loads incurred by material when stored on rooftop. The deck load limitations should be specified by the project designer.
- Store away from ignition sources as membrane will burn when exposed to open flame.

Precautions:

1. Refer to Material Safety Data Sheets (MSDS) for safety information.
2. Exercise caution when lifting, moving, transporting, storing or handling membrane rolls to avoid sources of punctures and possible physical damage.
3. Contact your Technical Coordinator at 1-800-428-4511 for specific recommendations regarding chemical or waste product compatibility with Firestone UltraPly TPO Platinum Membrane.

LEED® Information:

Post Consumer Recycled Content:	0%
Pre Consumer Recycled Content:	15%
Manufacturing Location:	Wellford, SC Tuscumbia, AL

CCMC 13348-R

UltraPly™ TPO Platinum™ Membrane

Product Sizes

Membrane Thickness: 0.080" (2.03 mm)
Membrane Weight: 0.42 lb/ft^2 (2.1 kg/m^2)

Available Sizes		Available Colors
5' x 100'	(1.5 x 30.5 m)	White, Tan, Gray
6' 2" x 100'	(1.9 x 30.5 m)	White
8' x 100'	(2.4 x 30.5 m)	White, Tan, Gray
10' x 100'	(3.0 x 30.5 m)	White, Tan, Gray
12' 4" x 100'	(3.8 x 30.5 m)	White

Physical Properties

Property	ASTM Standard	Performance Minimum	Typical Performance 80 mil
Overall Thickness:	D 751	0.039" (1.0 mm)	0.080" (2.03 mm) ± 10%
Coating over Scrim:	D 7635	0.015" (0.381 mm)	0.033" (0.84 mm)
Breaking Strength:	D 751, Grab Method	220 lbf (979 N)	460 lbf (2,046 N)
Elongation of Reinforcement Break:	D 751, Grab Method	15%	25%
Tearing Strength:	D 751	55 lbf (245 N)	120 lbf (534 N)
Brittleness Point:	D 2137	-40 ºF (-40 ºC)	Pass
Ozone Resistance, No Cracks:	D 1149	Pass	Pass
Properties After Heat Aging (Retained Values) (ASTM D 573 670 h at 240 °F (116 °C)):			
Breaking Strength:	D 751, Grab Method	90% Minimum	> 90%
Elongation at Break:	D 751, Grab Method	90% Minimum	> 90%
Tearing Strength:	D 751	60% Minimum	> 60%
Weight of Change:		± 1% Maximum	< 1%
Linear Dimension Change:	D 1204, 6 h at 158 °F (70 °C)	± 1% Maximum	< 1%
Water Absorption:	D 471	± 3% Maximum	< 3%
Weather Resistance, 80 °C Black Panel, no cracking, crazing when wrapped around a 3" mandrel and inspected at 7X magnification::	G 155	10,800 kJ/m^2 Minimum	> 20,160 kJ/m^2
Puncture Resistance:	FTM 101C, Method 2031	_____	450 lbf (2,002 N)
Dynamic Puncture Resistance MD:	D 5635	_____	Pass (60 J)
Dynamic Puncture Resistance CD:	D 5635	_____	Pass (60 J)
Static Puncture Resistance:	D 5602	_____	Pass (25 kg)

UltraPly™ TPO Platinum™ Membrane

Radiative Properties

Cool Roof Rating Council (CRRC): Initial / 3 yr	White	Tan	Gray
Solar Reflectance	0.79 / 0.68	0.61 / 0.55	0.34 / Pending
Thermal Emittance	0.85 / 0.83	0.81 / 0.84	0.89 / Pending
Solar Reflectance Index (SRI)	98 / 81	71 / 63	37 / Pending
Rated Product ID	0008		
Licensed Manufacturer ID	0608		
Classification	Production Line		

ENERGY STAR®: Initial / 3 yr	White	Tan
Solar Reflectance	0.79 / 0.78*	0.60 / 0.54
Thermal Emittance	0.85	0.81
* White membrane sample cleaned prior to age test.		

LEED®	White	Tan	Gray
Solar Reflectance – ASTM E 903	0.81	0.63	0.37
Thermal Emittance – ASTM E 408	0.95	0.95	0.95
Solar Reflectance Index (SRI) – ASTM E 1980	102	77	43

CRRC COOL ROOF RATING COUNCIL CHARTER MEMBER

ENERGY STAR

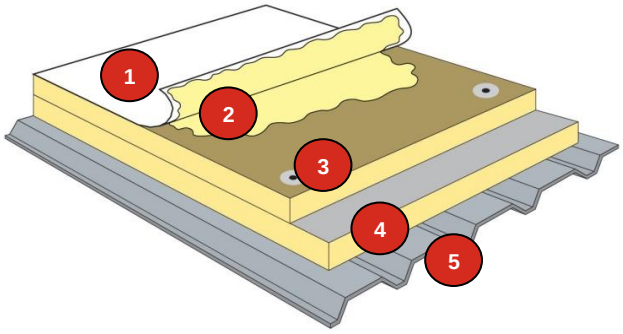
ENERGY STAR is only valid in the United States

Firestone GREEN ONE TEAM, ONE PLANET

Please contact your Firestone Roof Systems Advisor at 1-800-428-4511 for further information.

UltraPly™ TPO Membrane
Fully Adhered, Steel Deck

5, 10, 15, 20 Year Red Shield™ Warranty



1. Firestone UltraPly™ TPO Membrane
2. Fully Adhered with Bonding Adhesive
3. Mechanically Attached or Adhered Cover Board (Optional)
4. Mechanically Attached or Adhered Insulation
5. Steel Deck

Consult Firestone Technical Specifications, Guides and Details at www.firestonebpco.com

Slope Requirement
Positive slope required for warranty.[5]

Construction Type
New construction, complete tear-off, or recover with any wet or damaged materials removed prior to installation.

Building Height Limitation
Firestone UltraPly™ TPO Adhered Systems are limited to buildings 250' (76.2 m) or less.

Use of Air Barrier
An air barrier is required for projects with large wall openings greater than 10% of the total wall area.

Base Tie-Ins
Must be attached to substrates which provide a minimum of 200 lbf (1 kN) in any direction.

Increased Wind Speed and Codes
Any wind speed coverage exceeding 55 mph (88 km/h) or projects with codes requirements must be reviewed by a Firestone Roof Systems Advisor.

Deck Requirement
- ❑ Minimum 22 Gauge Steel

Fastener Type
- ❑ Firestone All Purpose Fastener *(Max. 15 Year Warranty)*
- ❑ Firestone Heavy Duty Fastener
- ❑ Firestone Heavy Duty Plus Fastener
- ❑ Firestone HailGard™ Fastener *(with HailGard Composite Board or OSB only)*

Insulation Adhesive*
- ❑ Firestone I.S.O. Twin Pack™ Insulation Adhesive
- ❑ Firestone I.S.O.Spray™ S Insulation Adhesive
- ❑ Firestone I.S.O. Fix™ II Insulation Adhesive
- ❑ Firestone I.S.O.Stick™ Insulation Adhesive

***Note:** Max. 4' x 4' boards must be used when attaching insulation with adhesives. Cleaning of the metal deck may be required to remove processing oils from manufacturing.

Adhesive Attachment
Max. 15 Year Warranty:
- ❑ Bead Spacing: F: 12", P: 12", C: 12"

20 Year Warranty:
- ❑ Bead Spacing: F: 12", P: 6", C: 4"
- ❑ Full Application *(I.S.O.Spray S Insulation Adhesive)*

Membrane Requirement
- ❑ UltraPly TPO, Any Thickness
- ❑ ReflexEON™ TPO, Any Thickness

Seaming Requirement
Firestone 1.5" Single Weld System (use robot welder). Joint covers are required at all joints and at angle changes 1:12 or greater.

Firestone Membrane Adhesive
- ❑ UltraPly Bonding Adhesive
- ❑ Single-Ply LVOC Bonding Adhesive
- ❑ Single-Ply LVOC Bonding Adhesive 1168
- ❑ Water Based Bonding Adhesive (P) (*Max. 15 Year Warranty*)

Edge Metal System
- ❑ Firestone EdgeGard™ System
- ❑ Firestone AnchorGard™ System
- ❑ Firestone Coping System
- ❑ Firestone Termination Bar
- ❑ Firestone Aluminum Drain Bar

Insulation Fastener and Insulation Plate Attachment Rates – Field Rates for Standard 55 mph Wind Speed

Insulation (Top Layer)	4' x 8'	Coverboard (Optional)	4' x 8'
1.0" to 1.4" Firestone ISO 95+™ GL or RESISTA™ Insulation	16	1/2" or 1.0" FiberTop Wood Fiber Board (*Max. 15 Year Warranty*)	16
1.5" to 1.9" Firestone ISO 95+ GL or RESISTA Insulation	12	Firestone ISOGARD™ HD Cover Board	12
2.0" to 4.0" Firestone ISO 95+ GL or RESISTA Insulation	8	1/4" SECUROCK® Gypsum-Fiber or DensDeck® ***I*** (Prime)	16 16***I***(12)
Firestone HailGard™ Composite Board	16	1/2" SECUROCK Gypsum-Fiber or DensDeck ***I*** (Prime)	12 12***I***(10)
Firestone ISOGARD™ HD Composite Board	8	5/8" SECUROCK Gypsum-Fiber or DensDeck ***I*** (Prime)	8 8***I***(8)

Detail Description

Wall Terminations:	Firestone Termination Bar with AP Sealant applied along the caulk lip. Surface mounted or inserted counter flashing may also be used in accordance with current Firestone details.
Curb & Wall Flashings:	Curbs, walls, and expansion joints must be anchored with appropriate base tie-in detail, either using seam plates and fasteners or using UltraPly QuickSeam Reinforced Perimeter Fastening (RPF) Strip and Batten Strip or 2" Metal Seam Plates. Curbs and walls must be flashed using minimum 0.045" UltraPly TPO Membrane or UltraPly TPO 18" Curb Flashing. Flashings may be sealed with welded details or QuickSeam products when acceptable. Details may include UltraPly TPO Coated Metal.
Corners:	UltraPly TPO Inside/Outside Corners or UltraPly QuickSeam Corner Flashing.
Roof Edges/Parapets:	Firestone AnchorGard™ or EdgeGard™ Fascia or Drain Bar systems. ANSI/SPRI ES-1 rated edge metal may also be used / Firestone Coping System or UltraPly TPO Coated Metal
Penetrations:	Flash with UltraPly QuickSeam or UltraPly Pipe Flashing (weldable), UltraPly TPO Penetration Pocket, or field fabricate with UltraPly TPO Unsupported Flashing.

Notes:
1. *Only Firestone brand products are covered in a Red Shield warranty.*
2. *Refer to the Firestone Technical Database at www.firestonebpco.com for additional information regarding UltraPly TPO Roof Systems.*
3. *Refer to the Firestone RoofGenuity™ tool to create roof assemblies with high-performance Firestone products at www.RoofGenuity.com.*
4. *DensDeck is a registered trademark of Georgia-Pacific Gypsum LLC.*
5. *It is the installing contractor's responsibility to follow applicable building codes.*
6. *SECUROCK is a registered trademark of USG Corporation..*

Firestone Building Products Company, LLC
250 West 96th Street • Indianapolis, IN 46260
Technical: 1-800-428-4511 • Sales: 1-800-428-4442 • www.firestonebpco.com
Rev. 3/29/2013

Appendix B.9 – Firestone InvisiWeld Literature

Firestone
BUILDING PRODUCTS

UltraPly™ TPO InvisiWeld™ Roofing System Application Guide

June 10, 2013

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2.01 GENERAL

The following application guide provides the instructions for the installation of Firestone UltraPly™ TPO or ReflexEON™ TPO membranes, using Firestone's UltraPly™ TPO InvisiWeld™ system technology. Reference to the InvisiWeld Design Guide, Technical Information Sheets, RhinoBond Tool Instruction manual (from OMG, Inc.) and other sections of Firestone's Technical Specifications is necessary to ensure that the finished roof system is installed in compliance with Firestone requirements and, therefore, eligible to receive a Firestone Warranty.

The Firestone UltraPly TPO InvisiWeld roof system refers to an alternate attachment method (other than fully adhered and mechanically attached) to affix Firestone's TPO membranes to various approved substrates. Following the installation of the approved roof insulation using a special TPO coated InvisiWeld metal insulation plate, the membrane system is attached using a non-penetrating, induction welding technology, whereby the TPO membrane is welded to the plates using an induction welding tool as shown in Figure 1, and provided by others. In doing so, the insulation plate acts as the point of attachment for both the membrane and the insulation.

NOTE: If a proposed application falls outside this specification, contact a Firestone Roof Systems Advisor for additional information.

Figure 1. InvisiWeld Machine and Magnetic Tool

2.02 JOB SITE CONSIDERATIONS (CAUTION AND WARNINGS)

A. Safety

1. Keep all adhesives, sealants and cleaning materials away from all ignition sources (i.e., flames, fire, sparks, etc.). Do not smoke while using these materials.
2. Consult container labels, Material Safety Data Sheets and Technical Information Sheets for specific safety instructions for all products used on the project.

B. Cautions

1. Care must be used when installing fasteners to avoid possible conduits and other piping, both in and under the deck.
2. Store Firestone UltraPly TPO or ReflexEON TPO membrane in the original undisturbed plastic wrap in a manner to protect it from damage.
3. Do not use oil-based or bituminous-based roof cement, mastics or caulks in direct

contact with Firestone UltraPly TPO or ReflexEON TPO membranes.

4. Insulation must be properly stored and protected from ignition sources, moisture, and damage.
5. Follow all Occupational Safety and Health Administration (OSHA), National Roofing Contractors Association (NRCA) and other industry recommendations for fire and fall protection.

2.03 ROOF SUBSTRATE PREPARATION

A. Correct Substrate Defects

1. Defects in the substrate that require corrective action before work can commence should be brought to the attention of the General Contractor or Owner in writing, and addressed by them.
2. For re-roofing applications, remove existing roof system components as specified by the project designer and documents. Components or conditions that are discovered during installation that could be detrimental to the performance of the new roof system should be brought to the attention of the project designer for corrective action.
3. Good roofing practice requires a complete removal of the existing roof to the structural deck if soundness and integrity of the existing roof system cannot be verified. Recovering an existing roof system with a new roof is an alternative to removing existing roof components. Nondestructive testing, however, in conjunction with examination of core cuts, must be performed to determine the condition of the existing roof system and decking.
4. The building owner or project designer is responsible for assuring that all wet or damaged insulation and/or substrates are removed and replaced in re-roofing applications. A reliable diagnostic technique is taking and evaluating a series of roof core cuts. There are three other techniques available to make this determination by indirect means: nuclear moisture detection, infrared thermography, and electric capacitance. These techniques provide measurement of factors that can be associated with the presence of moisture, which can then be correlated to the roofing cuts to verify the results of the nondestructive testing.

B. Rooftop Moisture

1. Ponded water, snow, frost, dew, and ice must be removed from the substrates/work surfaces before installing the UltraPly TPO InvisiWeld system.

C. Prepare Surfaces

1. Acceptable substrates to receive the UltraPly TPO InvisiWeld system must be properly prepared before membrane installation. The surface(s) must be relatively even, clean, dry, smooth, and free of sharp edges, fins, loose or foreign materials, oil, grease, and other materials that may damage the membrane. Rough surfaces that could damage the membrane must be overlaid with acceptable insulation.

D. Fill Voids

1. All surface voids of the immediate substrate to receive UltraPly TPO InvisiWeld system greater than ¼" (6 mm) wide must be filled with insulation or other approved filler.

E. Vapor Retarder

1. Install vapor retarder as specified by the project designer.

2.04 WOOD NAILER LOCATION AND INSTALLATION

Wood nailers shall be installed as specified by the project designer or as noted in Firestone details and the system design guide. Install wood nailers as follows:

A. Chemical Treated Wood Nailers

1. Chemical treating for fire resistance or other purposes (other than pressure treating for rot resistance, i.e. CCA, ACZA, CBA, ACQ or other copper treatments) may affect the performance of the Firestone membrane and accessories. Submit MSDS sheets with active ingredients listed for any chemically treated lumber not listed that will contact the membrane. Contact your Roof Systems Advisor to evaluate compatibility.

B. Position Wood Nailer

1. Total wood nailer height must match the total thickness of roof insulation installed, with a 1/8" (3 mm) gap between each nailer length and at each nailer intersection.

C. Secure Wood Nailer

1. Wood nailers shall be firmly fastened to the deck or building. Mechanically fasten wood nailers to resist a minimum 200 lb (890 N) force in any direction typically 12" (305 mm) on center. Refer to attachment requirements as specified by the project designer.

D. Taper Wood Nailer

1. The wood nailer shall be tapered (as required) so the top surface of the wood nailer abutting the insulation matches the height of the insulation.

E. Size of Wood Nailer

1. All wood nailers shall extend into the field of the roof a minimum of ½" (13 mm) beyond any metal edged detail.

F. Wood Nailer by Others

1. Make these specifications and details available when others will install nailers. Work that compromises the integrity of the system may jeopardize the warranty.
Note: Because of recent EPA regulations regarding treated wood, new treatments for lumber may be highly corrosive to fasteners. Contact the fastener manufacturer for recommendations on fasteners if attaching nailers that have been treated with corrosive materials.

2.05 INSULATION ATTACHMENT

A. Install Insulation

1. Install only as much Firestone insulation as can be covered with roofing membrane and completed/made watertight before the end of the day's work and before the onset of inclement weather.

B. Fit Insulation

1. Neatly fit insulation at all penetrations, projections, and nailers. Insulation should

fit loosely, filling any gaps greater than ¼" (6 mm) with acceptable insulation or filler. Edges of insulation boards running parallel with the deck should be fully supported by the deck's top flange. Under no circumstance should the membrane be left unsupported over a space greater than ¼" (6 mm). Tapered insulation with acceptable facer for bonding must be installed around roof drains to provide proper slope for drainage as shown in Firestone details.

C. Stagger Insulation Joints

1. When installing multiple layers of insulation, all joints should be staggered. Staggering of insulation joints is not required to receive a Firestone warranty.

2.06 MECHANICAL ATTACHMENT OF INSULATION

A. Insulation Installation

1. The insulation shall be attached to decking before installation of UltraPly TPO InvisiWeld Membrane System. This can be accomplished by the mechanical attachment of the insulation using an approved Firestone fastener and the InvisiWeld insulation attachment plate (as shown in Detail UT-IW-1). Refer to Firestone's Technical Information Sheet #1111 for product data and application data on the InvisiWeld plate. The fastener type and density is dependant on the deck type, wind uplift design requirements and the manufacturer's recommendations.

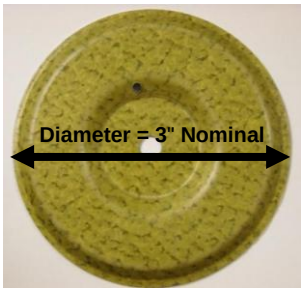


Figure 2.
Firestone UltraPly TPO InvisiWeld Plate

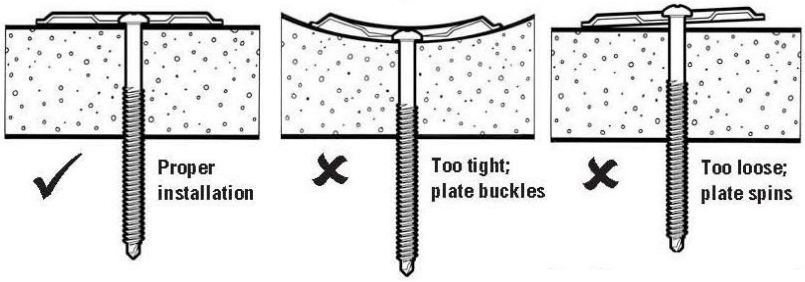


Figure 3. Proper Installation of Plate

B. Caution

1. Special care should be taken when fastening plates, so as not to overdrive or under-drive the fasteners into the structural deck (as illustrated in Figure 3). Overdriving the fasteners will result in a deformation or "cupping" of the plate and will result in an uneven or inadequate bond to the membrane, when welded. Under-driving the fastener will result in a loose plate with insufficient clamping force and a protruding fastener head that could cause damage to the membrane during welding and through normal roof traffic.

C. Mechanical Attachment

1. Attach Firestone approved insulation using Firestone InvisiWeld Insulation plates and Firestone approved fasteners as follows:
   a) Refer to InvisiWeld Insulation attachment patterns, as shown in Detail # UT-IW-1 for the specific attachment pattern and fastening rates. Refer also to specific code requirement for project fastening requirements.

b) Refer to Technical Information Sheet of fastener selected for attachment to determine deck penetration requirements as shown in the cross section on Detail UT-IW-2.
c) When installing a multilayer insulation assembly, the fastening pattern is determined by the type and thickness of the top layer of insulation.
d) Ensure that the fasteners are fully seated, but not overdriven. Overdriven fasteners will "cup" insulation plates, reducing their effectiveness.
e) Multiple layers of insulation may be installed using a common fastener. Fasteners should be sized to accommodate the total thickness of insulation plus any require substrate penetration.
Note: When attaching insulation or cover board using the InvisiWeld plates and approved fasteners, follow a straight line, linear pattern or grid pattern as shown in Detail UT-IW-1 for the specified fastening pattern. This allows the plates below the membrane to be located easily, making for an easier and faster installation. Also, with a grid pattern, it is much easier to inspect the condition of the welded plate and account for the number of plates welded.

2.07 FACTORY MUTUAL (FM) REQUIREMENTS FOR INSULATION ATTACHMENT

A. For specific reference to the FM requirements for the InvisiWeld system, refer to FM Global Property Loss Prevention Data Sheets 1-29, Section 2.2.7.2.1 for the prescriptive enhanced fastening rates for corner and perimeter areas, as required for the FM insured building.

B. Generally, for a point attached system, increased fastening density is obtained by decreasing the spacing between fastener points in one or both directions. Ensure that the total tributary area to each fastener is no more than 60% and 40% in the perimeter and corners, respectively, of the FM Approved roof field spacing.

C. Table 1 below illustrates the InvisiWeld fastener densities required to meet typical FM requirements for the field, perimeter and corner fastening of the roof system. Layouts for the fastening patterns are shown in Detail UT-IW-1.

FM Rating (psf)	Attachment per 4' x 8' (1.2 x 2.4 m) Insulation Board		
	Field	Perimeter	Corner
90	6	10	16
120	8	14	20
150	12	20	30

Table 1. FM Approvals for field, perimeter and corner prescriptive enhancements for insulation attachment - InvisiWeld System

2.08 USE OF AIR OR VAPOR BARRIER WITH INVISIWELD SYSTEM

When an approved air or vapor barrier is used in conjunction with the Firestone UltraPly TPO InvisiWeld system, give special attention to the number of fasteners used in the system to secure the insulation. At a minimum, the fastener density for attaching insulation boards in systems with an air/vapor barrier is 1 per 4 ft^2 (1 per 0.4 m^2), or 8 per 4' x 8' board (8 per 1.2 x 2.4 m board). Since the wind load on the insulation board will be greater when an air/vapor barrier is used, the prescriptive perimeter and corner enhancements will follow those of fully adhered systems with the same number of fasteners per unit area, but arranged in straight linear fashion (see Detail UT-IW-1).

Table 2. Minimum Fastening Requirements for InvisiWeld™ System with Air/Vapor Barrier			
Insulation Thickness	**Attachment per 4' x 8' (1.2 x 2.4 m) Insulation Board**		
	Field	**Perimeter**	**Corner**
0.5" to 1.4" (12.7 to 33.6 mm)	16	16	16
1.5" to 1.9" (38.1 to 48.3 mm)	12	12	12
2" or greater (50.8 mm or greater)	8	8	8

Table 2. Minimum Fastening Requirements for field, perimeter and corner areas using the prescriptive enhancements for insulation attachment – InvisiWeld System with air/vapor barrier (Refer to Firestone's TPO Single Ply Design Guide – Table 1.08-6 or FM Approvals LPDS 1-29 Section 2.2.2.2)

2.09 ULTRAPLY TPO OR REFLEXEON TPO MEMBRANE ATTACHMENT

A. Beginning at low point of roof, place membrane without stretching over substrate and allow to relax at least 30 minutes before attachment or splicing. In colder weather allow for longer relax time.

B. Lay out the membrane panels so that field and flashing splices are positioned to shed water. Seam overlaps may be placed over InvisiWeld plate. Welding of the plate will not be affected. Seaming of the overlap seam may be affect due to the robotic welded tracking over the plate.

C. Install membrane without wrinkles and without gaps or fish-mouths in seams; bond and test seams and laps in accordance with membrane manufacturer's instructions and details.

D. Welding equipment shall be provided by others but approved for use by Firestone Building Products for use with the UltraPly TPO membrane. All roofing contractors intending to use the equipment shall have successfully completed a training course provided by a Firestone Building Products Technical Service Representative prior to welding.

E. Perform a tool calibration with induction welding tool by making test welds with the UltraPly TPO membrane and InvisiWeld plate. Weld some spare membrane to the plates at various energy settings of the induction welder. Perform a peel test at the different energy settings. Then set the device at the lowest energy setting that creates a bond that covers 100% of the bonding area of the InvisiWeld plate.

F. All membrane to be welded shall be clean and dry.

G. Follow induction tool manufacturer's printed guidelines. Activate the weld between the UltraPly TPO membrane and InvisiWeld plate using the electromagnetic induction device as supplied by others. The induction coil, demarked by a red circle on the device, must be positioned over the center of the InvisiWeld plate, ± 1" (25 mm). Cycle time will be affected by available power. Use at least a 12 gauge, heavy gauge power cord, no more than 100' (30.5 m) in length.

H. When the induction welding cycle is complete, immediately place a magnetic cooling clamp over the welded UltraPly TPO membrane and plate assembly. This will ensure that there is adequate clamping of the membrane to the plate during cooling, affecting a proper weld. The magnetic cooling clamp device must be left in place for

at least 60 seconds while the weld cools and sets.

I. Repeat steps G and H for every InvisiWeld plate in assembly.

J. The bottom of the induction welder and the magnetic clamps must be kept clean to prevent scarring of the UltraPly TPO membrane. These surfaces should be wiped clean of debris frequently.

K. Continuous welding operations will cause the temperature of the magnetic clamps to rise. Should the temperature build up to the point that surface melting of the TPO membrane becomes visually evident, cool the magnetic clamps by dipping them into a pail of clean water as often as required in order to avoid damaging the membrane.

L. Secure membrane at all locations where membrane terminates at a roof edge using mechanically fastened reinforced perimeter fastening strips, InvisiWeld Plates, HD plates, or metal edging as indicated or as recommended by roofing manufacturer. **InvisiWeld plates may be used for base tie-in securement. Do not use InvisiWeld plates for roof edge securement.**

2.10 MEMBRANE SEAMING

A. Clean the Lap Splice Area

1. Wearing chemical resistant gloves and using a clean white cotton rag dampened with Firestone Splice Wash (SW-100), thoroughly clean the selvage edge area of the top sheet and an area on bottom sheet at least 2 ¾" (70 mm) wide if the seam area has become contaminated with dirt, debris, moisture or other contaminates. Membrane left exposed or unwrapped for more than 12 hours must be cleaned before any welding activity.

B. Equipment and Test Splice Requirements

1. The speed of the welding machine shall be adjusted to provide proper seam strength based on ambient conditions. Adjust the wheel guide by placing unit on top of the membrane with the outer edge of the Drive/Pressure wheel in contact with the membrane edge
2. Ample power source shall be provided to heat welding equipment. A generator dedicated to the heat welding equipment shall be used on all installations. Refer to the welding and generator equipment requirements in the Technical Information Section of this manual for minimum requirements. For specifics, consult the welder manufacturer's data sheets.
3. When weather conditions vary, adjustments to the welding machine must be made. It is recommended that this be done using spare or test material before starting welding of the finished roofing material. In addition, there shall be destructive tests performed daily and at the beginning of welding and after interruptions in the welding process (such as power failure, welder shut down, job site condition change, after break or lunch). Periodically check and correct the welder settings, including at the start of each work day welding will occur.

C. Hot Air Weld Lap Splices

1. Horizontal field splices should be welded first. Wherever possible, all field splices on the horizontal surface (including flashing) should be completed using an automatic heat welder that has been designed for hot air welding of thermoplastic membranes. Refer to the welding equipment requirements in the

Technical Information Sheets for minimum requirements. For specifics, consult the welder manufacturer's data sheets.

2. Seams made with the automatic welder shall be a minimum of 1.5" (38 mm) wide. Seams made with hand welders shall be a minimum of 2.0" (50 mm) wide. Use silicone hand rollers to assure proper mating of surfaces as hand welding proceeds.
3. On vertical surface welds, or where an automatic welder is not practical, hand welders shall be used.

D. Seam Inspection

1. Probe all completed welds with a dull cotter pin puller type tool to verify seam integrity. Do not probe welds until they have cooled. Any welds found to be insufficiently fused need to be repaired on a daily basis.

E. T-Joint Patches

1. T-joint patches shall be installed at all intersections of field seams when membrane is greater than 0.045" (1.14 mm). Membrane to receive T-joint cover shall have the edged eased by heating and rolling to minimize any step-down. Refer to Lap Splice and T-Joint Detail Section of Firestone's Technical Manual.

F. Cut Edge Sealant

1. All membrane lap edges with exposed scrim (cut edges) shall be sealed with Firestone UltraPly TPO Cut Edge Sealant or UltraPly TPO General Purpose Sealant.

2.11 ADDITIONAL MEMBRANE SECUREMENT AND BASE TIE-IN FLASHING

A. Provide membrane securement

1. Secure the membrane at all locations where the membrane undergoes an angle change greater than 1" in 12" (25 mm in 305 mm). This typically occurs at roof edges, curbs, wall intersections, parapets, etc. InvisiWeld plates may be used as a mechanical base tie-in. The InvisiWeld plate outside edge must be 1" (25 mm) away from the transition and spaced 12" (305 mm) o.c. Base tie-in may also be achieved using Firestone HD Seam Plates and Firestone Fasteners applied either horizontally into the deck or vertically into the wall in accordance with Firestone Base Tie-In Details. Refer to the Firestone System Design Guide or Firestone Technical Information Sheets to determine the applicable fastener and penetration requirements for specific substrate conditions.

2.12 FLASHING-PENETRATIONS

A. General

1. Remove all loose existing flashing (i.e., lead flashings, bituminous materials, mastics, etc.).
2. Flash all penetrations that pass through the UltraPly TPO or ReflexEON TPO membrane in accordance with Firestone standard TPO details as indicated in the Technical Information Manual.
3. The flashing seal must be made directly to the penetration.

B. Pipes, Round Supports, Structural Steel Tubing, etc.

1. Flash pipes with Firestone UltraPly TPO Pre-molded Pipe Flashing where practical.
2. Refer to the Firestone Technical Information Sheet for minimum and maximum pipe diameters that can be successfully flashed with Firestone UltraPly TPO Pre-Molded Pipe Flashings.
3. Flash inside and outside corners with Firestone pre-molded products per Firestone details
4. Firestone UltraPly TPO Unsupported Flashing is only to be used at non 90 degree inside and outside corners, “T” joints, and field wrapped pipe boots and other special conditions where allowed by Firestone details.

C. Roof Drains (cast iron only)

1. Remove all existing flashing (including lead flashing), roofing materials and cement from the existing drain in preparation for UltraPly TPO membrane and Firestone Water Block Seal.
2. Provide a clean, even finish on the mating surfaces between the clamping ring and the drain bowl.
3. Install tapered insulation with acceptable bonding surfaces around the drain to provide a smooth transition from the roof surface to the drain. Slope into drain shall not exceed 1” in 12” (25 mm in 300 mm).
4. Position the UltraPly TPO membrane, then cut a hole for the roof drain to allow a ½" (13 mm) minimum and ¾" (19 mm) maximum inside the clamping ring.
5. Using a punch or other suitable device, make round holes (sized to receive clamping bolts) in the membrane to align with clamping bolts. Do not cut the membrane back to the bolt holes.
6. Install Firestone Water Block Seal on the clamping ring seat flange below the membrane. Use a minimum of one half of a 10-ounce (295 CC) tube for a 10" (250 mm) drain.
7. Install the roof drain clamping ring and clamping bolts. Tighten the clamping bolts to achieve constant compression of the Water Block Seal.

D. Pipe Clusters and Unusual Shaped Penetrations

1. Fabricate Firestone UltraPly TPO Coated metal penetration pockets to allow a minimum clearance of 1" (25 mm) between the penetrations and all sides of the pocket.
2. Secure Firestone QuickSeam or weldable penetration pockets, and flash per current Firestone details.
3. Fill penetration pockets with Firestone Pourable Sealer to shed water from penetrations. Firestone Pourable Sealer shall be poured to a depth of 2" (50 mm) minimum.
4. Firestone UltraPly TPO unsupported flashing may also be used for some details.

E. “Hot” Pipes (Greater than 160 °F [60 °C])

1. Protect UltraPly TPO components from direct contact with steam or heat sources that exceed the in-service temperature of 160 °F (71 °C).
2. Pipes and roof penetrations exceeding 160 °F (71 °C) shall be flashed to an intermediate, or separator, sleeve to protect UltraPly TPO components from these direct heat sources.

F. Flexible Penetrations

1. Flexible roof penetrations shall be flashed by means of a watertight

"gooseneck".
2. Watertight "gooseneck" shall be set in Water-block Seal, secured to deck, and flashed in accordance with Firestone Details.

G. Scuppers

1. Remove any existing scuppers, and install a new scupper sleeve fabricated from Firestone UltraPly TPO coated metal.
2. Secure new scupper to the structure.
3. Flash new scupper in accordance with Firestone Details.

H. Expansion Joints

1. Install expansion joints in accordance with Firestone details where specified by project designer.
2. Flash expansion joints in accordance with Firestone details.

2.13 FLASHINGS: WALLS, PARAPETS, MECHANICAL EQUIPMENT CURBS, ETC.

A. General

1. Using the largest piece(s) of continuous Firestone UltraPly TPO membrane practical, flash all walls, parapets, curbs, etc, to the height of an 8" (203 mm) minimum.

B. Evaluate bonding substrate. Add acceptable bonding substrate as required.

1. The following substrates require the installation of ⅝" (16 mm) exterior grade or "Wolmanized" plywood, anchored in accordance with project designer's requirements: interior gypsum board, stucco, cobblestone, textured masonry, exterior gypsum panels, corrugated metal panels, and all other uneven or loose substrates.

C. Curb and Base Flashing with UltraPly TPO Membrane

1. Apply UltraPly Bonding Adhesive, Firestone Water-based Bonding Adhesive, or Bonding Adhesive at about the same time to both the membrane flashing and the surface to receive the flashing at about the same time to allow approximately the same drying time.

   NOTE: When using UltraPly TPO Membrane as flashing and UltraPly TPO Bonding Adhesive or Water-Based Bonding Adhesive, the adhesive must be applied to both the flashing and the curb as a contact adhesive.
2. Apply Firestone's UltraPly or Water-based Bonding Adhesive by rolling the adhesive on the mating surfaces evenly, avoiding puddles or globs, at the specified coverage rate. Refer to the Technical Information Sheets for the specific adhesive.
3. Allow flash off period for bonding adhesive.
4. Test bonding adhesive for readiness. Touch the bonding adhesive surface with a clean, dry finger to be certain that the adhesive does not stick or string. As you are touching the adhesive, push straight down to check for stringing, and push forward on the adhesive at an angle to ensure that the adhesive is ready throughout its thickness. If either motion exposes wet or stringy adhesive when the finger is lifted, then the adhesive is not ready for bonding. Flash off time will vary depending on ambient air conditions. This is especially true for water-based adhesives. Firestone Water-based Bonding Adhesive will change appearance

from opaque to nearly transparent, indicating it is ready for bonding. Coverage rate will differ with varying substrates and ambient conditions.

5. Once bonding adhesive has properly flashed off, evenly roll the membrane flashing up the vertical substrate, and take care to avoid wrinkles.
6. Broom the membrane flashing after bonding, using a stiff push broom to ensure proper contact and bonding.
7. Complete the splice between the membrane base flashing and the main roof UltraPly TPO or ReflexEON TPO membrane by hot air welding. Complete lap splices in accordance with Firestone details.
8. Install termination of base flashing in accordance with Firestone details.
9. Install intermediate attachment over membrane flashing 36" (914 mm) o.c. in accordance with Firestone Details.
   a) Intermediate attachment may be eliminated if:

      Wall surface is smooth without noticeable high spots or depressions, such as plywood, poured or pre-cast concrete, hollow core block or masonry walls where mortar joints are flush with masonry surface.

      And:

      The termination of membrane flashing is a Termination Bar or membrane flashing extending completely under coping to the outside wall to the outside face edge.

2.14 FLASHING - GRAVEL STOPS OR ROOF EDGE METALS

Use Firestone prefabricated Coping, AnchorGard, EdgeGard or other product as indicated. Install in accordance with Firestone details.

A. Use UltraPly TPO Coated Metal per Firestone details.

   1. When using UltraPly TPO Coated Metal, a perimeter UltraPly TPO or ReflexEON TPO sheet must be placed parallel to metal edge with selvage edge positioned to weld to the edge metal.
   2. Coated metal edge detail must provide enough room to permit T-joint cover or strip-in of details with sufficient width wood nailer for support.

B. Use other metals formed as needed for special conditions and flashed using TPO QuickSeam Flashing.

   1. Install gravel stop metal as specified by project designer. Flange of gravel stop metal shall be flashed using TPO QuickSeam Flashing. Maximum warranty length for this detail is 20 years.
   2. Apply Firestone TPO QuickPrime Plus to flange of gravel stop/edge metal with QuickScrubber or QuickScrubber Plus pad and handle with long back and forth strokes with heavy pressure on splicing area. Stir the TPO QuickPrime Plus before and during use. Dip the Firestone QuickScrubber or QuickScrubber Plus pad into TPO QuickPrime Plus, keeping the pad flat. Change pads every 200' (61 m) or when pad no longer holds the proper amount of TPO QuickPrime Plus.
   3. Allow a brief flash off time – usually less than 10 minutes – for the TPO QuickPrime Plus before applying TPO QuickSeam Flashing.
   4. Install TPO QuickSeam Flashing, centered over the flange edge of the gravel stop/edge metal. Using a silicone coated rubber roller, roll the TPO QuickSeam Flashing immediately after installation of TPO QuickSeam Flashing.

2.15 MEMBRANE REPAIR

A. Repair punctures/cuts/damage to UltraPly TPO or ReflexEON TPO membrane.

1. The repair material shall be heat welded UltraPly TPO or ReflexEON TPO membrane and extend 2" (50.8 mm) minimum past the damaged area in all directions. Round all corners of the repair piece. For example a pinhole will require a minimum 4" x 4" (102 mm x 102 mm) patch.

B. Inspect the plates.

1. At each InvisiWeld bonded plate location, the condition of the plate bonded or attached membrane should be inspected for membrane abrasion at the plate peripheral edges, and for any debris, or holes in the membrane over the plate. In the event that any abrasion or membrane damage is found, the entire area must be patched with a 4" x 4" (102 mm x 102 mm) T-Joint patch that covers the plate area completely. UltraPly QuickSeam™ T-joint covers may also be used.

Note: For inspection purposes, Firestone recommends the use of a bathroom plunger to inspect the individual InvisiWeld plate welds. By applying the rubber end of a plunger to the membrane adjacent to the welded InvisiWeld plate and pulling upwards, the condition of the weld can be assessed This is a good tool to ensure that no InvisiWeld plate welds were missed during roofing.

C. Clean the membrane

1. When making a repair to UltraPly TPO or ReflexEON TPO membrane that has been in service for some time, it is necessary to remove accumulated field dirt. Scrub the membrane with a scrub brush and warm soapy water, followed by rinsing with clean water, and wipe with clean cotton rags. For membrane with significant accumulation of dirt, cleaning with acetone and clean cotton cloths may be required. Firestone Splice Wash SW-100 may then be used.

D. Install splice per splicing procedures.

2.16 TEMPORARY CLOSURE

A. Temporary closures to ensure that moisture does not damage any completed section of the new roofing system are the responsibility of the roofing contractor. This is not covered under any Firestone warranty.

B. Completion of flashings, terminations, and temporary closures should be completed as required to provide a watertight condition.

C. Any material contaminated by temporary closure shall be removed and discarded before resumption of installation.

D. See V-Force™ Membrane Technical Information Sheet for further information.

2.17 ROOF WALKWAYS

A. Install walkways in locations as specified by the project designer in accordance with Firestone requirements.

B. Walkways shall consist of 30" (762 mm) wide Firestone UltraPly TPO Walkway Pad.

C. Heat weld the edges of the walkway material to the UltraPly TPO or ReflexEON membrane using the welding procedures in Section 2.09.

2.18 SHEET METAL WORK

A. For specific installation instructions for the Firestone prefabricated metal edge treatments: Firestone Coping, AnchorGard, EdgeGard or UltraPly TPO Coated Metal or System, refer to the respective Technical Information Sheet.

B. For all other sheet metal work not supplied by Firestone, refer to fabrication and installation requirements established by the project designer.

2.19 CLEAN UP

A. If cleaning is required, the UltraPly TPO or ReflexEON TPO membrane may be cleaned by gently scrubbing with soapy non-abrasive soap and water followed by rinsing the area completely with clean water.

B. Firestone Splice Wash SW-100 may also be used sparingly with clean cotton cloths to clean the membrane.

2.20 FIRESTONE ULTRAPLY TPO INVISIWELD SYSTEM RECOVER OVER METAL BUILDING

A. Metal Building Recover – Substrate Preparation

1. A dry, clean and smooth substrate shall be prepared to receive the Firestone UltraPly TPO InvisiWeld system.
2. The applicator shall inspect the substrate for defects, such as excessive surface roughness, contamination, structural inadequacy, or any other condition that may adversely affect the quality of work.
3. The substrate shall be clean, smooth, dry, and free of flaws, sharp edges, loose and foreign material, oil and grease. Roofing shall not start until all defects have been corrected.
4. All roof surfaces shall be free of water, ice and snow.
5. Compressible fill material or spray, expanding urethane foam shall be used to minimize air infiltration under wood nailers for corrugated metal roof panels.
6. The Firestone UltraPly TPO InvisiWeld system shall be applied over compatible or acceptable substrates only.

2.21 INVISIWELD METAL BUILDING RECOVER – INSULATION ATTACHMENT TO PURLINS

A. Approved Insulation fill material, with a minimum compressive strength of 20 psi (140 kPa) must be inserted in the existing metal standing seam roof panel to provide a level substrate for installation of the approved cover board or insulation boards, as shown in Detail UT-IW-2. The fill layer must be cut to fit inside the metal panel seam and secured in place to fit flush with the top of the standing seam. Note: For Factory Mutual insured buildings, polystyrene insulation may not be applied directly to steel deck.

B. Insulation shall be installed according to insulation manufacturer's instructions.

C. Top layer of insulation shall be the membrane underlayment or substrate, cover board or any other approved Firestone insulation product. Edges shall be butted together with no gaps greater than ¼" (6 mm).

D. Insulation shall be neatly cut to fit around penetrations and projections with gaps not exceeding ¼" (6 mm).
E. If applicable, install tapered insulation around drains to create a drain sump.
F. Do not install more insulation board than can be covered with Firestone TPO membrane by the end of the day or the onset of inclement weather.
G. Use at least 2 layers of insulation when the total insulation thickness for the overlayment exceeds 2.5" (64 mm). Stagger joints at least 12" (300 mm) between layers.
H. Mechanical Attachment – General
    1. Insulation shall be mechanically fastened to the purlins with Firestone Purlin fasteners or to the structural deck with approved Firestone fasteners and InvisiWeld plates. Attachment rate shall be according to Firestone Building Product's and FM (if insured by FM) recommendations for fastening rates and patterns for the InvisiWeld system into metal purlins (see table 3), but not less than 1 fastener per 6.4 ft^2 (0.6 m^2) or 5 fasteners per 4' x 8' (1.2 x 2.4 m) board. The quantity and locations of the fasteners and plates shall also cause the insulation boards to rest evenly on the roof deck/substrate. Each insulation board shall be installed tightly against the adjacent boards on all sides. With purlin attached system, use the standard Firestone or HD fasteners and Firestone 3" Insulation plate to ensure each board of insulation has at least 5 fasteners, one in each corner and one at the board mid center point. The grid attached systems are adequate for the insulation attachment. No additional insulation fastening is required.
    2. Fasteners are to be installed consistently in accordance with fastener manufacturer's recommendations. Fasteners are to have minimum penetration of 1" (25 mm) through the structural deck.
    3. Use fastener tools with a depth locator and torque-limiting attachment as recommended or supplied by fastener manufacturer to ensure proper installation.

2.22 INVISIWELD METAL BUILDING RECOVER – ATTACHMENT TO PURLINS

Fasten the insulation so the InvisiWeld plate and Firestone Purlin fastener will be centered over the structural purlin at a density according to Firestone's and the wind design requirements. Fasteners must tight enough that the InvisiWeld plate does not turn, but not so tight as to deform the InvisiWeld plate.

The minimum fastening requirement for the InvisiWeld metal roof recover system is at a purlin spacing of 10' (3 m) at a fastener spacing of 12" o.c. (300 mm) in the field of the roof. The minimum fastening for the perimeter and corner areas is at a purlin spacing of 5' (1.5 m) at a fastener spacing of 6" o.c. (150 mm).

A. Perimeter and Corner Areas
    1. The perimeter and corner area will be determined by building height and width and other conditions according to ASCE 7 guidelines, Firestone's Technical or FM LPDS 1-29 if insured by Factory Mutual. To meet the perimeter and corner uplift requirements, increase the fastening density by decreasing the spacing between fasteners along each fastener row in the perimeter and corner areas. The Firestone Purlin fastener spacing shall be a maximum of 60 percent of the field spacing for the perimeter and 40 percent of the field spacing for the corner, but never closer than 3" (76 mm). See Detail UT-IW-4 for more details.
    NOTES: Perimeter area is defined as the outer boundary of the roof. If the roof is broken into different levels, each roof area shall be treated as an individual roof

with its outer boundary being treated as a perimeter. Typically, internal expansion joints and firewalls are not considered to be full perimeters. Refer to Factory Mutual's Data Sheet 1-28 for more information.

NOTES: The ridge area is defined as the high point in the roof area formed by two intersecting planes. When the sum of the slopes is a minimum of 4" in 12" (30°), each side of the ridge shall be treated as a perimeter area.

B. InvisiWeld - Membrane Attachment to Metal Panel
   1. Fastener pullout tests shall be conducted on the metal roofing deck with approved fasteners by the manufacturer of the fasteners, or the specifier/designer for the project. A minimum of 15 pullouts for up to 50,000 ft^2 (4,650 m^2) of which 8 are to be in perimeter and corner zones; and, seven additional pullouts for each additional 50,000 ft^2 (4,650 m^2) or portion thereof.
   2. Fasten the insulation so the InvisiWeld plate and Firestone purlin fastener (depending on pullout value) are installed directly into the purlin through the insulation according to Firestone's specifications and any other wind design requirements. Fasteners must be tight enough that the InvisiWeld plate does not turn, but not so tight as to deform the InvisiWeld plate.
   3. InvisiWeld recover system over metal roof – typical ridge detail – See Detail UT-IW-5.
   4. InvisiWeld recover system over metal roof – typical eave detail – See Detail UT-IW-6
   5. For any additional specific wind requirement questions for the InvisiWeld system over a metal building, please direct all questions to a Firestone Roof Systems Advisor.

2.23 WARRANTY COVERAGE

A. Acceptable Fasteners

   1. The following fasteners are acceptable for use and eligible for warranty with the Firestone UltraPly TPO InvisiWeld system:
      - All Purpose Fasteners (Max 15 yr, New Construction)
      - Heavy Duty Fasteners
      - Purlin Fasteners

B. Acceptable Roof Deck Types

   1. The following roof deck types are acceptable for use and eligible for warranty with the Firestone UltraPly TPO InvisiWeld System:
      - Steel Decks
      - Wood Decks
      - Structural Concrete Decks

C. Acceptable Roof Insulation

   1. The following roof insulation types are acceptable for use as substrates and eligible for warranty with the Firestone UltraPly TPO InvisiWeld System:
      - Firestone Polyisocyanurate insulation (ISO 95+™ GL, RESISTA™)
      - Firestone ISOGARD™ HD Cover Board
      - Firestone FiberTop wood fiber insulation
      - DensDeck® cover board
      - SECUROCK®

2.24 AVAILABLE ROOF WARRANTIES

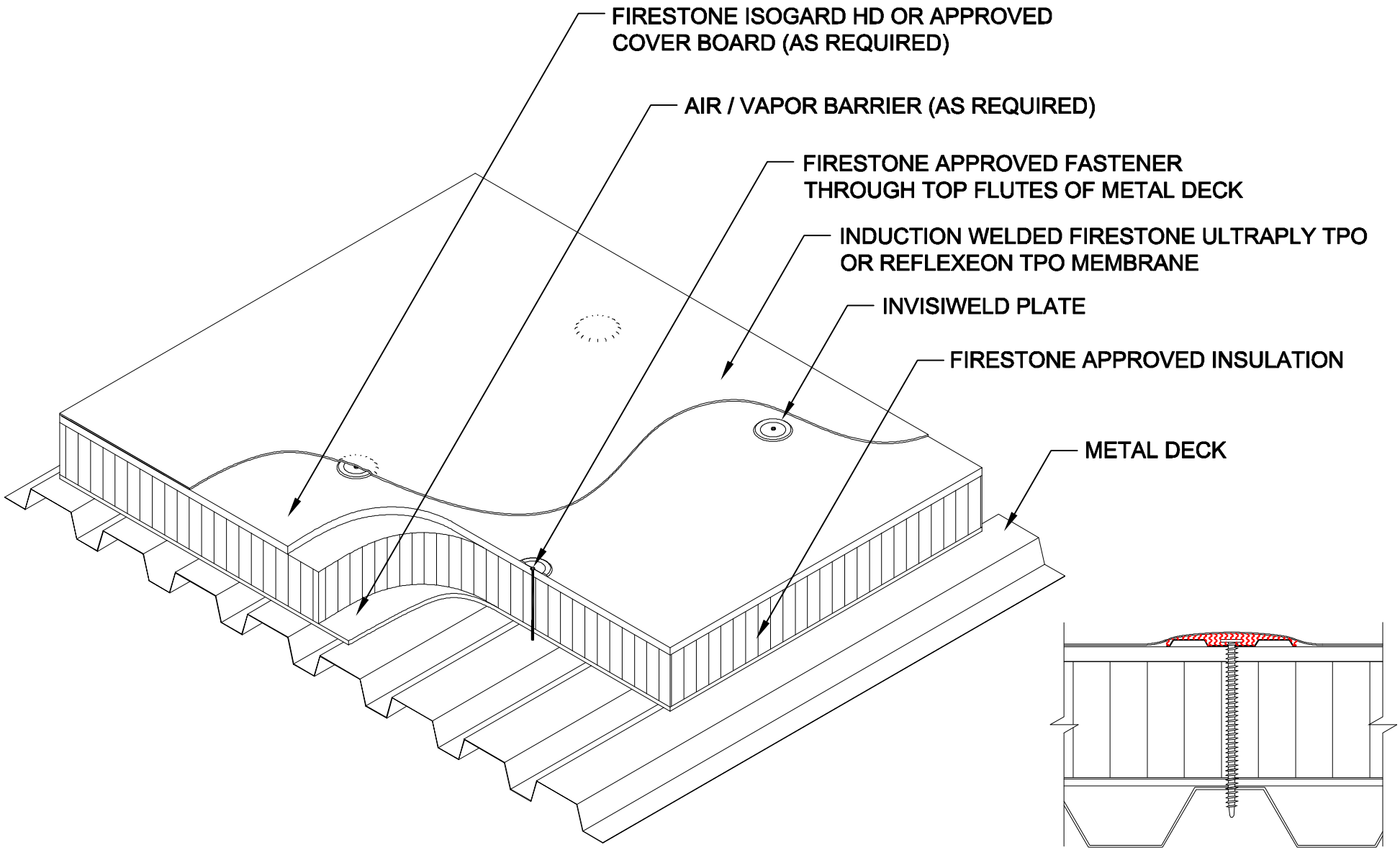
A. The following table shows the roof warranties, warranty duration, and system components available for the Firestone UltraPly TPO InvisiWeld system for new construction or re-cover applications.
B. For any specific warranty questions on the application of the Firestone UltraPly TPO InvisiWeld system, please contact a Firestone Roof Systems Advisor.

Note: Induction welding should not be used to attach membrane (with plate and induction welding tool) directly over extruded polystyrene (XPS), expanded polystyrene (EPS) or foil faced insulation boards.

Table 3. Firestone UltraPly™ TPO InvisiWeld™ System Attachment Requirements - Warranty Terms and Conditions

	Firestone Fastener	Membrane / Insulation Attachment (per 4' x 8' board)			Additional Insulation Attachment When Vapor Barrier is Used		
Red Shield™ Warranty		**F**	**P**	**C**	**F**	**P**	**C**
10 or 15 Years, New Construction	All-Purpose (AP)	6	9	12	**See Table 2**. Varies by Insulation Top Layer Thickness		
15 Years, Recover (Note 2)	Heavy Duty (HD)	6	9	12			
20 Years, (Note 2)	Heavy Duty (HD)	6	9	12			
25 and 30 Year (Note 4)	Heavy Duty (HD)	6	9	12			
15 Years with Vapor Barrier	Heavy Duty (HD)	6	9	12			
20 Years with Vapor Barrier	Heavy Duty (HD)	6	9	12			
72 mph Wind Speed Coverage	Heavy Duty (HD)	6	9	12			
80 mph Wind Speed Coverage	Heavy Duty (HD)	8	12	16			
For all Wind Speed Warranties above 80 mph, contact your Firestone Roof System Advisor at 1-800-428-4511							
FM Global		**F**	**P**	**C**	**F**	**P**	**C**
FM 1-90	Heavy Duty (HD)	6	10	16	Contact Firestone Roof Systems Advisor		
FM 1-120	Heavy Duty (HD)	8	14	20			
FM 1-150	Heavy Duty (HD)	12	20	30			
Metal Building Recover		**F**	**P**	**C**	**F**	**P**	**C**
10, 15, or 20 Years	Membrane - Purlin Fastener	12.0" o.c.	6.0" o.c.	6.0" o.c.	N/A		
	Insulation - Heavy Duty (HD)	N/A			5	5	5
Note: Membrane must be attached to InvisiWeld plates that are installed directly into purlins with Firestone purlin fasteners, at a maximum of 10' o.c. in the field and 5' o.c. for perimeter and corners purlin spacing.							

Note(s):
1. Refer to Firestone Detail UT-IW-7 for fastening patterns
2. For 15 year warranties, membrane must be 0.045" or greater, and for 20 year warranties, membrane must be 0.060" or 0.080" (1.52 or 2.03 mm) thickness.
3. F = Field; P = Perimeter; C = Corner
4. 0.080" (2.03 mm) UltraPly TPO membrane must be used for 25 and 30 year warranties.



MAXIMUM WARRANTY: **20 YEARS**

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FIRSTONE ULTRAPLY TPO INVISIWELD ASSEMBLY

ULTRAPLY™ TPO

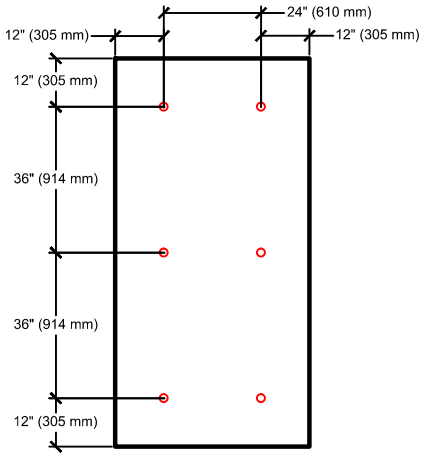
ACCEPTABLE SYSTEMS: FIRESTONE ULTRAPLY TPO INVISIWELD SYSTEM

ISSUE / REVISION DATE: 2/4/2010

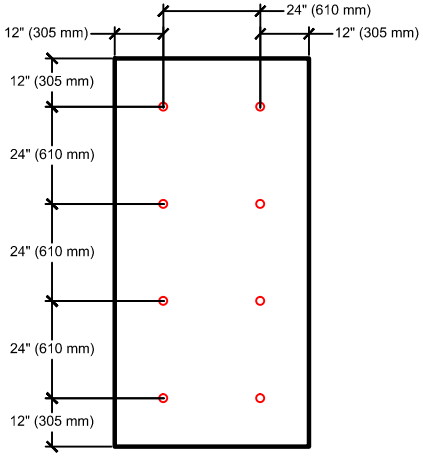
NOT TO SCALE

DETAIL NO.

UT-IW-2



6 PER 4'X8' BOARD



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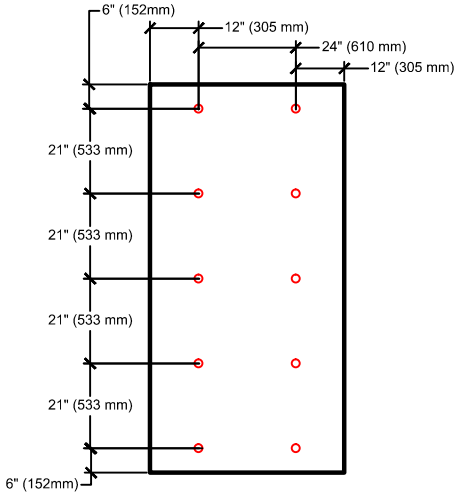

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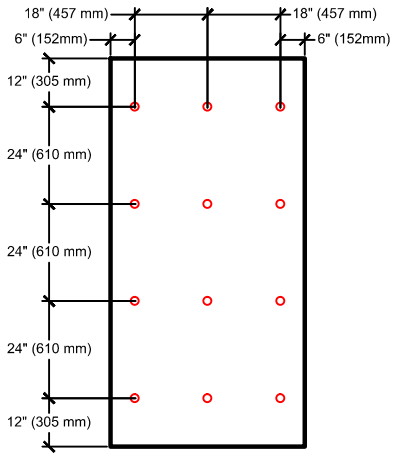

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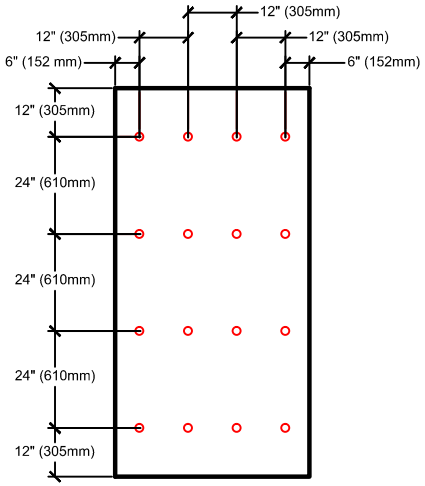
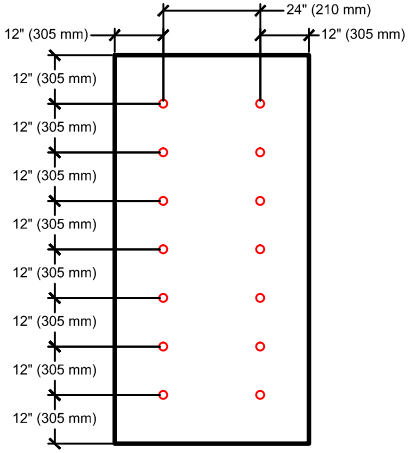
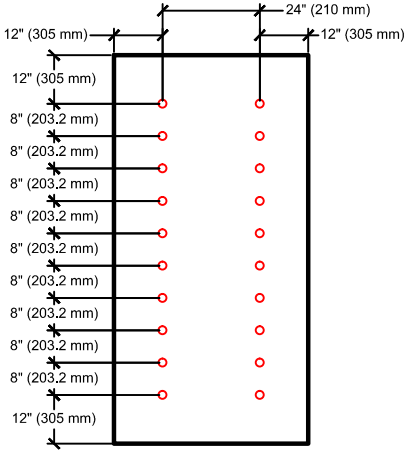


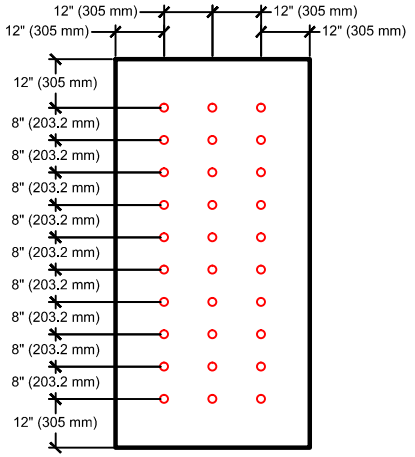
16 PER 4'X8' BOARD



14 PER 4'X8' BOARD



20 PER 4'X8' BOARD



30 PER 4'X8' BOARD

MAXIMUM WARRANTY: **20 YEARS**

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FIRESTONE ULTRAPLY TPO INVISIWELD SYSTEM INSULATION ATTACHMENT

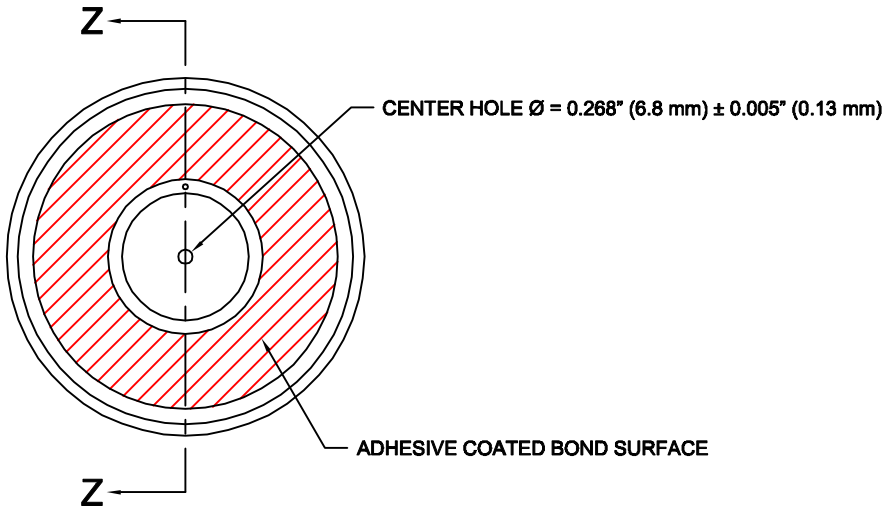
ULTRAPLY™ TPO

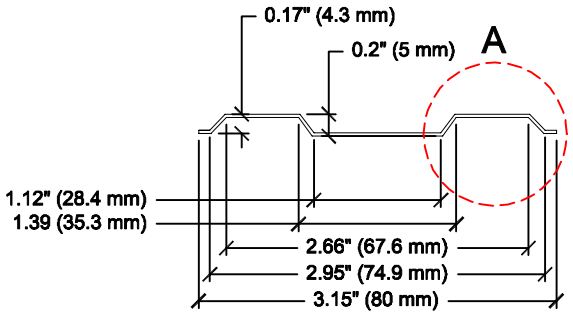
ACCEPTABLE SYSTEMS: FIRESTONE ULTRAPLY TPO INVISIWELD SYSTEM

ISSUE / REVISION DATE: 2/4/2010

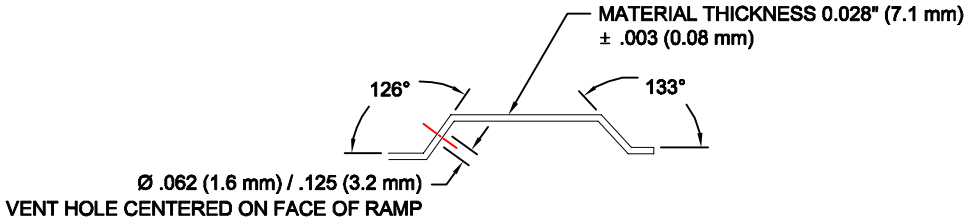
NOT TO SCALE

DETAIL NO. UT-IW-7





SECTION Z-Z



DETAIL A
SCALE 2:1

MAXIMUM WARRANTY: **20 YEARS**

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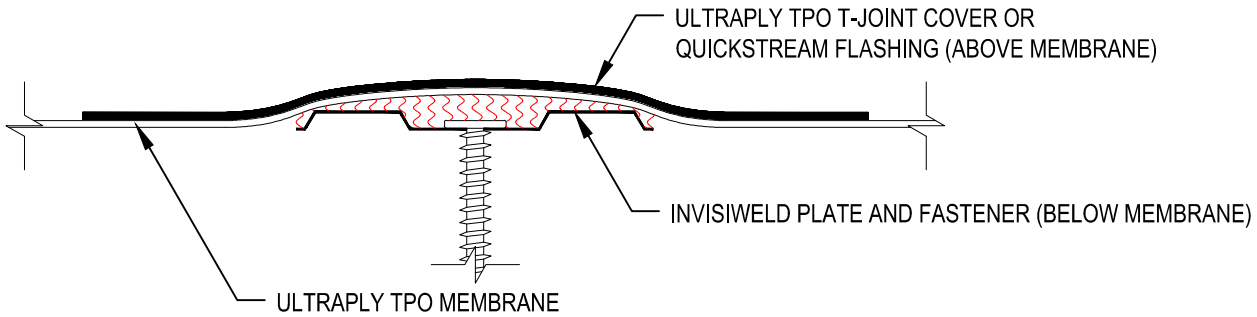
FIRESTONE ULTRAPLY TPO INVISIWELD PLATE
PART NO. W56 TPO PL04

ULTRAPLY™ TPO | ACCEPTABLE SYSTEMS: FIRESTONE ULTRAPLY TPO INVISIWELD SYSTEM

ISSUE / REVISION DATE: 2/4/2010

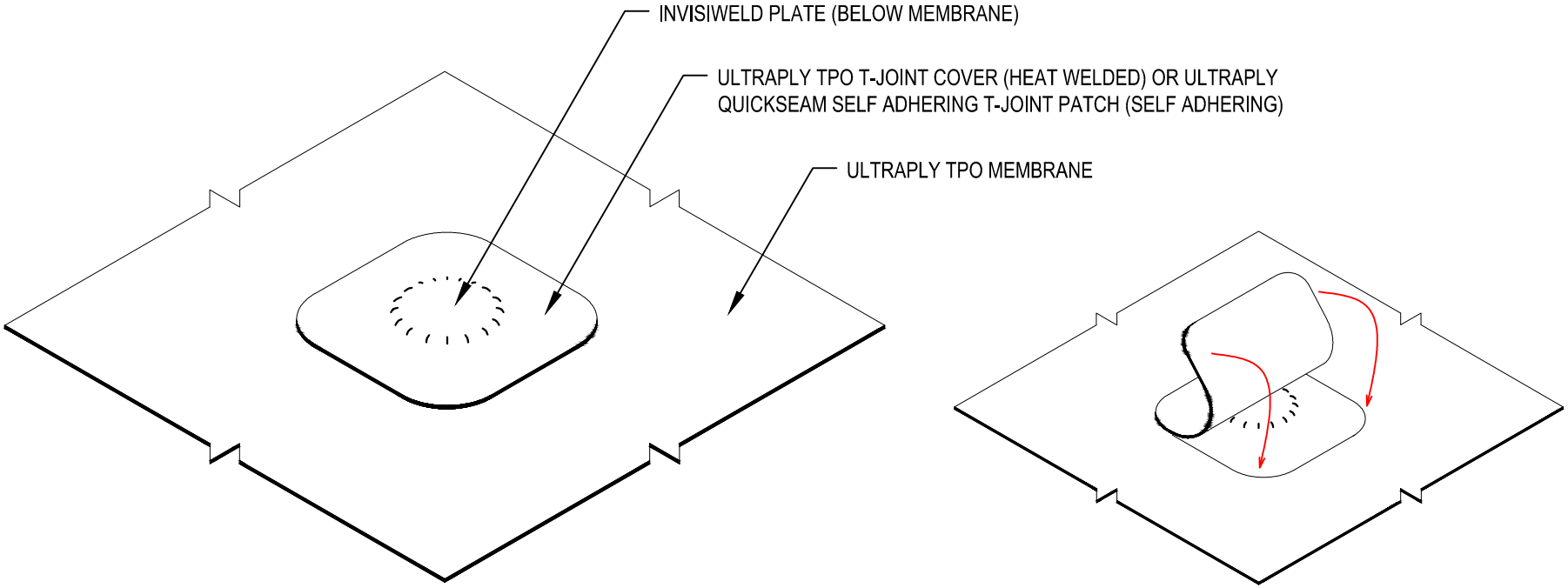
NOT TO SCALE

DETAIL NO. UT-IW-1



NOTES:

1. REFER TO FIRESTONE WEB SITE FOR MOST CURRENT INFORMATION.
2. USE TPO QUICKPRIME TO CLEAN AND PRIME TPO MATING SURFACES PRIOR TO INSTALLATION OF QUICKSEAM PRODUCTS WITH CONTINUOUS BEAD OF ULTRAPLY TPO GP SEALANT.
3. ULTRAPLY TPO FLASHING (UNSUPPORTED) (4"x4" MIN. WITH ROUNDED CORNERS) MAY BE USED IN LIEU OF T-JOINT COVER.
4. WHEN REINFORCEMENT OF TPO MEMBRANE IS EXPOSED, REFER TO UT-LS-14 FOR CUT EDGE SEALANT APPLICATION.



MAXIMUM WARRANTY: **20 YEARS**

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MEMBRANE REPAIR OVER INVISIWELD PLATE

INVISIWELD™

ACCEPTABLE SYSTEMS: ALL

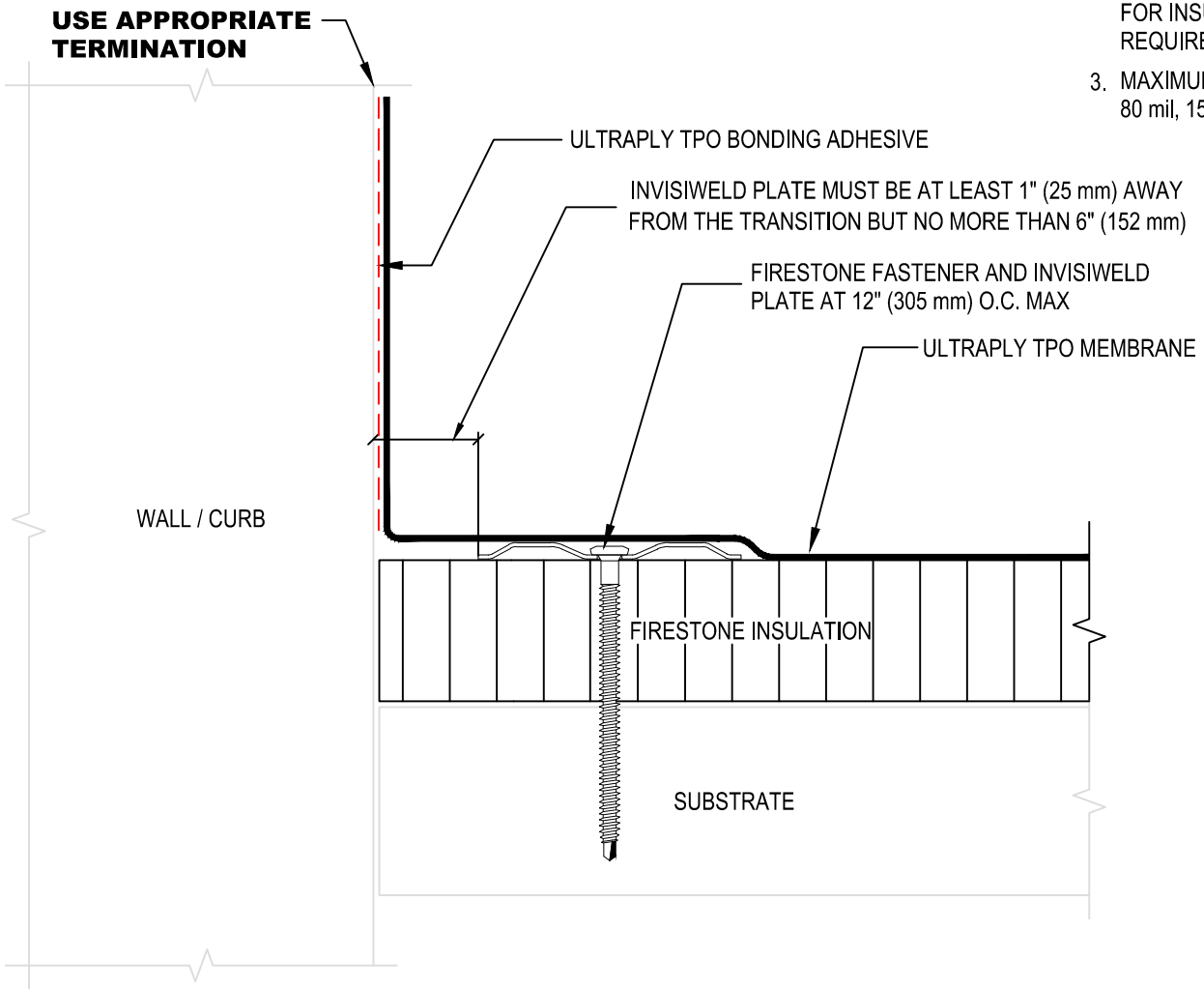
ISSUE / REVISION DATE: 2/1/2010

NOT TO SCALE

DETAIL NO. UT-IW-8

NOTES:

1. REFER TO FIRESTONE WEBSITE FOR MOST CURRENT INFORMATION.
2. MAXIMUM 6" (152 mm) LONG FASTENERS. (NOTE: WOOD BLOCKING MAY BE SUBSTITUTED FOR INSULATION TO REDUCE FASTENER LENGTH REQUIREMENT).
3. MAXIMUM WARRANTY OF 20 YEARS FOR 60 mil AND 80 mil, 15 YEARS FOR 45 mil.



MAXIMUM WARRANTY: **20 YEARS**

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BASE TIE-IN CONTINUOUS FLASHING USING INVISIWELD PLATE

INVISIWELD™ SYSTEM

ACCEPTABLE SYSTEMS: ALL

ISSUE / REVISION DATE: 9/4/2012

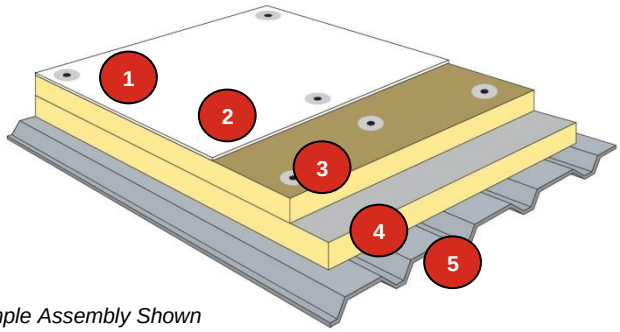
NOT TO SCALE

DETAIL NO. UT-IW-9

UltraPly™ TPO InvisiWeld™ System

Various Decks

5, 10, 15, 20 Year Red Shield™ Warranty



Sample Assembly Shown

1. Firestone UltraPly™ TPO Membrane
2. InvisiWeld™ System Attachment
3. Mechanically Attached or Adhered Cover Board (Optional)
4. Mechanically Attached Insulation
5. Steel, Structural Concrete, Wood or Metal Building Recover

Consult Firestone Technical Specifications, Guides and Details at www.firestonebpco.com

Slope Requirement
Positive slope required for warranty.[5]

Construction Type
New construction, complete tear-off, or recover with any wet or damaged materials removed prior to installation.

Building Height Limitation
Firestone UltraPly™ TPO InvisiWeld Systems are limited to buildings 120' (36.6 m) or less..

Use of Air Barrier
An air barrier is required for projects with large wall openings greater than 10% of the total wall area. If air barrier is used, use the fully adhered insulation attachment rates.

Base Tie-Ins
Must be attached to substrates which provide a minimum of 200 lbf (1 kN) in any direction.

Increased Wind Speed and Codes
Any wind speed coverage exceeding 55 mph (88 km/h) or projects with codes requirements must be reviewed by a Firestone Roof Systems Advisor.

Deck Requirement
- ❑ Minimum 22 Gauge Steel
- ❑ Minimum 3000 psi Structural Concrete
- ❑ Minimum 1/2" Plywood
- ❑ Minimum 7/16" OSB
- ❑ Metal Building Recover (MBR)

Fastener Type
- ❑ Firestone All Purpose Fastener (Steel or Wood Only)
- ❑ Firestone Heavy Duty Fastener
- ❑ Firestone Concrete Drive Fastener (Concrete Deck Only)
- ❑ Firestone Purlin Fastener (MBR Only)

Membrane Requirement
Max. 15 Year Warranty:
- ❑ UltraPly TPO, Minimum 0.045"

20 Year Warranty:
- ❑ UltraPly TPO, Minimum 0.060"

Seaming Requirement
Firestone 1.5" Single Weld System (use robot welder). Joint covers are required at all joints and at angle changes 1:12 or greater.

Seam Attachment – Metal Building Recover Only:
❑ 12” o.c. in the field using Purlin Fasteners & InvisiWeld Plates with intermediate insulation attachment and 6” o.c. in the perimeter and corners. Maximum 10’ row spacing in the field and maximum 5’ row spacing in the perimeters.

Edge Metal System
- ❑ Firestone EdgeGard™ System
- ❑ Firestone AnchorGard™ System
- ❑ Firestone Coping System
- ❑ Firestone Termination Bar
- ❑ Firestone Aluminum Drain Bar

InvisiWeld Plate Attachment Rates (Field – Perimeter – Corner)

Insulation (Top Layer)	4' x 8'	Coverboard (Optional)	4' x 8'
1.0" to 4.0" Firestone ISO 95+ GL or RESISTA Insulation	6-9-12	1/2" or 1.0" FiberTop Wood Fiber Board	6-9-12
		1/2" Firestone ISOGARD™ HD Cover Board	6-9-12
		1/4", 1/2", or 5/8" SECUROCK® or DensDeck® (Prime)	6-9-12 (6-9-12)

Detail Description

Wall Terminations:	Firestone Termination Bar with AP Sealant applied along the caulk lip. Surface mounted or inserted counter flashing may also be used in accordance with current Firestone details.
Curb & Wall Flashings:	Curbs, walls, and expansion joints must be anchored with appropriate base tie-in detail, either using seam plates and fasteners, using UltraPly QuickSeam Reinforced Perimeter Fastening (RPF) Strip and Batten Strip or 2" Metal Seam Plates, or InvisiWeld Plates and fasteners. Curbs and walls must be flashed using minimum 0.045" UltraPly TPO Membrane or UltraPly TPO 18" Curb Flashing. Flashings may be sealed with welded details or UltraPly QuickSeam products when acceptable. Details may include TPO Coated Metal.
Corners:	UltraPly TPO Inside/Outside Corners or UltraPly QuickSeam Corner Flashing.
Roof Edges/Parapets:	Firestone AnchorGard™ or EdgeGard™ Fascia or Drain Bar systems. ANSI/SPRI ES-1 rated edge metal may also be used / Firestone Coping System or UltraPly TPO Coated Metal. Do not use InvisiWeld Plates for roof edge securement.
Penetrations:	Flash with UltraPly QuickSeam or UltraPly Pipe Flashing (weldable), UltraPly TPO Penetration Pocket, or field fabricate with UltraPly TPO Unsupported Flashing.

Notes:
1. *Only Firestone brand products are covered in a Red Shield warranty.*
2. *Refer to the Firestone Technical Database at www.firestonebpco.com for additional information regarding UltraPly TPO Roof Systems.*
3. *Refer to the Firestone RoofGenuity™ tool to create roof assemblies with high-performance Firestone products at www.RoofGenuity.com.*
4. *DensDeck is a registered trademark of Georgia-Pacific Gypsum LLC.*
5. *It is the installing contractor’s responsibility to follow applicable building codes.*
6. *SECUROCK is a registered trademark of USG Corporation.*

Firestone Building Products Company, LLC
250 West 96th Street • Indianapolis, IN 46260
Technical: 1-800-428-4511 • Sales: 1-800-428-4442 • www.firestonebpco.com

Appendix B.10 – Built-Up Roof Firestone Literature

FIRESTONE BUILT-UP ROOFING SYSTEMS
APPLICATION GUIDE
3/14/2011

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2.01.1 GENERAL

This Guide provides instructions for the installation of Firestone's BUR Roof Systems. Reference to the Design Guide, Technical Information Sheets (T.I.S.), and other sections of Firestone's Technical Documents is necessary to ensure that the finished roof system is installed in compliance with Firestone requirements. Extended warranties may require special considerations with regards to fasteners, insulations, flashing, and attachment requirements. Refer to the System Design Guide of this Technical Manual for specific requirements.

NOTE: If a proposed application falls outside this Guide contact your Coordinator at 800-428-5411 for additional information.

2.02.1 JOB SITE CONSIDERATIONS (CAUTION AND WARNINGS)

A. Keep all adhesives, sealants and cleaning materials away from all ignition sources. Do not smoke while using these materials.
B. Consult container labels, Material Safety Data Sheets and Technical Information Sheets for specific safety instructions for all products used on the project.
C. Care must be used when installing fasteners to avoid possible conduits and other piping in and under the deck.
D. Fumes from adhesive solvents may be drawn into the building during installation through rooftop intakes. Refer to Firestone's Technical Information Sheet "Recommended Guidelines for Application of Roofing Materials to an Occupied Building".
E. Store Firestone ply sheet rolls on end to protect them from becoming damaged. Do not stack B.U.R. rolls.
F. Insulation must be properly stored and protected from ignition sources, moisture and damage.
G. Cold weather:
1. When the outside temperature is below 40 °F (4.4 °C), certain combinations of temperature and humidity may cause condensation on the surface of solvent-based adhesives and primers. If this condition occurs, discontinue the application. When the ambient air conditions no longer cause condensation on adhesive surfaces, re-apply additional adhesive or primer and proceed.
2. The consistency of sealants, adhesives and primers will begin to thicken as the temperature drops and membrane will become stiff. To minimize this, the following is recommended:
   a. Start work with sealants, adhesives, and primers that have been stored between 60 °F (15.5 °C) and 80 °F (26.7 °C). Insulated heated boxes may be helpful.
   b. Complete test areas to determine if conditions will cause problems such as condensation with the application of the material.
   c. Stop the operation or change to another warm container when material becomes too thick or stiff to properly apply.
3. Do not use heat guns or open flames to dry adhesives and primers.

H. Follow all OSHA and NRCA provisions for fire protection.

2.03.1 ROOF SUBSTRATE PREPARATION

A. Correct Substrate Defects:

1. Defects that need to be corrected before work can commence should be brought to the attention of the General Contractor and/or Building Owner in writing and addressed by them.
2. For re-roofing applications, remove existing roof system components as specified by the project designer. If components are discovered during installation that could be detrimental to the performance of the new roof system, they should be brought to the attention of the project designer for corrective action.
3. Good roofing practice requires a complete tear-off to the structural deck if soundness and integrity of the existing roof system cannot be verified. Recovering an existing roof system is an alternative to removing existing roof components. However, non-destructive testing, in conjunction with core cuts, must be completed to determine the condition of the existing roof system and decking.
4. The building owner or project designer is responsible for assuring that all wet insulation and/or wet substrate materials are removed prior to the commencement of re-roofing application. The diagnostic technique is taking and evaluating a series of roof cuts. There are three other techniques that are currently available to make this determination by indirect means:
    - nuclear moisture detection
    - infrared thermography
    - electric capacitance.
5. These techniques provide measurement of factors that can be associated with the presence of moisture, which can then be correlated to the roofing cuts to verify the results of the non-destructive testing.

B. Remove Moisture:

Ponded water, snow, frost and/or ice, must be removed from the work surface(s) prior to installing a Firestone B.U.R. Roofing System.

C. Prepare Surface:

Acceptable substrates to which the Firestone BUR Roofing System will be installed must be prepared prior to membrane installation. The surface must be relatively even, clean, dry, smooth, free of sharp edges, fins, loose or foreign materials, oil, grease and other materials that may damage the membrane. Rough surfaces that could cause damage to the membrane must be overlaid with insulation.

D. Prime substrates as necessary:

Prime the substrates as necessary with ASTM D-41 primer, at a rate of 1-1/2 to 2 gallons per 100 square feet (0.61 to 0.82 L/sq. m)

E. Fill Voids:

All surface voids of the immediate substrate greater than 1/4” (6.35 mm) wide must be filled with insulation or other appropriate material.

F. Install Vapor Retarder (When Specified):

Install a vapor retarder as specified by the project designer.

2.04.1 WOOD NAILER LOCATION AND INSTALLATION

Wood nailers must be installed as specified by the project designer or as noted in Firestone Details and the System Design Guide. Install wood nailers as follows:

A. Position Wood Nailer

Total wood nailer height must match the total thickness of insulation being used and should be installed with a 1/8" (3.2 mm) gap between each length and each change of direction.

B. Secure Wood Nailer

Wood nailers must be firmly fastened to the deck or building. Mechanically fasten wood nailers to resist a force of 200 lbf (890 N) in any direction, typically 12‟ (304.8 mm) o.c. Refer to attachment requirements as specified by the project designer.

C. Taper Wood Nailer

The wood nailer must be tapered (if applicable) so that it will always be flush at the point of contact with the insulation (refer to Firestone Details).

D. Chemical Treating of Wood Nailer

Do not use chemically treated wood that may affect the performance of the Firestone BUR membrane and accessories.

E. Installation of Wood Nailers by Others

Make these specifications and details available when nailers are to be installed by others. Work that compromises the integrity of the system may jeopardize the warranty for the project.

2.05.1 INSULATION INSTALLATION

A. Install Insulation:

Install only as much insulation as can be covered with roofing membrane and completed before the end of the day's work or before the onset of inclement weather.

B. Fit Insulation:

Neatly fit insulation to all penetrations, projections, and nailers. Insulation should be loosely fitted, with gaps greater than 1/4" (6.4 mm) filled with acceptable insulation**.** On metal decks, the edge of the board parallel with the roof deck should be completely supported. The membrane should not be left unsupported over a space greater than 1/4" (6.4 mm). Firestone recommends that Tapered insulation with acceptable facers for bonding be installed around roof drains so as to provide proper slope for drainage as shown in Firestone Details.

C. Stagger Insulation Joints:

When installing multiple layers of insulation, all joints between layers shall be staggered.

2.05.1.1 Attach Insulation

A. Mechanical Attachment:

Insulation may be attached using Firestone Insulation Plates and Fasteners. The choice of fastener type depends on the substrate. Contact your Technical Coordinator at 800-428-5411 for information.

1. Refer to Firestone Technical Information Sheets for attachment patterns and insulation fastening rates.
2. When installing a multi-layer insulation assembly, the fastening pattern is determined by the type and thickness of the top layer of insulation and code requirements.
3. For proper performance, fasteners must be fully seated, but not overdriven. Insulation plates may cup if fasteners are overdriven.
4. Multiple layers may be installed using a common fastener.

B. Asphalt Attachment:

Insulation may be attached using a solid mopping of ASTM D 312 Type III or Type IV asphalt or Firestone SEBS Asphalt, except DensDeck. If asphalt attachment is desired for DensDeck products they must be installed in Type III asphalt as follows: "**Mopping asphalt temperature must not exceed 450 °F when mopping to DensDeck Prime. Use only ASTM D 312 Type III asphalt**."

1. The insulation should be no larger than 4' X 4' (1.2 m X 1.2 m).
2. The substrate may require priming prior to installing the insulation. Refer to the Firestone Asphalt Design Guide for specific information.
3. The asphalt shall be at the manufacturer's stated Equiviscous Temperature (EVT) at the point of installation.
4. Built-Up Roofing plies should be installed in 25#/100 sq. ft (1.2 k/sq. m) +/- 15% to ensure that complete adhesion and a monolithic structure are achieved.
5. Insulation boards should be walked in to ensure complete adhesion to the substrate.

6. Additional layers of insulation may be installed in the same fashion.

C. Adhesive Attachment:

1. Insulation may be attached using I.S.O. Fix, I.S.O.SPRAY S, I.S.O. Twin Pack or I.S.O. Stick.

a. Apply the adhesive in accordance with the instructions provided with the product and Firestone Technical Information Sheets.
b. It may be necessary to prime the substrate prior to installing the insulation in adhesive.
c. If installing on a metal deck (where allowed by specification), the edge of the board parallel with the roof deck must be completely supported.
d. The insulation boards must be no larger than 4' X 4' (1.2 m X 1.2 m).
e. Insulation boards must be walked in to ensure complete adhesion to the substrate.
f. Additional layers of insulation may be installed in the same fashion.

2.06.1 CANT STRIP INSTALLATION

Install non-combustible cant strips at all walls and curbs as required by the appropriate design specifications and details using hot asphalt or Firestone Multi-Purpose MB Flashing Cement. Refer to the Firestone Asphalt Design Guide at www.firestonebpco.com for additional information.

2.07.1 BASE SHEET INSTALLATION

2.07.1.1 Hot Asphalt Attachment

Base sheets may be attached to an appropriate substrate using ASTM D 312 Type III or IV asphalt or Firestone SEBS Mopping Asphalt. Refer to the on-line Design Guide for suitable substrates and the Technical Information Sheets for product information. Adhesion asphalt must be applied at the manufacturer's stated EVT at point of installation. Align subsequent rolls, shingling the laps, maintaining a minimum 2" (50.8 mm) side lap and minimum 6" (152.4 mm) end lap and repeat the application.

A. Solid Mopping

1. Starting at the low point of the roof, align the base sheet and unroll into a solid mopping of hot asphalt.
2. With a stiff push broom, immediately broom the base sheet to ensure full contact with the asphalt.

B. Spot Mopping

Firestone does not approve spot mopping.

Note:

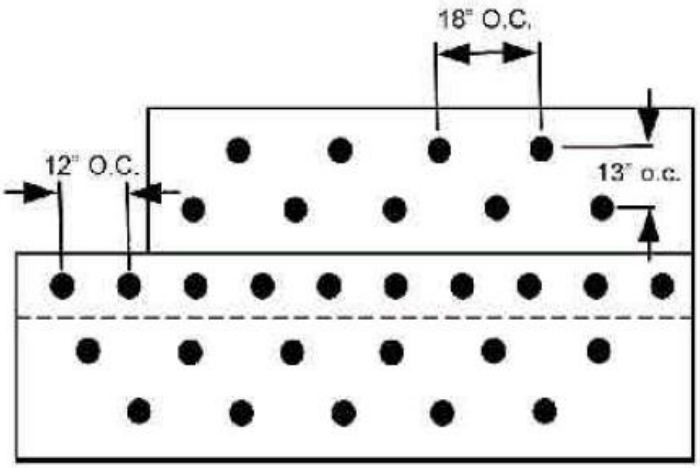
1. Firestone recommends that a half sheet be used as the first course to ensure that the base sheet laps and the cap sheet laps are not atop one another.
2. Do not install base or ply sheets directly to polyiso Insulation with a full mopping of hot asphalt. Base sheets can be mechanically attached. A Firestone FiberTop or DensDeck coverboard may be installed over Firestone ISO 95+ polyiso insulation before the base sheet is installed.

2.07.1.2 Mechanical Attachment

Starting at the low point of the roof, align the base sheet, unroll and allow the sheet to relax prior to attaching. Begin attachment at one end and work towards the other end, keeping the roll tight and wrinkle free. Align subsequent rolls, shingling the laps, maintaining a minimum 3" (76.2 mm) side lap and minimum 6" (152.4 mm) end lap and repeat the application. Stagger all end laps.

2.07.1.2.1 Base Sheet Attachment

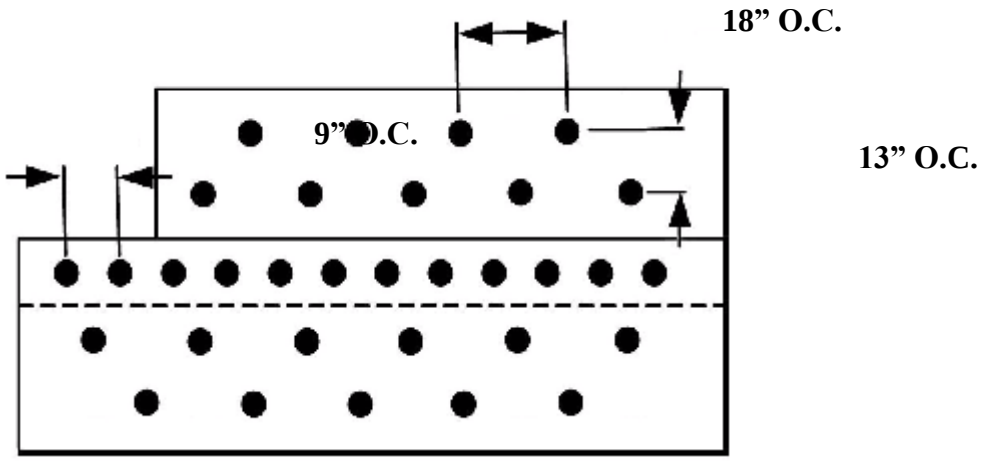
A. Using Firestone insulation plates and fasteners, base sheets may be attached through insulation into the deck.
B. Firestone fasteners may be used to install base sheets direct to a deck. When fastening base sheets direct to poured-in-place concrete, wood, gypsum, cementitious wood fiber, or lightweight concrete decks, refer to the on-line Design Guide for information on the proper fastener to be used with a particular deck type. Contact your Technical Coordinator at 800-428-5411 for specific information.
C. Direct-to-deck attachment of Firestone base sheets and cap sheets used as base sheets must be mechanically attached 12" (304.8 mm) o.c. in the side and end laps and 18" (457.2) o.c. in two staggered rows in the field of the sheet. Each row shall be 13" (330.2 mm) (approx.) in from the sides of the base sheet. See diagram below.



This attachment pattern applies to all Firestone base sheets and cap sheets used as base sheets.

2.07.1.2.2 Fasten Base Sheet Using Cap Nails

A. Using cap nails with 1" (25.4 mm) diameter steel heads, base sheets may be attached to plywood, wood plank, and oriented strand board decks. The base sheet must be mechanically attached with cap nails specified by the project designer at 9" (228.6 mm) o.c. in the side and end laps and 18" (457.2 mm) o.c. in two staggered rows in the field of the sheet.
B. Each row shall be 13" (330 mm) in from the sides of the base sheet.
C. Cap nails cannot be used to attach insulation, attach a base sheet through an existing insulated roof, attach a base sheet over a gravel surfaced built-up roof, or through a smooth surfaced un-insulated built up roof.
D. The fasteners used to attach base sheet must be manufactured for the particular deck type
See diagram below.



2.07.1.2.3 Fasten Base Sheet Using Specialty Fasteners

Using nail-in type fasteners and plates, base sheets may be attached to gypsum, cementitious wood fiber or lightweight insulating concrete decks. The base sheet must be mechanically attached with fasteners as specified by the project designer and the fastener manufacturer. Nail-in fasteners cannot be used to attach insulation, attach a base sheet through an existing insulated roof, attach a base sheet over a gravel surfaced built-up roof, or through a smooth surfaced built-up roof. The fasteners used to attach base sheet must be Factory Mutual Approved and manufactured for the particular deck type.

2.07.1.3 Cold Adhesive Attachment

Starting at the low point of the roof, install base sheet in a uniform application of Firestone Multi-Purpose MB Cold Adhesive. Align subsequent rolls, shingling the laps, maintaining a minimum 3” (76.2 mm) side lap and minimum 6” (152.4 mm) end lap and repeat the application.

1. Lay out the first base sheet by unrolling and aligning into final position.
2. Re-roll the sheet halfway and apply MB Cold Adhesive to the substrate with an airless sprayer or a 1/4” (6.4 mm) notched neoprene squeegee at a rate of 1-1/2 to 2 gallons per 100 square feet (0.6 to 0.8 L/sq. m). Some substrates may take more adhesive depending on the porosity and texture of the surface.
3. Roll the base sheet into the adhesive and broom into place.
4. Re-roll the other half and install using the same process.
5. Install additional base sheets in the same fashion, assuring that the application of the Multi-Purpose MB Cold Adhesive is applied fully in the lap areas as well.

2.07.1.4 Lap Base Sheets

Base sheets must be lapped a minimum of 2” (50.8 mm) for side laps when hot steep asphalt applied and 3" (76.2 mm) for side laps when mechanically attached, or applied in Firestone Multi-Purpose MB Cold Adhesive. End laps must be minimum 6" (152.4mm). In all cases, an offset of 12" (304.8 mm) minimum must be maintained between the side and end laps of the base sheet and the cap sheet.

2.08.1 INSTALLATION of METIRC PLY SHEETS

2.08.1.1 General

A. Install each ply felt in a full mopping of ASTM D 312 Type III (3) or Type IV (4) asphalt or IV CSA A123.4 Type III (3) or Type IV (4) or Firestone SEBS Mopping Asphalt. Install each ply felt so that it will be set firmly and uniformly into the asphalt without voids.
B. Do not walk on freshly laid BUR felts.
C. The asphalt temperature at the point of application must be within 25 °F of the EVT.
D. Apply adhesion asphalt uniformly at a rate of 25 lb per 100 sq. ft. ± 15%. Broom-in all ply sheets as they are installed.
E. Maintain a 2" (50.8 mm) headlap plus or minus 1/4" (6.4 mm) to assure the correct number of plies at any given point of the roof membrane. Maintain a minimum overlap of 12 inches (304.8 mm)at roll end laps.

2.08.1.2 Three-Ply Installation

Starting from the low point of the roof, apply a full 39.4" width of Firestone Ply IV or Ply VI . Apply a second layer of Ply felt 12 ½ " (317 mm) up from the lower edge of the fists ply. Apply a final full width of ply felt 12 ½ " (317 mm) up slope from the edge of the second ply in a shingle fashion so that at least three plies cover the entire roof surface. Extend Ply IV or Ply VI sheets 2" (51 mm) above the top of the cant as illustrated by Firestone Details.

2.08.1.3 Four-Ply Installation

Starting from the low point of the roof, apply a 9 3/8" (238 mm) width of Firestone Ply IV or Ply VI sheet, followed by an 18 3/4" (476 mm) width and a 28 1/8" (714 mm) width directly over each other. Apply remaining ply sheets in full 39" (1 m) widths in a shingle fashion so that at least four plies cover the entire roof surface. Extend Ply IV or Ply VI sheets 2" (51 mm) above the top of cants as illustrated by Firestone Details.

2.09.1 FLASHING

2.09.1.1 General

A. All flashing must be completed using Firestone SBS Membrane and any additional membrane layers as required by Firestone Details.
B. Remove existing flashings (i.e. metal, bituminous, mastic, etc.).
C. Flash penetrations in accordance with the appropriate Firestone Details (MB-P-1 through MB-P-6).
D. The flashing seal must be made directly to the penetration (except as shown in details with metal sleeves).

2.09.1.2 FLASHING - Walls, Parapets, Mechanical Equipment Curbs, Skylights, Gravel Stops, and Roof Edges

A. Flashing shall be installed in accordance with Firestone Details using Firestone SBS Flashing sheets (hot asphalt or Multi-Purpose MB Flashing Cement), SBS Torch Grade or Firestone UltraFlash Liquid Flashing.
B. The following substrates require an overlayment of 1/2" (12. 7 mm) exterior grade plywood mechanically fastened and covered with an approved, mechanically attached base sheet.

- Gypsum board (except 1/2" (12.7 mm) DensDeck Prime)
- Stucco
- Textured masonry
- Corrugated metal panels
- Other uneven substrates

C. Install the required base ply to the mechanically attached base.
D. After the base sheet and field membrane have been installed, cut flashing sections from the appropriate Firestone SBS Cap Sheet as necessary. Flashing sections shall be of a size that will not allow cooling of adhesion asphalt before they can be placed into final position. Flashing must extend a minimum of 6" (152.4 mm) onto the field membrane.

Note:
When torching to a granule surfaced sheet, granules must be embedded before a lap is made. Granule embedment is required prior to constructing end laps, base flashings, base tie-ins and membrane repairs. .Granule embedment, on the receiving surface can be accomplished by heating the surface and troweling-in all granules until a uniform black surface coated with compound is achieved in the lap area. Any area of the sheet not protected by a granule surface can be dressed with additional granules. Specialty tools are available that aid in the embedding of the granules. Contact your Technical Coordinator at 800-428-5411 for additional information.

2.09.1.3 Install Metal Flash AL

A. METAL FLASH-AL Application to Masonry.
Flash masonry parapet walls and curbs using Firestone SBS Poly Torch Base and Firestone Metal Flash-AL. The Firestone SBS Poly Torch Base reinforcing strip shall have minimum three (3) inch side laps and extend a minimum of six (6) inches onto the base ply surface and three (3) inches on the parapet wall above the cant in accordance with Firestone detail MB-BT-14.

1. Torch apply an SBS Poly Torch Base reinforcing sheet, fully adhering it in place. The laps of Firestone Metal Flash-AL flashing layer and the lap seams in the SBS Poly Torch Base reinforcing layer must not coincide.
2. After the final roofing ply has been applied to the top of the cant prepare the surface area of the field sheet that is to receive flashing sheet by heating the granule surface and embedding the granules.
3. Torch apply Firestone Metal Flash-AL into place using three foot widths always lapping the factory selvage edge. Extend the flashing sheet a minimum of six (6) inches beyond the toe of the cant onto the prepared surface of the finished roof and up the wall to the desired flashing height.
4. Exert pressure on the Firestone Metal Flash-AL sheet during application to ensure complete contact with the wall/roof surfaces preventing air pockets; this can be accomplished by using a damp sponge or shop rag. Check and seal all loose laps and edges. Nail the top edge of the flashing on 8 inch (203 mm) centers.

B. METAL FLASH-AL APPLICATION - WOOD SURFACES.
Flash wood or plywood parapet walls and curbs using a Firestone SBS Poly Torch Base reinforcing sheet followed by a layer of Firestone Metal Flash-AL flashing membrane. Firestone SBS Poly Torch Base reinforcing sheet shall have minimum three (3) inch side laps and extend a minimum of three (3) inches onto the base ply surface and to the top of the parapet wall curb etc.
1. Mechanically fasten an approved base sheet to the vertical wood surface on twelve (9) inch centers from the top of the cant to top of wall curb etc.
2. Fully adhere SBS Poly Torch Base that extends over the cant and on to the field of the roof.
3. After the final roofing ply has been installed, prepare the field sheet surface area that is to receive flashing by heating granular surfaces and embeding granules.

4. Torch apply the Firestone Metal Flash-AL into place using three foot widths always lapping the factory selvage edge. Extend the flashing sheet a minimum of six (6) inches beyond the toe of the cant onto the prepared surface of the finished roof and up the wall to the desired flashing height.
5. Exert pressure on the Firestone Metal Flash-AL sheet during application to ensure complete contact with the wall/roof surfaces preventing air pockets; this can be accomplished by using a damp sponge or shop rag. Check and seal all loose laps and edges. Nail the top edge of the flashing on nine (9) inch centers.

2.09.1.4 Special Consideration for Copper/Lead Coated Copper Edging

Special cleaning techniques must be used to prepare the metal surface to which the Firestone membrane will be adhered. Firestone requires the cleaning with acetone or lacquer thinner, using clean cotton cloths. After the surface has dried, apply ASTM D-41 asphalt primer at approximately one (1) gallon per 100 square feet (0.4 l/m^2). Allow the primer to dry before installing the Firestone membrane**.**

2.10.1 PENETRATION FLASHINGS

2.10.1.1 General

A. Remove all existing flashings (i.e. metal, bituminous, mastic, etc.).
B. Flash all penetrations which pass through the membrane in accordance with Firestone Details MB-P-1 through MB-P-6.
C. The flashing seal must be made directly to the penetration (except as shown in details with metal sleeves).

2.10.1.2 Roof Drains

These guidelines apply for installation of cast iron drains only. For acceptability of other drain types contact Firestone Roof Solutions Department and Firestone Details MB-D-1 and MB-D-2.
A. Remove existing flashings (including metal flashings), roofing materials and cement from the existing drain
B. Provide a clean even finish on the mating surfaces between the clamping ring and the drain bowl.
C. Install tapered insulation around the drain to provide a smooth transition from the roof surface to the drain. Slope should not exceed 1" per foot (8.3%).
D. Install the base sheet. Cut an opening in the base sheet so that it stops short of the clamping ring area.
E. Extend the Field Base Sheet down the bowl into the clamping ring. Do not allow base sheet laps into the clamping ring.
F Fully adhere the lead flashing in a continuous layer of Firestone Multi-Purpose MB Flashing Cement, and prime the top surface with ASTM D 41 asphalt primer.
G. .Install interply sheet(s) appropriate to the desired warranty.
H. Extend the field membrane down the drain sump and into the drain bowl.
I. Make round holes in the membranes and align with clamping bolts.
J. Install the roof drain clamping ring and clamping bolts. Tighten the clamping bolts to achieve continuous compression.

2.10.1.3 Pipe Clusters and Unusual Shaped Penetrations

Fabricate and secure penetration pockets in accordance with Firestone Detail MB-P-8.

2.10.1.4 Pipes

A. Pipes:

Many pipe penetrations can be flashed with a Firestone UltraFlash Liquid Flashing in accordance with Firestone Detail MB-P-7.

B. Hot Pipes:

Protect the roofing components from direct contact with steam or heat sources when the in-service temperature is in excess of 180 °F (82.2 °C). In all such cases, flash to an intermediate "cool" sleeve in accordance with Firestone Detail MB-P-9.

2.10.1.5 Scuppers

A. Remove existing scupper and provide a new welded watertight scupper.
B. Flash wall in accordance with Firestone Specification Detail MB-S-1 or MB-S-2.
C. Set welded watertight scupper in the approved Firestone adhesive and secure to the structure.
D. Flash in accordance with Firestone Details .MB-S-1 or MB-S-2

2.10.1.6 Expansion Joints/Area Dividers

Install expansion joints and roof dividers in accordance with Firestone Specification Details MB-E-1 through MB-E-4 as appropriate.

2.11.1 GRAVEL SURFACING AND COATINGS

2.11.1.1 Gravel Surfacing

For every 100 sq. ft of roof surface, install approximately 500 lb (24.4 kg/sq. m) of roofing gravel or 400 lb (19.5 kg/ sq. m) of slag (both + 25%) applied directly over a 60 lb per 100 $ft.^2$ (2.9 kg/sq. m) ± 15% flood coat of Type III or Type IV asphalt or Firestone SEBS Mopping Asphalt. No more asphalt must be spread or poured at one time than can be covered with gravel or slag before the asphalt cools. Gravel, slag or other accepted surfacing material shall comply with ASTM D 1863 and be 1/4" (6.4 mm) to 3/4" (19.1 mm) in diameter, substantially opaque, dry, free from dust or other foreign materials.

2.11.1.2 Application of Firestone Aluminum Fibered Roof Coating

1. If the system is to be coated, Firestone Aluminum Fibered Roof Coating may be applied from 30 to 90 days after the application of the B.U.R. membrane. Note that if the membrane is coated immediately, there may be some staining of the coating but this should disappear within about two months.
2. Substrate must be clean, dry and free of foreign materials such as oil, grease, and contaminants. If coating an existing weathered surface, the surface should be cleaned with pressure washers to remove loose dirt and allowed to dry.
3. Mix contents thoroughly to insure complete dispersion of aluminum pigments.
4. Apply at 60 °F (15.5 °C) or above, with no forecast of rain within 24 hours.
5. Use directly from the container and DO NOT THIN.
6. Pour Firestone Aluminum Fibered Roof Coating out of the container in small amounts and brush in parallel strokes to form an even layer. Over-brushing causes some of the aluminum sheen to lessen, reducing reflective qualities. Repeat as necessary to insure complete coverage. The coverage needed.
7. Coverage varies depending on the surface texture.
8. Replace and secure the cover of the can when not in use.
9. The Firestone Aluminum Fibered Roof Coating must be regularly maintained to ensure continuing warranty coverage.

Precautionary Information:

1. Firestone Aluminum Fibered Roof Coating is combustible and must be keep away from fire and other sources of ignition during storage
2. Always keep ample fire extinguishing equipment near any area of application.
3. Avoid skin contact and inhalation of vapors. Always work in well-ventilated areas with proper clothing and safety equipment.
4. Prevent fumes from entering rooftop air handling units.
5. Do not thin Firestone Aluminum Fibered Roof Coating.
6. Review all Material Safety Data Sheets prior to using Firestone Aluminum Fibered Roof Coating.
7. Store all unopened containers at room temperature, 60 °F (15.5 °C) to 80 °F (26.6 °C), until ready for use.

2.11.1.3 Application of Firestone Acrylic Coating System for Asphalt

The Firestone Acrylic Coating System for Asphalt is a two-coat system consisting of a first coat of Firestone Acrylic Base Coat for Asphalt followed by a second coat of Firestone AcryliTop PC-100 top coat.

A. It is essential that the Base Coat be applied on glaze coated BUR surfaces**,** as it is this coat that ensures good adhesion to asphaltic substrates and long-term performance of the two-coat system.
B. Substrates must be clean, dry and free of foreign material and contaminants. Install the Firestone Asphalt Roof System in accordance with all current Firestone specifications.
C. Roof inspection by Firestone, with subsequent repairs and re-inspection, is required prior to application of the Firestone Acrylic Coating System for Asphalt if a warranty is required.
D. The membrane surfaces must be clean, dry, and free of foreign material and contaminants prior to the Acrylic Base Coat for Asphalt application.
E. The membrane surface will require additional cleaning in the areas where dirt has accumulated due to ponding water.
F. Clean soiled areas with a mild detergent and water. Rinse the area thoroughly and allow it to dry before the application of the coating.
G. Apply Acrylic Base Coat for Asphalt in a one-coat application to achieve a minimum coverage rate of 1 gallon per hundred (100) square feet (0.4 m2 /L) on glaze coated BUR membranes.
H. Coatings can be spray or roller to achieve the proper coverage rate.
I. Allow Acrylic Base Coat for Asphalt to dry 24 hours before applying an AcryliTop PC-100 top coat. Dry time depends on ambient air conditions.
J. Inspect the application to assure that complete coverage of the membrane is achieved. Apply additional Acrylic Base Coat for Asphalt to areas with incomplete coverage.

B. Firestone AcryliTop PC-100

A. A top coat of AcryliTop PC-100 is applied in exactly the same manner as the Base Coat, at a minimum coverage rate of one gallon per 100 square feet (0.4 m^2 /L).
B. Inspect the application to assure complete coverage of the membrane. Apply additional AcryliTop PC-100 top coat to areas where complete coverage has not been achieved.
C. Coverage will be visually obvious as the AcryliTop PC-100 top coat is white, tan, or gray and will be covering the yellow tint of the Acrylic Base Coat for Asphalt.
D. Allow the AcryliTop PC-100 top coat to dry 24 hours before allowing traffic on the roof.
E. The coating must be regularly maintained to ensure any continuing warranty coverage and may be required to ensure continuing fire or all other code approvals.

Precautionary Information:

1. Do not contaminate the coating with foreign materials.
2. DO NOT apply the acrylic products when ambient air temperatures will be below 45 °F (7.2 °C) within a 24-hour period after application.
3. Do not apply acrylic products when inclement weather is expected within 24 hours.
4. Do not expose acrylic products to temperatures greater than 140 °F (60 °C) or lower than 33 °F (0.6°C).
5. Do not thin Firestone acrylic products.
6. Recommended cleaner is water.
7. It is recommended that periodic inspections of the roof system be conducted by the owner, with the subsequent re-application of Firestone White Acrylic Coating System to areas that may need touch-ups. Where the asphalt surface is exposed, it will be necessary to re-apply a coat of Acrylic Base Coat for Asphalt before re-applying the AcryliTop PC-100 top coat.
8. Review Material Safety Data Sheets prior to using Acrylic Base Coat for Asphalt and AcryliTop PC-100 top coat.

2.12.1 PLY SHEET REPAIR

When necessary to repair the ply sheets, use the following criteria:

A. A wrinkle or fishmouth must be cut and laid flat, so as not to create a hump or void, and repaired with a section of Firestone Ply Sheet installed in hot asphalt and equal to the number of plies cut out.

B. If the repair is due to a puncture in the membrane system, repair the area by installing a minimum of 4 plies of Firestone Ply IV or Ply VI sheets in hot asphalt over the affected area.

2.13.1 TEMPORARY CLOSURE

A. Temporary closures must be used to prevent water from flowing beneath the roofing system during inclement weather.

1. The roof membrane must extend at least two (2) feet (609.6 mm) over the last row of insulation (where applicable).
2. Apply a continuous layer of asphalt or roofing cement onto the substrate and the membrane edge. Mating surfaces must be smooth, clean, dry and free of any loose foreign material and gravel.
3. Firmly embed roof membrane into the asphalt or roofing cement and provide continuous pressure over the length of the cut-off by using sufficient weight.

B. The closure described in A. above is an overnight tie-in only and is not intended for long-term use. If temporary tie-in must remain for more than one day's time, it must be checked on a daily basis to assure the tie-in remains sealed and reworked if necessary.

C. Refer to Firestone's acceptable tie-in detail when long-term tie-ins are necessary.

D. Temporary tie-ins must be completely removed providing a clean surface for the new roofing system.

E. Tie-ins, either temporary or permanent, are not warranted by Firestone.

2.14.1 ROOF WALKWAYS

Install asphalt composition walk pads as specified by the project designer. Walk pads shall be fully bonded to the roof surface in a full mopping of asphalt or heat welded with appropriate membrane.

2.15.1 SHEET METAL WORK

A For specific installation instructions for Firestone Sheet Metal, refer to the Asphalt System Design Guide.

B For sheet metal work not supplied by Firestone, refer to fabrication and installation requirements specified by the project designer as well as industry standards.

END OF SECTION

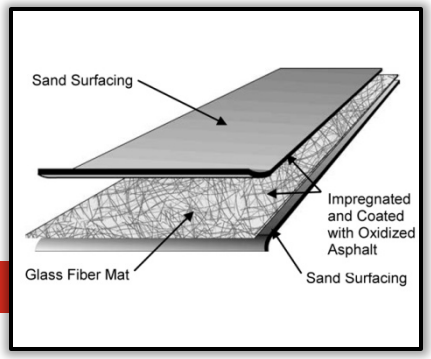
TECHNICAL INFORMATION SHEET

Firestone BUILDING PRODUCTS

MB Base

Item Description
MB Base Sheet

Item Number
W70RAC8500



Meets ASTM D 4601, Type II. Tested in Accordance with D 146.

Product Information

Description:

Firestone MB Base Sheet is high-performance roofing base sheet, which is asphalt impregnated and coated and has a glass fiber mat reinforcement. It has been designed to provide superior durability and ease of installation in asphalt roofing systems.

By using only pure roofing grade asphalt, with little or no fillers, Firestone MB Base Sheet offers better flexibility and workability than typical heavily filled base sheets. Firestone MB Base Sheet may be used as a base ply in SBS, APP Modified Bitumen and Built-Up Roofing Systems.

Product Packaging

Property	Value
Roll Width:	39.45" (1.00 m)
Roll Length:	98.7' (30.1 m)
Net Coverage:	300 ft^2 (27.5 m^2)*
Roll Weight:	75 lb (34.0 kg)
Pallet Size:	51" x 39" (1.1 m x 1.0 m)
Rolls per Pallet:	25
Weight per Pallet:	1,935 lb (878.5 kg)
Pallets Per Truckload:	20

Method of Application:

1. MB Base Sheet shall be installed with Firestone fasteners and insulation plates, conventional hot asphalt, or Firestone MB Cold Adhesive.
2. When installed with cold adhesive, this membrane **must** be applied using Firestone MB Cold Adhesive (or other approved Firestone Cold Adhesive). Use of non-Firestone adhesives will void all warranties and may cause damage to the membrane.

Storage:

- All material should be stored out of the weather in a clean, dry area in its original unopened packaging at a minimum of 40 °F (4 °C) and a maximum of 140 °F (60 °C) so that it will be a minimum of 40 °F (4 °C) at the time of application.
- **Stack Firestone MB Base rolls squarely in original unopened packaging no more than two (2) pallets high.**
- If material must be stored temporarily on the roof before application, it must be elevated from the roof surface on a pallet, stored on end, and covered from the weather with a light colored opaque tarp in a neat, safe manner not to exceed the allowable live load of the storage area.

MB Base

Precautions:

1. Refer to Material Safety Data Sheets for B.U.R. Ply Sheets.
2. Take care when transporting and handling Firestone MB Base rolls to avoid punctures and other types of physical damage.
3. Isolate waste products, petroleum products, grease, oil (mineral and vegetable) and animal fats from all Firestone roofing membranes.

Performance Advantages:

- The glass fiber mat provides high tensile strength and excellent dimensional stability.
- Meets the criteria for an Underwriters Laboratories (UL) G-2 base sheet.
- Approved for use in Factory Mutual tested roofing assemblies.
- Designed for use in all climatic zones.

LEED® Information:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: Tuscaloosa, AL

Physical Properties (Meets ASTM D 4601, Type II. Tested in Accordance with D 146.)

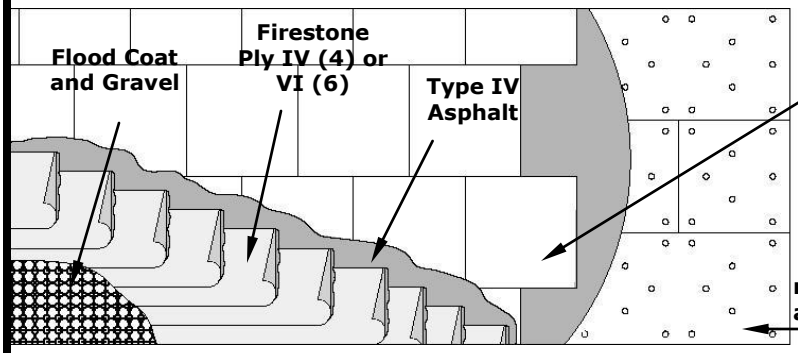
Property	ASTM Standard Required Value	Firestone Value
Width of Roll:	39.4" (1.0 m)	39.4" (1.0 m)
Product Thickness:	N/A	45.0 mil (1.1 mm)
Net Dry Mass – Coated Sheet, min.:	14.5 lb/100 ft^2 (708.0 g/m^2)	23.3 lb/100 ft^2 (1,122.9 g/m^2)
Moisture at Time of Manufacture, max.:	1.0%	0.7%
Mass of Desaturated Glass Mat, min.:	1.7 lb/100 ft^2 (83.0 g/m^2)	1.9 lb/100 ft^2 (93.0 g/m^2)
Ash, (Glass Mat Only):	70 to 88%	75.0%
Surfacing and Stabilizer, max.:	65.0%	42.0%
Asphalt, min.:	7.0 lb/100 ft^2 (342.0 g/m^2)	11.6 lb/100 ft^2 (566.4 g/m^2)
Breaking Strength, min.:	44.0 lbf/in, MD (7.7 kN/m), MD	65.2 lbf/in, MD (11.4 kN/m), MD
	44.0 lbf/in, XMD (7.7 kN/m), XMD	55.1 lbf/in, XMD (9.6 kN/m), XMD
Pliability, 1/2" (13 mm) Radius Maximum Failures, 10 Specimens:	N/A	0

Please contact your Firestone Roof Systems Advisor at 1-800-428-4511 for further information.

This sheet is meant to highlight Firestone products and specifications and is subject to change without notice. Firestone takes responsibility for furnishing quality materials which meet published Firestone product specifications. Neither Firestone nor its representatives practice architecture. Firestone offers no opinion on and expressly disclaims any responsibility for the soundness of any structure. Firestone accepts no liability for structural failure or resultant damages. Consult a competent structural engineer prior to installation if the structural soundness or structural ability to properly support a planned installation is in question. No Firestone representative is authorized to vary this disclaimer.

BUR Insulated Deck System Specifications

10-15-20 YEAR RED SHIELD



The Sample Assembly Shown is Generic. Please consult the information in this Specification for specific warranty requirements and refer to the Firestone Technical Database on the Firestone website.

Refer to the Firestone Technical Database at www.firestonebpco.com for additional information

Deck Requirements
( ) Min. 22 Gauge Steel
( ) Min. ½" (13 mm) Plywood/OSB
( ) Min. 2" (51 mm) Poured Gypsum
( ) Min. 2" (51 mm) Cementitious Wood Fiber

Slope Requirement
A minimum slope of ¼":12" must be provided to ensure positive drainage.

Firestone recommends that a design professional be consulted regarding the need for a Vapor Retarder

Insulation (Optional)

Firestone ISO 95+

Insulation Attachment
( ) Mechanically attach with Firestone Fasteners & Firestone Insulation Plates
( ) ASTM D 312 hot asphalt (1)
( ) Firestone I.S.O.Spray™ S
( ) Firestone I.S.O. FIX™ Adhesive
( ) Firestone I.S.O. Twin Pack™
( ) Firestone I.S.O. Stick™

Note: 4' x 4' boards must be used when attaching insulation with approved adhesives.

Cover Board (Optional)

( ) Firestone Dens-Deck Prime (1)
( ) Firestone Fiber Top

Mopping asphalt temperature must not exceed 450 °F when mopping to DensDeck Prime. Use only ASTM D 312 Type III asphalt.

Surfacing

( ) Asphalt Flood Coat and Gravel

10 to 12 years	15 years	20 years
( ) 1 Base sheet – applied in hot asphalt or mechanically attached **plus** ( ) 2 Ply IV (4) or Ply VI (6) applied in ASTM D 312, Type III or Type IV Asphalt **Surfacing:** ( ) Flood Coat & Gravel **Flashing:** ( ) One ply fully adhered SBS Granule Surfaced Cap Sheet	( ) 1 Base sheet – applied in hot asphalt or mechanically attached **plus** ( ) 3 Ply IV (4) or Ply VI (6) felts applied in ASTM D 312, Type III or Type IV asphalt **or** ( ) 4 Ply IV (4) or Ply VI (6) felts applied in ASTM D 312 Type III or Type IV asphalt **Surfacing:** ( ) Flood Coat & Gravel **Flashing:** ( ) One ply fully adhered MB Base or SBS Base Sheet ( ) One ply fully adhered SBS Granule Surfaced Cap Sheet	( ) 1 Base sheet applied in ASTM D 312 hot asphalt **plus** ( ) 3 Ply IV (4) or Ply VI (6) felts applied in ASTM D 312, Type IV (4) asphalt **or** ( ) 4 Ply IV (4) or Ply VI (6) felts applied in ASTM D 312 Type IV asphalt **Surfacing:** ( ) Flood Coat & Gravel **Flashing:** ( ) One ply fully adhered SBS Base Sheet **plus** ( ) One ply fully adhered SBS Granule Surfaced Cap Sheet

Base Sheet Options:

( ) MB Base M
( ) SBS Base Sheet
( ) SBS Poly Base
( ) SBS Premium Base
( ) SBS Smooth
( ) SBS Poly Torch Base*
( ) SBS Glass Torch Base*

*can **not** be installed in hot asphalt

1. **Mopping asphalt temperature must not exceed 450 °F when mopping to DensDeck Prime. Use only ASTM D 312 Type III asphalt.**

Only Firestone supplied products are covered under the Firestone Warranty

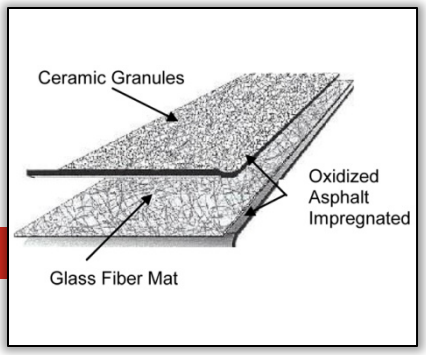
Firestone Building Products Company, LLC
250 WEST 96TH Street
Sales: 1-800-428-4442 Technical 1-800-428- 4511
www.firestonebpco.com

Rev. 6-13-2010

Venting Base

Item Description
1 Roll: Venting Base Sheet

Item Number
W70RACVTBSG



Meets ASTM D 4897, Type II

Product Information

Description:

Firestone Venting Base Sheet consists of an oxidized asphalt compound reinforced with a nonwoven, glass fiber mat and surfaced with factory-applied ceramic granules on the underside to aid in underside venting. Firestone Venting Base Sheet has a light coat of sand on the top surface.

Firestone Venting Base Sheet is designed to be mechanically fastened over lightweight concrete roof decks as a base for a Firestone modified bitumen or built-up asphalt roof system. The roofing membrane can be applied to the mechanically attached Venting Base sheet by conventional hot asphalt, Firestone MB Cold Adhesive or by use of a roofing torch.

Product Packaging

Property	Value
Roll Width:	39.4" (1.0 m)
Roll Length:	32.6' (9.9 m)
Net Coverage:	100 ft^2 (9.3 m^2)*
Roll Weight:	67 lb (30.4 kg)
Pallet Size:	44" x 48" (1.1 m x 1.2 m)
Rolls per Pallet:	30
Weight per Pallet:	2,045 lb (927.6 kg)
Pallets Per Truckload:	21
* Note: Net coverage is dependent on the number of splices made during installation.	

Method of Application:

Venting Base sheet shall be installed using mechanical attachment with appropriate fasteners. Membrane is installed with granule surface to the deck.

Storage:

- Firestone Venting Base rolls shall be stored on end to prevent damage and flattening of the roll. All material should be stored out of the weather in a clean, dry area in its original unopened packaging at a minimum of 40 °F (4 °C) and a maximum of 140 °F (60 °C) so that it will be a minimum of 40 °F (4 °C) at the time of application.
- **Stack Firestone Venting Base rolls squarely in original unopened packaging no more than two (2) pallets high.**
- If material must be stored temporarily on the roof before application, it must be elevated from the roof surface on a pallet, stored on end, and covered from the weather with a light colored opaque tarp in a neat, safe manner not to exceed the allowable live load of the storage area.

Venting Base

Precautions:

1. Refer to Material Safety Data Sheets (MSDS) for B.U.R. Ply Sheets.
2. Take care when transporting and handling Firestone Venting Base rolls to avoid punctures and other types of physical damage.
3. Isolate waste products, petroleum products, grease, oil (mineral and vegetable) and animal fats from all Firestone roofing membranes.

Performance Advantages:

1. The glass fiber mat provides high tensile strength and excellent dimensional stability.
2. Meets the criteria for an Underwriters Laboratories (UL) G-2 base sheet.
3. Approved for use in Factory Mutual tested roofing assemblies.
4. Designed for use in all climatic zones.

LEED® Information:

Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: Erie, PA
Mobile, AL

FM APPROVED

MIAMI-DADE COUNTY APPROVED

CLASSIFIED C UL US

Physical Properties (Meets ASTM D 4897, Type II)

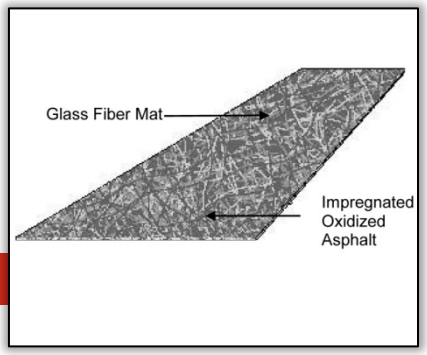
Property	ASTM Requirement	Firestone Typical Performance
Width of Roll:	39.4" (1.0 m)	39.4" (1.0 m)
Area of Roll, min.:	104 ft^2 (9.6 m^2)	106.9 ft^2 (10.0 m^2)
Product Thickness:	N/A	115.0 mil (2.92 mm)
Mass of Coated Sheet, min.:	55.0 lb/100 ft^2 (2,685 g/m^2)	62.7 lb/100 ft^2 (3,060 g/m^2)
Moisture at Time of Manufacture, max.:	1.0%	0.7%
Mass of Desaturated Glass Mat, min.:	1.7 lb/100 ft^2 (83.0 g/m^2)	1.87 lb/100 ft^2 (91.7 g/m^2)
Ash, (Glass Mat Only):	70 to 88%	75.8%
Surfacing and Stabilizer, max.:	22.0 lb/100 ft^2 (1,075 g/m^2)	16.98 lb/100 ft^2 (837 g/m^2)
Mass of Asphalt, min.:	12.0 lb/100 ft^2 (586.0 g/m^2)	13.7 lb/100 ft^2 (669.0 g/m^2)
Mass of Mineral Granules Retained on a 212 Micron Sieve:	8.0 lb/100 ft^2 (391.0 g/m^2)	30.0 lb/100 ft^2 (1,465.0 g/m^2)
Mass of Mineral matter Passing on a 212 Micron Sieve on Basis of Total Mass of Coating and Surfacing:	60.0%	55.4%
Breaking Strength, min. at 77 °F (25 °C):	44.0 lbf/in, MD (7.7 kN/m), MD	79 lbf/in, MD (13.8 kN/m), MD
	44.0 lbf/in, XMD (7.7 kN/m), XMD	61 lbf/in, XMD (10.7 kN/m), XMD

Please contact your Firestone Roof Systems Advisor at 1-800-428-4511 for further information.

Ply VI (6)

Item Description
1 Roll: Ply VI (6) Sheet

Item Number
W70RAC8760



Meets ASTM D 2178, Type VI. Tested in Accordance with D 146.

Product Information

Description:

Firestone Ply VI (6) Sheet is an asphalt impregnated, glass fiber mat reinforced, roofing ply, which has been designed to provide superior durability and ease of application.

The Firestone Ply VI (6) Sheet is designed to construct Firestone Asphalt Built-Up Roof Systems and can also be used in conjunction with Firestone Modified Bitumen Base and Cap Sheets to build Hybrid Systems. Firestone Ply VI (6) Sheet may be used as a ply in Modified Bitumen and Built-Up Roofing Systems.

Product Packaging

Property	Value
Roll Width:	39.25" (1.0 m)
Roll Length:	160.5' (48.9 m)
Net Coverage:	525 ft^2 (48.8 m^2)*
Thickness:	35 mil (0.9 mm)
Roll Weight:	50 lb (22.7 kg)
Pallet Size:	46" x 46" (1.2 m x 1.2 m)
Rolls per Pallet:	25
Weight per Pallet:	1,250 lb (449.4 kg)
Pallets Per Truckload:	36
* Note: Net coverage is dependent on the number of splices made during installation.	

Method of Application:

1. Ply VI (6) Sheet shall be installed with Firestone approved conventional hot asphalt or Firestone SEBS Mopping Asphalt.
2. This product is not designed to be installed in cut-back asphalt cold adhesive.

Storage:

- All material should be stored out of the weather in a clean, dry area in its original unopened packaging at a minimum of 40 °F (4 °C) and a maximum of 140 °F (60 °C) so that it will be a minimum of 40 °F (4 °C) at the time of application.
- **Stack Firestone Ply VI (6) rolls in original unopened packaging no more than two (2) pallets high.**
- If material must be stored temporarily on the roof before application, it must be elevated from the roof surface on a pallet, stored on end, and covered from the weather with a light colored opaque tarp in a neat, safe manner not to exceed the allowable live load of the storage area.

Ply VI (6)

Precautions:

1. Refer to Material Safety Data Sheets (MSDS) for B.U.R. Ply Sheets.
2. Take care when transporting and handling Firestone B.U.R. rolls to avoid punctures and other types of physical damage.
3. Isolate waste products, petroleum products, grease, oil (mineral and vegetable) and animal fats from all Firestone roofing membranes.

Performance Advantages:

- The glass fiber mat provides high tensile strength and excellent dimensional stability.
- Meets the criteria for an Underwriters Laboratories (UL) G-1 base sheet.
- Approved for use in Factory Mutual tested roofing assemblies.
- Designed for use in all climatic zones.

LEED® Information:

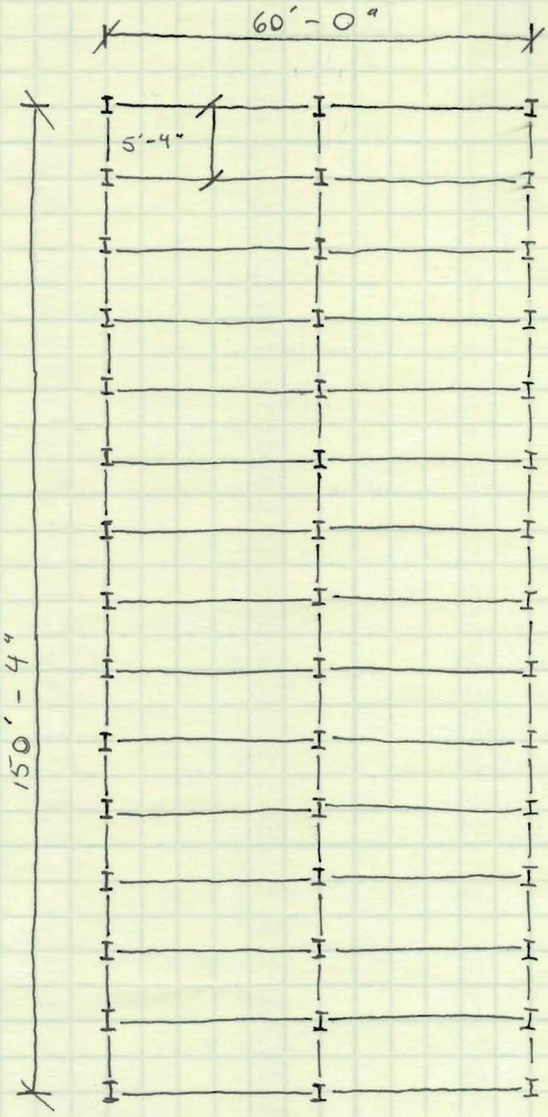
Post Consumer Recycled Content: 0%
Post Industrial Recycled Content: 0%
Manufacturing Location: Tuscaloosa, AL

Physical Properties (Meets ASTM D 2178, Type VI. Tested in Accordance with D 146.)

Property	ASTM Standard Required Value	Firestone Value
Width of Roll:	39.25" (1.0 m)	39.25" (1.0 m)
Area of Roll:	525 ft^2 (48.8 m^2)	525 ft^2 (48.8 m^2)
Product Thickness:	N/A	35 mil (0.9 mm)
Net Dry Mass:	6.2 lb/100 ft^2 (303 g/m^2)	8.9 lb/100 ft^2 (375 g/m^2)
Bituminous Saturant (Asphalt), min.:	3.0 lb/100 ft^2 (146 g/m^2)	7.0 lb/100 ft^2 (295 g/m^2)
Moisture at Time of Manufacture, max.:	1.0%	< 1.0%
Mass of Desaturated Mat, min.:	1.7 lb/100 ft^2 (83 g/m^2)	1.85 lb/100 ft^2 (90 g/m^2)
Ash, (Glass Mat Only):	70 to 88%	79%
Surfacing and Stabilizer, max.:	3.2 lb/100 ft^2 (156 g/m^2)	3.0 lb/100 ft^2 (146 g/m^2)
Breaking Strength, min.:	60 lbf/in (10.5 kN/m)	65 lbf/in (11.4 kN/m)
Pliability, 1/2" (13 mm) Radius Maximum Failures, 10 Specimens	N/A	0

Please contact your Firestone Roof Systems Advisor at 1-800-428-4511 for further information.

Appendix B.11 – Structural Breadth Work



- Triple Span Condition
- 4" Rigid Insulation

Cooling:

Built-Up:	Metal Deck	- 2 psf
	Insulation	- 8 psf
	BUR	- 30 psf
	Misc. DL	- 30 psf
	Snow	- 30 psf
	Total	100 psf

TPO: Same as Built-Up Roof - 100 psf

Garden:	Metal Deck	- 2 psf
	Insulation	- 4 psf (2")
	Garden Roof	- 100 psf
	Misc. DL	- 30 psf
	Snow	- 30 psf
	Total	166 psf

Built-Up + TPO Roofs:

$w_{TL} = 2 + 8 + 30 + 30 + 30 = 100$ psf @ 5'-4" span, 3 or more

Try 1.5B Vulcraft Roof Deck

- For max construction span, need B24 → 5'-10" (Table) ≥ 5'-4" (Given) ∴ OK
- w_{TL} for strength, B24 carries 128 psf > 100 psf (Given) ∴ Condition does not Control
- Max load for L/240, B24 carries 90 psf for L/240, $90 \times \frac{240}{180} = 120$ psf > 100psf ∴ Condition does not Control

Use B24 Deck

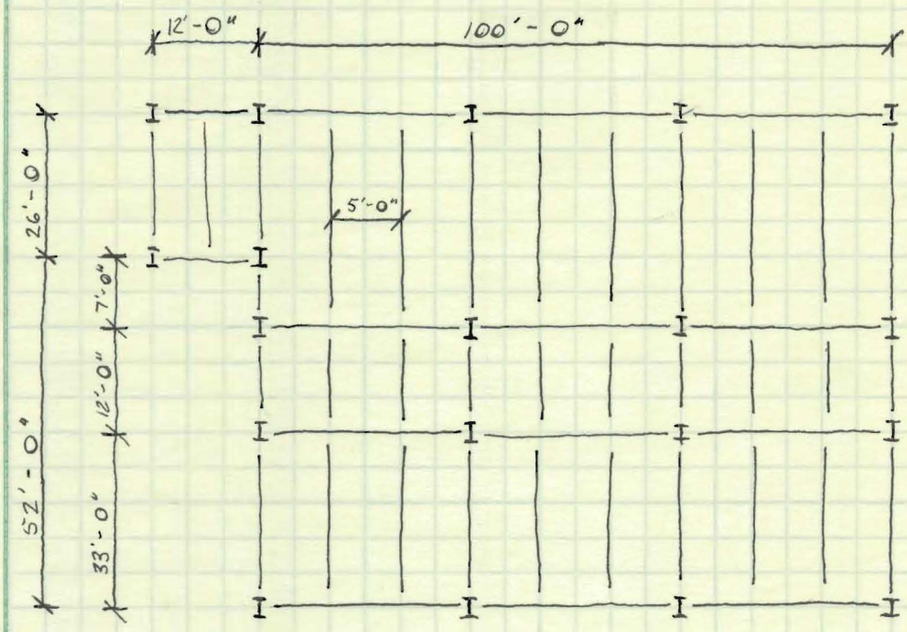
Garden Roof:

$w_{TL} = 2 + 4 + 100 + 30 + 30 = 166$ psf @ 5'-4" span, 3 or more

Try 1.5B Vulcraft Roof Deck

- For max construction span, need B18 → 9'-1" (Table) ≥ 5'-4" (Given) ∴ OK
- w_{TL} for strength, B18 carries 174 psf > 166 psf (Given) ∴ Condition does not Control
- Max load for L/240, B18 carries 217 psf for L/240, $217 \times \frac{240}{180} = 289$ > 166 psf ∴ Condition does not control

Use B18 Deck



- Triple Span Condition
- 4" Rigid Insulation

Loading:

Built-Up:		
	Metal Deck	- 2 psf
	Insulation	- 8 psf
	BUR	- 30 psf
	Misc. DL	- 10 psf
	Snow	- 30 psf
	Total	80 psf

TPO: Same as Built-Up Roof = 80 psf

Garden:		
	Metal Deck	- 2 psf
	Insulation	- 4 psf
	Garden	- 100 psf
	Misc. DL	- 10 psf
	Snow	- 30 psf
	Total	146 psf

Built-Up Roof & TPO Roof:

$W_{TL} = 2 + 8 + 30 + 10 + 30 = 80$ psf @ 5'-0" span, 3 or more

Try 1.5B Vulcraft Roof Deck

- For max construction span, need B24 → 5'-10" (Table) ≥ 5'-0" (Given) ∴ OK
- W_{TL} for strength, B24 carries 154 psf ≥ 80 psf (Given) ∴ Condition does not Control
- Max Load for L/240, B24 carries 120 psf. $120 \times \frac{240}{180} = 160$ psf > 80 psf
  ∴ Condition does not control

Use B24 Deck

Garden Roof:

$W_{TL} = 2 + 4 + 100 + 10 + 30 = 146$ psf @ 5'-0" span, 3 or more

Try 1.5B Vulcraft Roof Deck

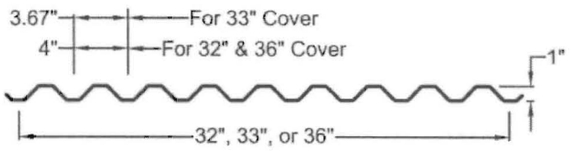
- For max construction span, need B24 → 5'-10" (Table) ≥ 5'-0" (Given) ∴ OK
- W_{TL} for strength, B24 carries 154 psf > 146 psf (Given) ∴ Condition does not Control
- Max Load for L/240, B24 carries 120 psf, $120 \times \frac{240}{180} = 160$ psf > 146 psf
  ∴ Condition does not control

Use B24 Deck

Appendix B.12 – Vulcraft Deck Catalog

1.0 E

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0



Type E deck provides a very economical roof deck for use on shorter spans. 1" or more rigid insulation should be used with Type E deck. Installation of rigid insulation should be with mechanical fasteners.

This deck also lends itself for use as a building siding.

SECTION PROPERTIES

Deck type	Design thickness in.	W psf	Section Properties				V_a lbs/ft	F_y ksi
			I_p in^4/ft	S_p in^3/ft	I_n in^4/ft	S_n in^3/ft		
E26	0.0179	1.06	0.040	0.067	0.042	0.071	2216	60
E24	0.0239	1.38	0.057	0.098	0.059	0.103	3867	60
E22	0.0295	1.67	0.073	0.130	0.073	0.134	4754	60
E20	0.0358	2.01	0.088	0.167	0.088	0.165	5744	60

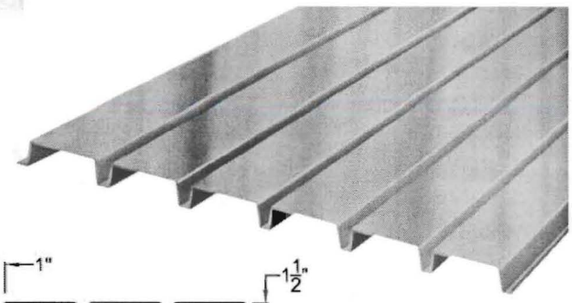
VERTICAL LOADS FOR TYPE 1.0E

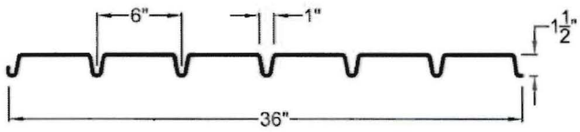
No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (PSF) / Load Causing Deflection of L/240 or 1 inch (PSF) Span (ft.-in.) ctr to ctr of supports										
			2-6	3-0	3-6	4-0	4-6	5-0	5-6	6-0	6-6	7-0	7-6
1	E26	2'-10	257 / 168	178 / 97	131 / 61	100 / 41	79 / 29	64 / 21	53 / 16	45 / 12	38 / 10	33 / 8	29 / 6
	E24	3'-5	376 / 239	261 / 138	192 / 87	147 / 58	116 / 41	94 / 30	78 / 22	65 / 17	56 / 14	48 / 11	42 / 9
	E22	3'-10	498 / 306	346 / 177	254 / 112	195 / 75	154 / 53	125 / 38	103 / 29	86 / 22	74 / 17	64 / 14	55 / 11
	E20	4'-2	640 / 369	444 / 214	327 / 135	250 / 90	198 / 63	160 / 46	132 / 35	111 / 27	95 / 21	82 / 17	71 / 14
2	E26	3'-4	267 / 414	187 / 240	138 / 151	106 / 101	84 / 71	68 / 52	56 / 39	47 / 30	40 / 24	35 / 19	30 / 15
	E24	4'-0	390 / 586	272 / 339	200 / 214	153 / 143	121 / 101	98 / 73	81 / 55	68 / 42	58 / 33	50 / 27	44 / 22
	E22	4'-6	506 / 738	353 / 427	260 / 269	199 / 180	158 / 127	128 / 92	106 / 69	89 / 53	76 / 42	65 / 34	57 / 27
	E20	5'-0	623 / 889	435 / 515	320 / 324	246 / 217	194 / 152	158 / 111	130 / 84	109 / 64	93 / 51	81 / 41	70 / 33
3	E26	3'-4	330 / 325	232 / 188	171 / 118	132 / 79	104 / 56	84 / 41	70 / 30	59 / 23	50 / 18	43 / 15	38 / 12
	E24	4'-0	485 / 459	338 / 266	249 / 167	191 / 112	151 / 79	123 / 57	102 / 43	85 / 33	73 / 26	63 / 21	55 / 17
	E22	4'-6	629 / 578	440 / 334	324 / 211	249 / 141	197 / 99	160 / 72	132 / 54	111 / 42	95 / 33	82 / 26	71 / 21
	E20	5'-0	774 / 697	541 / 403	399 / 254	306 / 170	242 / 119	197 / 87	163 / 65	137 / 50	117 / 40	101 / 32	88 / 26

Notes: 1. Minimum exterior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches. If these minimum lengths are not provided, web crippling must be checked.

1.5 A

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICC ER-3415
FM Global Approved[2]





Type A (narrow rib) deck provides an economical roof system when utilized with thinner insulation materials. It also allows the maximum area for adhesive contact, and its nestable quality eliminates the need for die-set ends.

1/2" rigid insulation may be used with Type A deck.

SECTION PROPERTIES

Deck type	Design thickness in.	W psf	Section Properties				V_a lbs/ft	F_y ksi
			I_p	S_p	I_n	S_n		
			in^4/ft	in^3/ft	in^4/ft	in^3/ft		
A22	0.0295	1.80	0.104	0.098	0.120	0.106	1700	33
A20	0.0358	2.16	0.134	0.122	0.145	0.130	2049	33
A19	0.0418	2.51	0.163	0.145	0.170	0.152	2377	33
A18	0.0474	2.84	0.190	0.167	0.193	0.172	2679	33

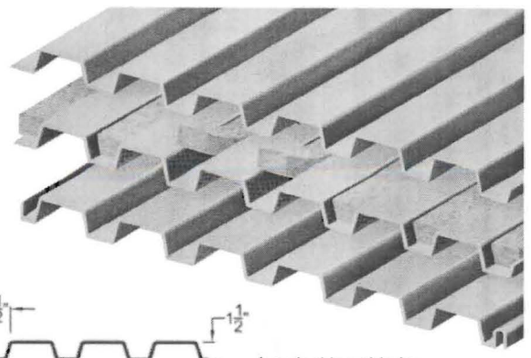
VERTICAL LOADS FOR TYPE 1.5A

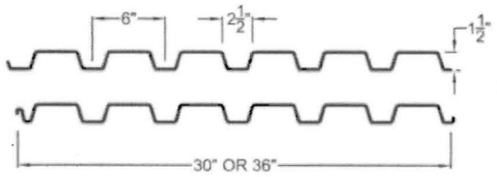
No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (PSF) / Load Causing Deflection of L/240 or 1 inch (PSF) Span (ft.-in.) ctr to ctr of supports										
			4-0	4-6	5-0	5-6	6-0	6-6	7-0	7-6	8-0	8-6	9-0
1	A22	3'-9	81 / 107	64 / 75	52 / 55	43 / 41	36 / 32	31 / 25	26 / 20	23 / 16	20 / 13	18 / 11	16 / 9
	A20	4'-8	100 / 137	79 / 96	64 / 70	53 / 53	45 / 41	38 / 32	33 / 26	29 / 21	25 / 17	22 / 14	20 / 12
	A19	5'-6	119 / 167	94 / 117	76 / 85	63 / 64	53 / 49	45 / 39	39 / 31	34 / 25	30 / 21	26 / 17	24 / 15
	A18	6'-2	138 / 195	109 / 137	88 / 100	73 / 75	61 / 58	52 / 45	45 / 36	39 / 30	34 / 24	30 / 20	27 / 17
2	A22	4'-7	87 / 276	69 / 194	56 / 141	46 / 106	39 / 82	33 / 64	28 / 52	25 / 42	22 / 35	19 / 29	17 / 24
	A20	5'-9	106 / 344	84 / 242	68 / 176	56 / 132	47 / 102	40 / 80	35 / 64	30 / 52	27 / 43	24 / 36	21 / 30
	A19	6'-10	124 / 411	98 / 289	80 / 210	66 / 158	55 / 122	47 / 96	41 / 77	36 / 62	31 / 51	28 / 43	25 / 36
	A18	7'-4	140 / 473	111 / 332	90 / 242	75 / 182	63 / 140	53 / 110	46 / 88	40 / 72	35 / 59	31 / 49	28 / 41
3	A22	4'-7	108 / 216	85 / 152	69 / 111	57 / 83	48 / 64	41 / 50	35 / 40	31 / 33	27 / 27	24 / 23	21 / 19
	A20	5'-9	132 / 270	105 / 189	85 / 138	70 / 104	59 / 80	50 / 63	44 / 50	38 / 41	33 / 34	30 / 28	26 / 24
	A19	6'-10	155 / 322	122 / 226	99 / 165	82 / 124	69 / 95	59 / 75	51 / 60	44 / 49	39 / 40	35 / 34	31 / 28
	A18	7'-4	175 / 370	138 / 260	112 / 190	93 / 142	78 / 110	67 / 86	58 / 69	50 / 56	44 / 46	39 / 39	35 / 32

Notes: 1. Minimum exterior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches. If these minimum lengths are not provided, web crippling must be checked.
2. FM Global approved numbers and spans available on page 21.

1.5 B, BI, BA, BIA, BSV

Maximum Sheet Length 42'-0
Extra charge for lengths under 6'-0
ICC ER-3415
FM Global Approved[2]





Interlocking side lap is not drawn to show actual detail.

SECTION PROPERTIES

Deck type	Design thickness in.	W psf	Section Properties				V_a lbs/ft	F_y ksi
			I_p	S_p	I_n	S_n		
			in^4/ft	in^3/ft	in^4/ft	in^3/ft		
B24	0.0239	1.46	0.107	0.120	0.135	0.131	2634	60
B22	0.0295	1.78	0.155	0.186	0.183	0.192	1818	33
B20	0.0358	2.14	0.201	0.234	0.222	0.247	2193	33
B19	0.0418	2.49	0.246	0.277	0.260	0.289	2546	33
B18	0.0474	2.82	0.289	0.318	0.295	0.327	2870	33
B16	0.0598	3.54	0.373	0.408	0.373	0.411	3578	33

ACOUSTICAL INFORMATION

Deck Type	Absorption Coefficient						Noise Reduction Coefficient[1]
	125	250	500	1000	2000	4000	
1.5BA, 1.5BIA	.11	.18	.66	1.02	0.61	0.33	0.60

[1] Source: Riverbank Acoustical Laboratories.
Test was conducted with 1.50 pcf fiberglass batts and 2 inch polyisocyanurate foam insulation for the SDI.

Type B (wide rib) deck provides excellent structural load carrying capacity per pound of steel utilized, and its nestable design eliminates the need for die-set ends.

1" or more rigid insulation is required for Type B deck.

Acoustical deck (Type BA, BIA) is particularly suitable in structures such as auditoriums, schools, and theatres where sound control is desirable. Acoustic perforations are located in the vertical webs where the load carrying properties are negligibly affected (less than 5%).

Inert, non-organic glass fiber sound absorbing batts are placed in the rib openings to absorb up to 60% of the sound striking the deck.

Batts are field installed and may require separation.

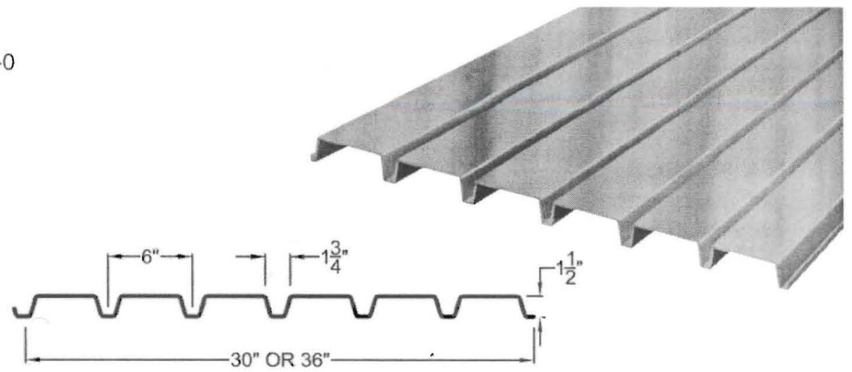
VERTICAL LOADS FOR TYPE 1.5B

No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (PSF) / Load Causing Deflection of L/240 or 1 inch (PSF) Span (ft.-in.) ctr to ctr of supports										
			5-0	5-6	6-0	6-6	7-0	7-6	8-0	8-6	9-0	9-6	10-0
1	B24	4'-8	115 / 56	95 / 42	80 / 32	68 / 26	59 / 20	51 / 17	45 / 14	40 / 11	35 / 10	32 / 8	29 / 7
	B22	5'-7	98 / 81	81 / 61	68 / 47	58 / 37	50 / 30	44 / 24	38 / 20	34 / 17	30 / 14	27 / 12	25 / 10
	B20	6'-5	123 / 105	102 / 79	86 / 61	73 / 48	63 / 38	55 / 31	48 / 26	43 / 21	38 / 18	34 / 15	31 / 13
	B19	7'-1	146 / 129	121 / 97	101 / 75	86 / 59	74 / 47	65 / 38	57 / 31	51 / 26	45 / 22	40 / 19	36 / 16
	B18	7'-8	168 / 152	138 / 114	116 / 88	99 / 69	85 / 55	74 / 45	65 / 37	58 / 31	52 / 26	46 / 22	42 / 19
	B16	8'-8	215 / 196	178 / 147	149 / 113	127 / 89	110 / 71	96 / 58	84 / 48	74 / 40	66 / 34	60 / 29	54 / 24
2	B24	5'-10	124 / 153	103 / 115	86 / 88	74 / 70	64 / 56	56 / 45	49 / 37	43 / 31	39 / 26	35 / 22	31 / 19
	B22	6'-11	100 / 213	83 / 160	70 / 124	59 / 97	51 / 78	45 / 63	39 / 52	35 / 43	31 / 37	28 / 31	25 / 27
	B20	7'-9	128 / 267	106 / 201	89 / 155	76 / 122	66 / 97	57 / 79	51 / 65	45 / 54	40 / 46	36 / 39	32 / 33
	B19	8'-5	150 / 320	124 / 240	104 / 185	89 / 145	77 / 116	67 / 95	59 / 78	52 / 65	47 / 55	42 / 47	38 / 40
	B18	9'-1	169 / 369	140 / 277	118 / 213	101 / 168	87 / 134	76 / 109	67 / 90	59 / 75	53 / 63	48 / 54	43 / 46
	B16	10'-3	213 / 471	176 / 354	149 / 273	127 / 214	110 / 172	95 / 140	84 / 115	74 / 96	66 / 81	60 / 69	54 / 59
3	B24	5'-10	154 / 120	128 / 90	108 / 69	92 / 55	79 / 44	69 / 35	61 / 29	54 / 24	48 / 21	43 / 17	39 / 15
	B22	6'-11	124 / 167	103 / 126	87 / 97	74 / 76	64 / 61	56 / 50	49 / 41	43 / 34	39 / 29	35 / 24	31 / 21
	B20	7'-9	159 / 209	132 / 157	111 / 121	95 / 95	82 / 76	72 / 62	63 / 51	56 / 43	50 / 36	45 / 31	40 / 26
	B19	8'-5	186 / 250	154 / 188	130 / 145	111 / 114	96 / 91	84 / 74	74 / 61	65 / 51	58 / 43	52 / 37	47 / 31
	B18	9'-1	210 / 289	174 / 217	147 / 167	126 / 132	108 / 105	95 / 86	83 / 71	74 / 59	66 / 50	59 / 42	54 / 36
	B16	10'-3	264 / 369	219 / 277	185 / 214	158 / 168	136 / 135	119 / 109	105 / 90	93 / 75	83 / 63	74 / 54	67 / 46

Notes: 1. Minimum exterior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches.
If these minimum lengths are not provided, web crippling must be checked.
2. FM Global approved numbers and spans available on page 21.

1.5 F

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICC ER-3415
FM Global Approved[2]



Type F (intermediate rib) deck is designed to provide the most economical combination of structural load carrying capacity and insulation materials. The rib openings permit fast and easy installation, and the nestable design eliminates the need for die-set ends. 1" rigid insulation is recommended for Type F deck.

SECTION PROPERTIES

Deck type	Design thickness in.	W psf	Section Properties				V_a lbs/ft	F_y ksi
			I_p in^4/ft	S_p in^3/ft	I_n in^4/ft	S_n in^3/ft		
F22	0.0295	1.73	0.113	0.112	0.129	0.121	1944	33
F20	0.0358	2.09	0.145	0.139	0.157	0.148	2347	33
F19	0.0418	2.42	0.177	0.166	0.183	0.172	2726	33
F18	0.0474	2.74	0.206	0.190	0.208	0.195	3077	33

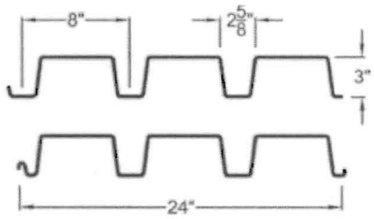
VERTICAL LOADS FOR TYPE 1.5F

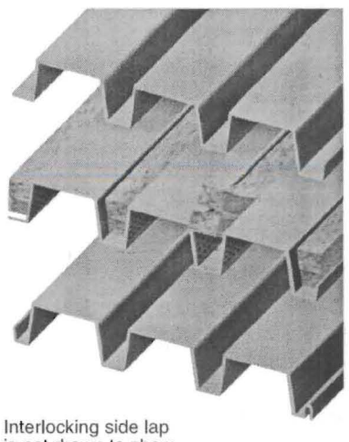
No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (PSF) / Load Causing Deflection of L/240 or 1 inch (PSF) Span (ft.-in.) ctr to ctr of supports										
			4-0	4-6	5-0	5-6	6-0	6-6	7-0	7-6	8-0	8-6	9-0
1	F22	4'-3	92 / 116	73 / 81	59 / 59	49 / 45	41 / 34	35 / 27	30 / 22	26 / 18	23 / 14	20 / 12	18 / 10
	F20	5'-4	114 / 149	90 / 104	73 / 76	61 / 57	51 / 44	43 / 35	37 / 28	33 / 23	29 / 19	25 / 15	23 / 13
	F19	6'-0	137 / 181	108 / 127	87 / 93	72 / 70	61 / 54	52 / 42	45 / 34	39 / 28	34 / 23	30 / 19	27 / 16
	F18	6'-5	156 / 211	124 / 148	100 / 108	83 / 81	70 / 63	59 / 49	51 / 39	44 / 32	39 / 26	35 / 22	31 / 19
2	F22	5'-3	99 / 299	78 / 210	63 / 153	52 / 115	44 / 88	38 / 70	32 / 56	28 / 45	25 / 37	22 / 31	20 / 26
	F20	6'-6	121 / 373	96 / 262	78 / 191	64 / 143	54 / 110	46 / 87	40 / 70	35 / 57	30 / 47	27 / 39	24 / 33
	F19	7'-1	140 / 444	111 / 312	90 / 227	75 / 171	63 / 132	53 / 104	46 / 83	40 / 67	35 / 56	31 / 46	28 / 39
	F18	7'-8	159 / 511	126 / 359	102 / 262	85 / 196	71 / 151	61 / 119	52 / 95	46 / 77	40 / 64	35 / 53	32 / 45
3	F22	5'-3	123 / 234	97 / 164	79 / 120	65 / 90	55 / 69	47 / 55	41 / 44	35 / 35	31 / 29	28 / 24	25 / 21
	F20	6'-6	151 / 292	119 / 205	97 / 149	80 / 112	67 / 86	57 / 68	50 / 54	43 / 44	38 / 36	34 / 30	30 / 26
	F19	7'-1	175 / 348	139 / 244	112 / 178	93 / 134	78 / 103	67 / 81	58 / 65	50 / 53	44 / 43	39 / 36	35 / 31
	F18	7'-8	198 / 400	157 / 281	127 / 205	105 / 154	89 / 119	76 / 93	65 / 75	57 / 61	50 / 50	44 / 42	40 / 35

Notes: 1. Minimum exterior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches. If these minimum lengths are not provided, web crippling must be checked.
2. FM Global approved numbers and spans available on page 21.

3 N, NI, NA, NIA

Maximum Sheet Length 42'-0
Extra Charge for Lengths Under 6'-0
ICC ER-3415
FM Global Approved[2]





Interlocking side lap is not drawn to show actual detail.

SECTION PROPERTIES

Deck type	Design thickness in.	W psf	Section Properties				V_a lbs/ft	F_y ksi
			I_p in^4/ft	S_p in^3/ft	I_n in^4/ft	S_n in^3/ft		
N22	0.0295	2.26	0.659	0.382	0.884	0.433	2232	33
N20	0.0358	2.71	0.848	0.501	1.079	0.552	3287	33
N19	0.0418	3.15	1.045	0.597	1.260	0.659	4217	33
N18	0.0474	3.56	1.238	0.688	1.430	0.749	4771	33
N16	0.0598	4.46	1.683	0.893	1.807	0.944	5988	33

ACOUSTICAL INFORMATION

Deck Type	Absorption Coefficient						Noise Reduction Coefficient[1]
	125	250	500	1000	2000	4000	
3NA, 3NIA	.18	.39	.88	.93	.58	.39	0.70

[1] Source: Riverbank Acoustical Laboratories.
Test was conducted with 1.50 pcf fiberglass batts and 2 inch polyisocyanurate foam insulation for the SDI.

Acoustical deck (Type 3 NA, NIA) is particularly suitable in structures such as auditoriums, schools and theaters where sound control is desirable. Acoustic perforations are located in the vertical webs where the load carrying properties are negligibly affected (less than 5%).

Inert, non-organic glass fiber sound absorbing batts are placed in the rib openings to absorb up to 70% of the sound striking the deck.

Batts are field installed and may require separation.

VERTICAL LOADS FOR TYPE 3N

No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (PSF) / Load Causing Deflection of L/240 or 1 inch (PSF) Span (ft.-in.) ctr to ctr of supports										
			10-0	10-6	11-0	11-6	12-0	12-6	13-0	13-6	14-0	14-6	15-0
1	N22	11'-7	50 / 43	46 / 37	42 / 32	38 / 28	35 / 25	32 / 22	30 / 20	28 / 18	26 / 16	24 / 14	22 / 13
	N20	13'-2	66 / 56	60 / 48	55 / 42	50 / 37	46 / 32	42 / 28	39 / 25	36 / 23	34 / 20	31 / 18	29 / 16
	N19	14'-7	79 / 69	71 / 59	65 / 51	59 / 45	55 / 40	50 / 35	47 / 31	43 / 28	40 / 25	37 / 22	35 / 20
	N18	15'-11	91 / 81	82 / 70	75 / 61	69 / 53	63 / 47	58 / 42	54 / 37	50 / 33	46 / 30	43 / 27	40 / 24
	N16	18'-6	118 / 110	107 / 95	97 / 83	89 / 73	82 / 64	75 / 56	70 / 50	65 / 45	60 / 40	56 / 36	52 / 33
2	N22	13'-8	56 / 122	51 / 105	47 / 92	43 / 80	39 / 71	36 / 62	34 / 55	31 / 50	29 / 44	27 / 40	25 / 36
	N20	15'-6	72 / 152	65 / 131	60 / 114	55 / 100	50 / 88	46 / 78	43 / 69	40 / 62	37 / 55	34 / 50	32 / 45
	N19	16'-11	86 / 182	78 / 157	71 / 137	65 / 120	60 / 105	55 / 93	51 / 83	47 / 74	44 / 66	41 / 60	38 / 54
	N18	18'-1	98 / 211	89 / 182	81 / 158	74 / 139	68 / 122	63 / 108	58 / 96	54 / 86	50 / 77	47 / 69	44 / 62
	N16	20'-4	123 / 276	112 / 238	102 / 207	93 / 181	86 / 159	79 / 141	73 / 125	68 / 112	63 / 100	59 / 90	55 / 82
3	N22	13'-8	69 / 95	64 / 82	58 / 72	53 / 63	49 / 55	45 / 49	42 / 43	39 / 39	36 / 35		
	N20	15'-6	90 / 119	81 / 103	74 / 90	68 / 78	63 / 69	58 / 61	53 / 54	50 / 48	46 / 43		
	N19	16'-11	107 / 143	97 / 123	89 / 107	81 / 94	75 / 83	69 / 73	64 / 65	59 / 58	55 / 52		
	N18	18'-1	122 / 165	111 / 143	101 / 124	92 / 109	85 / 96	78 / 84	72 / 75	67 / 67	63 / 60		
	N16	20'-4	154 / 216	139 / 186	127 / 162	116 / 142	107 / 125	99 / 111	91 / 98	85 / 88	79 / 79		

Notes: 1. Minimum exterior bearing length required is 1.50 inches. Minimum interior bearing length required is 3.00 inches. If these minimum lengths are not provided, web crippling must be checked.
2. FM Global approved numbers and spans available on page 21.

Appendix C – Analysis 3

Appendix C.1 – Existing Conditions Plan

Existing Conditions Plan

University Engineering Building
Mid-Atlantic University, United States

Jeremy Feath

Analysis 3: Underground Spring

Appendix C.2 – Sump Pump Literature

SUMP PUMPS

HP33/HP50

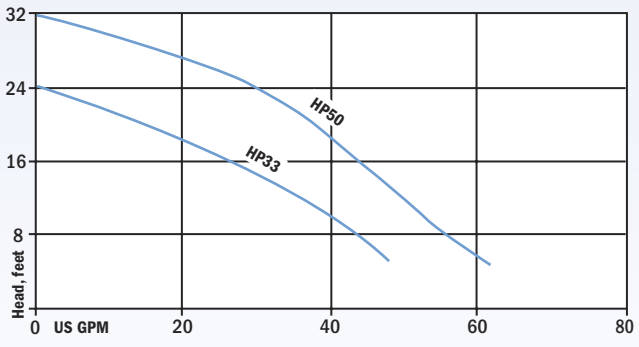
Ideal for applications with small diameter sump pits

Typical Application	Basement sumps, dewatering, light effluent, water transfer
Capacities	up to 62 GPM (235 LPM)
Heads	up to 32 ft. (9.8 m)
Electrical	1/3 HP, 115V, 1ø, 9.8A, 60Hz; 1/2 HP, 115V, 1ø, 12A, 60Hz;
Motor	1/3 or 1/2 HP shaded pole with thermal overload, 1550 RPM
Continuous Liquid Temperature	130°F (54°C)
Minimum Recommended Sump Diameter	10" (25.4 cm)
Automatic Operation	2-Pole float switch
Materials of Construction	Cast iron
Impeller	Thermoplastic, vortex type
Discharge Size	1-1/2" NPT (38.1 mm)
Solids Handling	1/2" (12.7 mm)
Power Cord	10' or 20', 16/3, SJTW-A, SJTW

Superior Features

- 2-pole switch design permits easier fit in sump pits as small as 10" in diameter
- Oil-filled motor for maximum heat dissipation
- Thermal overload protection, shaded pole motor with no starting switch or relay
- Carbon/ceramic seal protects motor against water leakage
- Lubricated ball bearings and shaft seal for longer service life
- Easy field-serviceable pump, intake screen volute base, switch and power cord
- Anti-airlock hole in base reduces labor

Performance



HTS33A1

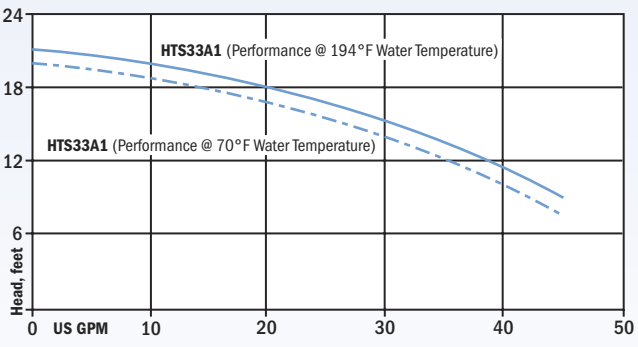
Submersible sump pump designed for high temperatures up to 194°F

Typical Application	Boiler blow-down, condensate pits and hot water transfer
Capacities	up to 45 GPM (170 LPM)
Heads	up to 21 ft. (6.4 m)
Electrical	115V, 1ø, 12.0 FLA, 60Hz
Motor	1/3 HP shaded pole with thermal overload, 1550 RPM
Continuous Liquid Temperature	194°F (90°C) with switch; 200°F (93°C) manual
Minimum Recommended Sump Diameter	18" (457.2 mm)
Automatic Operation	Wide-angle float switch (manual available)
Materials of Construction	Cast iron
Impeller	Cast iron
Discharge Size	1-1/2" NPT (38.1 mm)
Solids Handling	3/4" (19.1 mm)
Power Cord	20', 16/3, SJOOW-A/SJOW

Superior Features

- Easily field serviceable
- Oil-filled motor for bearing lubrication and maximum heat dissipation
- Thermal overload protection, shaded pole motor with no starting switch or relay
- Heavy cast-iron motor housing for cooler motor which extends the life
- Maintenance-free operation
- Wide-angle, mercury-free, high-temperature mechanical float switch
- Automatic piggyback models available but can be operated manually by plugging directly into outlet
- Cast-iron vortex impeller and volute passes 3/4" solids

Performance



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HYD10157 Rev12/10

Appendix C.3 – Waterproofing Membrane Literature

TAMKO®
BUILDING PRODUCTS
P.O. Box 1404 • Joplin, MO 64802
tamko.com

TAMKO WATERPROOFING, FENESTRATION FLASHINGS, UNDERLAYMENTS AND ACCESSORIES FIVE YEAR LIMITED MATERIAL WARRANTY (A LIMITED WARRANTY)

For a complete list of products covered under this limited warranty - see reverse side.

This limited warranty is personal to the original owner and is not assignable or transferable under any circumstances

TERMS AND CONDITIONS

TAMKO BUILDING PRODUCTS, INC. ("TAMKO"), warrants to the original consumer purchaser (the "Owner") that, subject to the conditions set forth herein, for a period of five (5) years from the date of purchase (the "Term") for the TAMKO product identified below ("Product"), if manufacturing defects in the Product cause the Product to lose its watertight integrity and leaks result, then subject to the conditions, exclusions and other provisions detailed below, TAMKO, at its sole option, will either (1) refund the original purchase price of the Product; or (2) provide the amount of Product necessary to make repairs. This limited warranty does not cover any cost or expenses associated with removal, excavation, or replacement of concrete or other materials in connection with the testing, repair, removal, or replacement of the Product. **This limited warranty applies to Product applied in strict accordance with, and as part of, TAMKO published application instructions in effect at the time of the application. This Product is sold AS IS and without warranty of any kind when used in any other application.**

THIS LIMITED WARRANTY APPLIES ONLY TO PRODUCTS INSTALLED IN THE UNITED STATES (EXCLUDING HAWAII AND ALASKA) AND CANADA (EXCLUDING QUEBEC AND NEW BRUNSWICK). ALL PRODUCTS INSTALLED IN LOCATIONS WHERE THIS LIMITED WARRANTY DOES NOT APPLY ARE SOLD "AS IS" AND WITHOUT WARRANTY OF ANY KIND, INCLUDING ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

CONDITIONS TO WARRANTY COVERAGE:
This limited warranty is additionally specifically conditioned upon the following matters, each and all of which shall be a precondition to any of TAMKO's obligations hereunder:

1. **PROOF OF PURCHASE:** Claims under this limited warranty will require proof of purchase by the Owner. TAMKO shall not be responsible for any claims without such proof of purchase.
2. **NOTIFICATION TO TAMKO:** Within thirty (30) days following discovery of any leaks alleged to result directly from manufacturing defects, the Owner must notify TAMKO of such leaks by certified mail at P.O. Box 1404, Joplin, Missouri 64802.
3. **COMPLIANCE WITH TAMKO INSTRUCTIONS, RECOMMENDATIONS AND LIMITED WARRANTY:** In no event shall TAMKO be liable under this limited warranty or otherwise unless the Product has been stored, handled, installed and maintained in compliance with TAMKO's application instructions, specifications and recommendations, and unless all of the terms and provisions of this limited warranty have been complied with.
4. **BUILDING AND STRUCTURE PLANS:** Because TAMKO does not practice engineering or architecture, neither the issuance of this limited warranty nor any review or inspection of the building, structure, plans, specifications or construction by a TAMKO representative shall constitute any warranty or representation by TAMKO with respect to the building, structure, plans, specifications or construction or in any way constitute an extension of the terms and conditions of this limited warranty. ALL SUCH WARRANTIES AND REPRESENTATIONS ARE EXPRESSLY DISCLAIMED.
5. **NONWAIVER:** The Owner agrees that any post application inspection of the Product by TAMKO or its authorized representative shall not constitute a waiver of any terms, conditions, or limitations set forth in this limited warranty, including, but not limited to, the requirement that the Product be installed in full compliance with the terms and conditions set forth in TAMKO's most recent published application instructions, specifications and recommendations. FURTHER, THE OWNER HEREBY ACKNOWLEDGES THAT IT IS SOLELY THE OWNER'S RESPONSIBILITY TO DETERMINE THAT THE PRODUCT HAS BEEN INSTALLED IN COMPLIANCE WITH (I) ANY CONTRACT SPECIFICATIONS PROVIDED BY THE OWNER TO THE CONTRACTOR AND (II) THE TERMS AND CONDITIONS OF THIS LIMITED WARRANTY.

EXCLUSIONS FROM COVERAGE: TAMKO shall not be liable under any circumstances for:

1. Damage to any building or structure, either exterior or interior, or any property contained therein of for injuries or damages of any kind whatsoever.
2. Leaks or damages resulting from Acts of God including, but not limited to, lightning, flood, wind, earthquake, hurricane, tornado, hail or other violent storm or casualty or impact of objects.
3. Leaks or damages resulting from insurrection, war, riot or vandalism, exposure of the Product to ionized radiation or contamination by radioactivity from any nuclear source, or chemical attack on the Product as the result of exposure to chemicals including, but not limited to, aliphatic or aromatic solvents, chlorinated hydrocarbons, turpentine, oils, or organic or inorganic polar materials.
4. Inadequate drainage or leaks or damages resulting there from.
5. Structural defects or failures in the building(s) or structure(s) to which the Product is applied.
6. Building or structural expansion or additions or reductions, settling, shifting, distortion, failure or cracking of foundations or other system components exceeding 1/16" or leaks or damage caused or attributable to traffic, or for damage attributable to alterations.
7. Leaks or damage resulting from any additional installation on or through the Product or flashing after the the initial installation that is not consistent with TAMKO application instructions.
8. Repairs or alterations to the Product or other system components or leaks or damages resulting there from, after the initial installation unless done in a manner prescribed by TAMKO application instructions.
9. Infiltration or condensation of moisture around or under the foundation or other system components.
10. Splitting, cracking, blistering, delamination or separation of the Product due to underlying or overlying materials.
11. Misuse or abuse of the Product or leaks or damages resulting there from.
12. Faulty or improper workmanship or application of the Product or leaks or damages resulting there from.
13. Damages to the building or structure, its contents, foundation, or other system components.
14. Removal, excavation, or replacement of concrete or other materials in connection with the testing, repair, removal, or replacement of the Product.
15. Leaks from any cause other than inherent manufacturing defect in the Product.

RIGHT OF INSPECTION:
TAMKO shall have a reasonable time after notification of a leak to inspect the Product, and if TAMKO determines there are manufacturing defects covered by this limited warranty, TAMKO shall have ninety (90) days after receipt of notification to either (1) refund the purchase price of the Product or (2) provide the amount of replacement Product necessary to make repairs. TAMKO shall not be liable for any cost of repair other than as specifically set forth herein.

(over)

NO WARRANTY MODIFICATION:
This limited warranty may not be modified except in a writing signed by TAMKO's President. No representative, employee, agent of TAMKO or any person, other than the President of TAMKO, has any authority to assume for TAMKO any additional or other liability or responsibility in connection with the Product or this limited material warranty.

NON-TRANSFERABILITY:
This limited warranty shall accrue and inure only to the benefit of the Owner of the Product and shall not be assigned, sold, or transferred in any manner whatsoever. Except where prohibited by law, any assignment, sale or transfer of this limited warranty or of the building to which the Product is applied shall extinguish all obligations of TAMKO contained herein or hereunder and all implied warranties and conditions including warranties and conditions of merchantability and fitness for a particular purpose.

MANDATORY BINDING ARBITRATION:
EVERY CLAIM, CONTROVERSY, OR DISPUTE OF ANY KIND WHATSOEVER (EACH AN "ACTION") BETWEEN YOU AND TAMKO (INCLUDING ANY OF TAMKO'S EMPLOYEES AND AGENTS) RELATING TO OR ARISING OUT OF THE PRODUCT SHALL BE RESOLVED BY FINAL AND BINDING ARBITRATION, REGARDLESS OF WHETHER THE ACTION SOUNDS IN WARRANTY, CONTRACT, STATUTE OR ANY OTHER LEGAL OR EQUITABLE THEORY. TO ARBITRATE AN ACTION AGAINST TAMKO, YOU MUST INITIATE THE ARBITRATION IN ACCORDANCE WITH THE APPLICABLE RULES OF ARBITRATION OF THE AMERICAN ARBITRATION ASSOCIATION (WHICH ARE AVAILABLE ONLINE AT www.adr.com OR BY CALLING THE AMERICAN ARBITRATION ASSOCIATION AT 1-800-778-7879) AND PROVIDE WRITTEN NOTICE TO TAMKO BY CERTIFIED MAIL AT P. O. BOX 1404, JOPLIN, MISSOURI 64802 WITHIN THE TIME PERIOD PRESCRIBED IMMEDIATELY BELOW.

ANY ACTION BROUGHT BY YOU AGAINST TAMKO WILL BE ARBITRATED (OR, IF ARBITRATION OF THE ACTION IS NOT PERMITTED BY LAW, LITIGATED) INDIVIDUALLY AND YOU WILL NOT CONSOLIDATE, OR SEEK CLASS TREATMENT FOR, ANY ACTION UNLESS PREVIOUSLY AGREED TO IN WRITING BY BOTH TAMKO AND YOU.

LEGAL REMEDIES: EXCEPT WHERE PROHIBITED BY LAW, THE OBLIGATION CONTAINED IN THIS LIMITED WARRANTY IS EXPRESSLY IN LIEU OF ANY AND ALL OTHER OBLIGATIONS GUARANTEES, WARRANTIES AND CONDITIONS EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTIES OR CONDITIONS OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, AND OF ANY OTHER OBLIGATION OR WARRANTY ON THE PART OF TAMKO. IN NO EVENT SHALL TAMKO BE LIABLE FOR CONSEQUENTIAL OR INCIDENTAL DAMAGES OF ANY KIND. SOME STATES AND PROVINCES DO NOT ALLOW EXCLUSION OR LIMITATION OF IMPLIED WARRANTIES AND CONDITIONS OR INCIDENTAL OR CONSEQUENTIAL DAMAGES, SO THE ABOVE LIMITATIONS OR EXCLUSIONS MAY NOT APPLY TO YOU. NO ACTION FOR BREACH OF THIS LIMITED WARRANTY OR ANY OTHER ACTION RELATING TO OR ARISING OUT OF THE PRODUCT, ITS PURCHASE OR THIS TRANSACTION SHALL BE BROUGHT LATER THAN ONE YEAR AFTER ANY CAUSE OF ACTION HAS ACCRUED. IN JURISDICTIONS WHERE STATUTORY CLAIMS OR IMPLIED WARRANTIES AND CONDITIONS CANNOT BE EXCLUDED, ALL SUCH STATUTORY CLAIMS, IMPLIED WARRANTIES AND CONDITIONS AND ALL RIGHTS TO BRING ACTIONS FOR BREACH THEREOF EXPIRE ONE YEAR (OR SUCH LONGER PERIOD OF TIME IF MANDATED BY APPLICABLE LAWS) AFTER THE DATE OF PURCHASE. SOME STATES AND PROVINCES DO NOT ALLOW LIMITATIONS ON HOW LONG IMPLIED WARRANTIES AND CONDITIONS LAST, SO THE ABOVE LIMITATION MAY NOT APPLY TO YOU. THIS LIMITED WARRANTY GIVES YOU SPECIFIC LEGAL RIGHTS AND YOU MAY ALSO HAVE OTHER RIGHTS WHICH VARY FROM STATE TO STATE AND PROVINCE TO PROVINCE. Invalidity or unenforceability of any provision herein shall not affect the validity or enforceability of any other provision, all of which shall remain in full force and effect.

IF YOU ARE NOT SATISFIED WITH THE TERMS AND CONDITIONS OF THIS LIMITED WARRANTY, RETURN ALL UNOPENED MARKETABLE PRODUCTS TO THE ORIGINAL PLACE OF PURCHASE FOR A REFUND.

Material purchased from _____

TAMKO product applied:

- ☐ TW 60
- ☐ TW Window & Door Flash
- ☐ TW Moisture Wrap
- ☐ TW Flash-N-Wrap®-25
- ☐ TW Flash-N-Wrap®-40
- ☐ TW Thru-Wall Flashing Membrane
- ☐ TW Metal and Tile Underlayment
- ☐ Moisture Guard Plus®
- ☐ TW Underlayment
- ☐ TWM-1 Mastic
- ☐ TWP-1 Quick Dry Primer*
- ☐ TWP-2 Water-Based Primer*

_____
Owner

_____
Contractor's Name

_____
Contractor's Address

_____
City, State and Zip

_____
Date of Application

*This limited warranty applies to TAMKO's primer products when they are used in conjunction with another TAMKO product listed above.

Retain this limited warranty with the contractor's receipt for future reference.

TAMKO® TW-60
Self-Adhering Sheet Waterproofing Membrane

APPLICATION INSTRUCTIONS

SURFACE PREPARATION

Concrete-
The surface must be dry and have a smooth (not broomed) finish and be free of form release agents, voids and sharp protrusions. Forms should be removed as quickly as possible. On a horizontal deck do not apply membrane when forms are in place, unless the forms are vented. Concrete should be allowed to cure for a minimum of 7 days. Curing agents containing wax, oil, or pigment should not be used. Any holes or voids must be repaired with non-shrink grout. Cracks greater than 1/16" in width shall be cut out to a minimum of 1/4" with a minimum depth of 1/4" and sealed using a sealant suitable for use with rubberized asphalt per sealant manufacturer, prior to the installation of the sheet membrane. **Note: On masonry surfaces mortar joints must be flush to the face of the concrete block or brick and have a thorough parge coat.**

Expanded / Extruded Polystyrene (EXP/XPS) or Insulated Concrete Forms (ICF)-
Ultraviolet radiation in sunlight causes a rapid deterioration of the EPS surface which can create a chalky or dusty layer which could interfere with the membrane adhesion. If this occurs, or if the surface of the EPS is dirty, brush off the excess dirt and dust to provide a clean dry surface for the application of the membrane. Joints and voids in the surface over 1/4" should be filled with non-shrink grout, expandable foam or compatible crack filler.

Priming-
Priming is required on concrete and masonry surfaces, but may not be necessary on EPS/XPS and ICF surfaces that are clean and dry and have not developed a dusty layer due to sun exposure. Select either TWP-1*** Primer or TWP-2 Water-Based Primer, as appropriate, for the surface to be primed. DO NOT USE products containing solvents on EPS/XPS or ICF surfaces. Thoroughly mix the primer. Apply at recommended coverage rates with a sprayer or long nap roller and allow to dry as specified in the primer's application instructions. Drying times may vary according to weather conditions.

Flashing-
All penetrations and drains must be flashed with TW-60 membrane, extending the membrane a minimum of 6" on all sides. All cracks and joints must be sealed with a sealant suitable for use with rubberized asphalt per sealant manufacturer, and flashed with a 12" wide strip of TW-60 membrane centered on the axis of the corners.

HORIZONTAL APPLICATION
Starting at the low point of the surface and working to the high point, install TW-60 membrane by simultaneously rolling the sheet into place while removing the release film. Side laps should be 2 1/2", and end laps should be 5". Stagger all end laps. All terminating edges should be sealed with TWM-1 Mastic. Roll the entire membrane as soon as possible with a minimum 75 lb. garden roller wrapped with indoor/outdoor carpet.

If a flood test is required by the design professional, it should be conducted before the application of a protection layer. Check for leaks and make repairs immediately. Before flood testing be sure the structure is capable of withstanding the dead load of the water. Re-test after repairs have been made.

When TAMKO TW-60 is utilized as a waterproofing membrane in accordance with TAMKO Waterproofing Construction Detail TW-10 "Typical Balcony / Entry / Breezeway Outside Edge Detail" flood testing of the installation is considered good practice. The decision regarding necessity of a flood test is the responsibility of a design professional. When utilizing TW-60 as a waterproofing membrane on horizontal applications for balconies - the balcony must have a built-in positive slope away from the wall.

VERTICAL APPLICATION
Install TW-60 Sheet Membrane in lengths of 8' or less. Overlap edge seams 2 1/2". On walls above 8', apply in 8' sections, starting at the lowest point with the higher section overlapping the lower section 5". Use heavy hand pressure or a suitable roller to press membrane firmly against wall.

Terminations when applying to a concrete surface:
TW-60 sheet should be installed over the top of a wall or over the edge of a slab. If the membrane must terminate on a vertical surface, use a reglet or counter flashing. Press terminating edge firmly with a hammer handle or similar tool. Apply TWM-1 Mastic to all terminating edges.

TW-60 Sheet Membrane shall be installed on the base of the foundation wall, over the edge of the footing and the terminating edge pressed firmly against the vertical surface of the footing. Apply TWM-1 Mastic to all terminating edges including both vertical and horizontal.

Note: Failure to use adequate pressure at terminating edges will result in poor seal, potential leak and may affect coverage under the limited warranty. The use of mastic is not a substitute for a good seal.

Terminations when applying to EPS / XPS and ICF:
Apply a thick (min 3/8") bead of sealant suitable for use with rubberized asphalt and EPS / XPS and/or ICF per sealant manufacturer, at the termination of the waterproofing membrane and smooth with a putty knife to seal the termination. A non-deteriorating termination bar is required at the head of the waterproofing membrane.

MEMBRANE PROTECTION
Vertical surfaces must be protected immediately following installation of the membrane. Horizontal surfaces should be protected immediately. If a flood test is required the horizontal surface shall be protected immediately following the flood test. If the flood test is delayed, a temporary protection layer must be installed to protect the membrane from future operations and other trades. When TW-60 is utilized as a waterproofing membrane in accordance with TAMKO Waterproofing Construction Detail TW-10 "Typical Balcony / Entry / Breezeway Outside Edge Detail" flood testing of the installation is considered good practice. The decision regarding necessity of a flood test is the responsibility of a design professional.

***WARNINGS AND HAZARDS**
TWP-1 contains combustible solvents. Avoid exposure to sparks, open flame, heat, and other forms of ignition. Use in well-ventilated areas. Avoid breathing vapors. Refer to MSDS for detailed product information and warnings.

TAMKO® TW-60

PRODUCT DATA

Self-Adhering Sheet Waterproofing Membrane

APPLICATION INSTRUCTIONS

(CONTINUED)

PROTECTION COURSE FOR USE WITH TAMKO TW-60 WATERPROOFING MEMBRANE

Horizontal Application Protection Course

For horizontal applications where membrane protection is required in TAMKO's application instructions, another manufacturer's protection course that is designed for horizontal installations may be used in conjunction with TAMKO's TW-60 waterproofing membrane, provided the minimum requirements shown below are satisfied.

Vertical Application Protection Course

For vertical applications where membrane protection is required in TAMKO's application instructions, another manufacturer's protection course that is designed for vertical installations may be used in conjunction with TAMKO's TW-60 waterproofing membrane, provided the minimum requirements shown below are satisfied.

Protection Course Minimum Requirements

Asphalt composition boards used as protection course shall comply with ASTM D6506 Standard Specification for Asphalt Based Protection Board for Below-Grade Waterproofing.

Cellular polystyrene insulation used as protection course shall comply with ASTM C578 Specification for Rigid, Cellular Polystyrene Insulation, Types IV, V, VI, VII, X, or XII.

Fan-folded extruded polystyrene insulation used as protection course shall have compressive strength exceeding 15 psi when tested in accordance with ASTM D1621 Test Method for Compressive Properties of Rigid Cellular Plastics and maximum water absorption of 0.4% when tested in accordance with ASTM C272 Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions.

Plastic drainage panels used as protection course shall have puncture strength exceeding 50 lbs when tested in accordance with ASTM D4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

BACK FILL

Back fill must be clean fill with no rocks, pails or wood. After back fill is in place, it must be tamped with a tamper to compress the fill.

REPAIRING MINOR DAMAGE TO THE TW-60 MEMBRANE

Patch Repair:

Minor damaged areas of TAMKO TW-60 Membrane that are no larger than 4" by 4" in size (e.g. tears, holes, fishmouths, and delaminations) can be repaired by installing a patch of TW-60 extending a minimum of 12" beyond the damaged area on all sides.

End Lap Repair:

Loose end laps no wider than 4" can be repaired by cutting and removing the loose material and applying a patch that extends 12" beyond the area on all sides.

A patch Repair or an End Lap Repair must begin with removal of dust, dirt, and other materials that may interfere with adhesion from the area receiving the patch. Remove or cut non-adhered, torn, or otherwise damaged membrane as necessary, creating a fully-adhered surface to receive the patch. The underlying substrate must not be damaged while performing a Patch Repair or an End Lap Repair.

Install the TW -60, applying sufficient pressure by hand or with a roofing seam roller to promote adhesion to the underlying material. Seal the edges of the patch by applying a 1/4" to 3/8" bead of TWM-1 mastic; smooth the bead with a trowel.

INSTALLATION OF TW-60 OVER PREVIOUSLY INSTALLED LAYER OF TW-60

A second layer of TAMKO TW-60 Self-Adhering Sheet Waterproofing Membrane may be applied over an existing layer of TW-60 provided that appropriate surface preparation of the existing material is successfully accomplished.

As required for direct installation to a substrate, the surface of the existing layer must be free of dust, dirt and other materials or conditions that could interfere with adhesion of the second layer. Irregularities in the installed TW-60 must be corrected prior to installation of the second layer; this includes removing or cutting non-adhered, torn , or otherwise damaged membrane or surface film. Take care to prevent damage to underlying substrates, such as insulated concrete forms, with these types of corrections. Side and end laps of the second layer must not coincide with side and end laps of the first layer.

The decision for surface suitability of the first layer is subjective and rests with the applicator; TAMKO assumes no responsibility for improper application (refer to TAMKO Waterproofing Limited Warranty) of the first or second layer, including improper application due to poor adhesion from an improper surface.

Upon installation of the second layer of TW-60, the first layer of TW-60 is recognized as part of the assembly substrate and considered "sold AS IS" and without warranty of any kind.

Failure to properly apply TAMKO TW-60 Self-Adhering Sheet Waterproofing Membrane according to the Application Instructions may affect coverage under the applicable 5-year limited warranty.

TAMKO® TW-60
Self-Adhering Sheet Waterproofing Membrane

CAUTION: This product contains crystalline silica. Crystalline silica has been classified as a "known" human carcinogen by the International Agency for Research on Cancer (IARC) and the National Toxicology Program. The National Institute for Occupational Safety and Health has concluded that the fumes of heated roofing asphalt are a potential occupational carcinogen. The physical nature of this product may help limit any inhalation or dermal hazard during application and/or removal. However, physical forces such as sawing, grinding or drilling during demolition work and heating or burning may increase the inhalation or dermal exposure hazard of this product. Take precautions to prevent breathing and contact with skin.

Information included in this product data sheet was current at time of printing. To obtain a copy of the most current version of this product data sheet, visit us online at tamko.com or call us at 800-641-4691.

This product is covered by a 5-year limited warranty. For information regarding or a copy of TAMKO's limited warranty, contact your local TAMKO representative, visit us online at tamko.com, or call us at 800-641-4691.

tamko.com

Corporate	220 West 4th Street, Joplin, Missouri 64801	800-641-4691
Central District	220 West 4th Street, Joplin, Missouri 64801	800-641-4691
Northeast District	4500 Tamko Drive, Frederick, Maryland 21701	800-368-2055
Southeast District	2300 35th Street, Tuscaloosa, Alabama 35401	800-228-2656
Southwest District	7910 South Central Expressway, Dallas, Texas 75216	800-443-1834
Western District	5300 East 43rd Avenue, Denver, Colorado 80216	800-530-8868

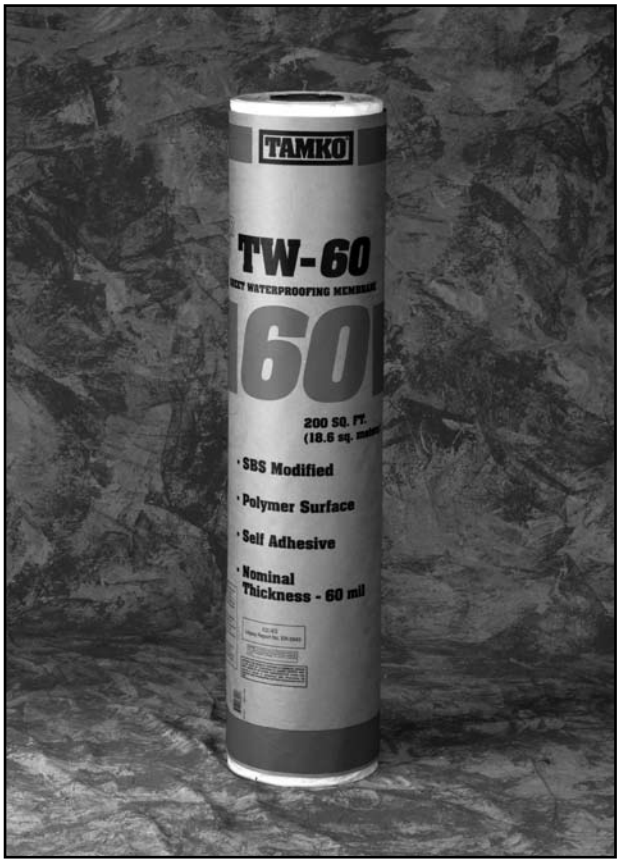
TAMKO® BUILDING PRODUCTS

TAMKO® TW-60
Self-Adhering Sheet Waterproofing Membrane

PRODUCT DATA

DESCRIPTION
TAMKO® TW-60 is a flexible, self-adhering rubberized asphalt sheet membrane with a polymer film on the surface and a removable treated release film on the adhesive side.

USES
TW-60 is especially well suited for below-grade waterproofing of foundation walls, tunnels, earth shelters, and similar structures. TW-60 is also suitable for waterproofing plaza decks, parking decks, balconies, and terraces.



ADVANTAGES
- Excellent tensile, elongation, and permeance characteristics.
- Rubberized asphalt sheet and polymer surfacing provide superior waterproofing protection.
- Treated release film for easier installation and handling.
- Available in factory pre-cut widths of 6", 9", 12", 18", and 39-3/8" rolls.
- High temperature resistance up to 240°F.
- Available in Winter and Summer Grade formulations.
- ICC-ES ESR-2260.

LIMITATIONS
- Membrane or primer must not be applied to damp, frosty or contaminated surfaces.
- Membrane must not be left exposed to sunlight for more than 30 days.
- Membrane must not come into contact with products containing coal-tar pitch.
- Best applied between the temperatures of 35°F and 90°F.

PRODUCT DATA*

Asphalt Modifier	SBS
Product Thickness	60 mil

Roll Width	Roll Size	Coverage per Ctn.	Rolls per ctn.
6"	6" x 61'	183 sq. ft.	6
9"	9" x 61'	183 sq. ft.	4
12"	12" x 61'	183 sq. ft.	3
18"	18" x 61'	183 sq. ft.	2
39-3/8"	39-3/8" x 61'	200 sq. ft.	1 roll/wrapper

*All values stated as nominal at time of manufacture.

TYPICAL PHYSICAL PROPERTIES

Property	Test Method	Typical Value
Tensile, Membrane	ASTM D 412 (C)	425 psi
Tensile, Film	ASTM D 882	6300 psi
Elongation**	ASTM D 412 (C)	600% (min.)
Permeance	ASTM E 96 (BW)	0.05 perms (max.)
Low Temp. Flexibility	ASTM D 1970 (modified)[1]	Unaffected @ -20°F
Crack Cycling (100 cycles)	ASTM C 836	Unaffected @ -15°F
Peel Strength	ASTM D 903	9.0 lb/in. width (min.)
Lap Adhesion	ASTM D 1876	5.5 lb/in. width
Puncture Resistance	ASTM E 154	60 lb. (min.)
Hydrostatic Head	ASTM D 5385	231 ft. (min.)
Resistance to Soil Organisms (Fungi)	ASTM E 154	No effect (Permeability)

**% elongation to ultimate failure of rubberized asphalt membrane.

[1] Testing done using the procedure in ASTM D 1970 with adhesive side away from the mandrel.

TAMKO® TW-60
Self-Adhering Sheet Waterproofing Membrane

PRODUCT DATA

DESCRIPTION
TAMKO® TW-60 is a flexible, self-adhering rubberized asphalt sheet membrane with a polymer film on the surface and a removable treated release film on the adhesive side.

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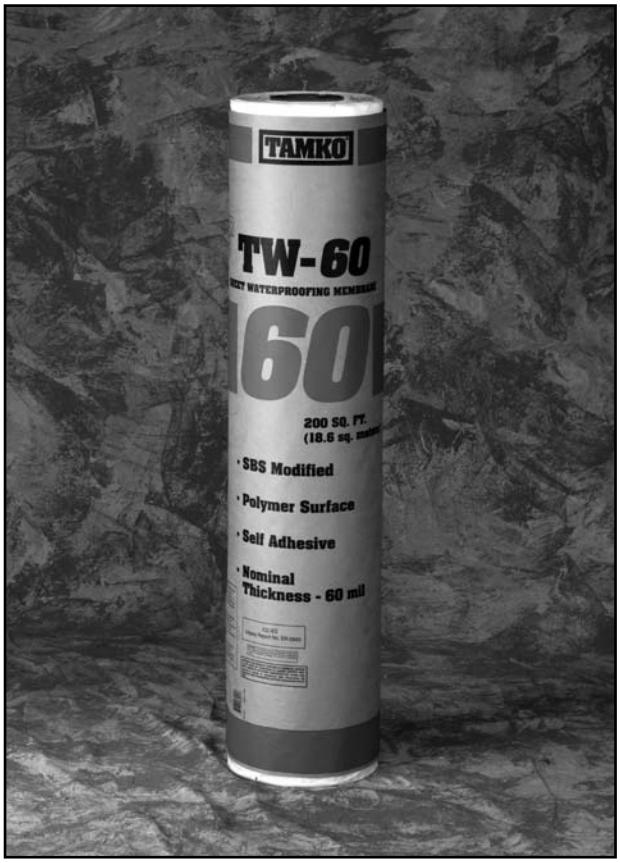

ADVANTAGES
- Excellent tensile, elongation, and permeance characteristics.
- Rubberized asphalt sheet and polymer surfacing provide superior waterproofing protection.
- Treated release film for easier installation and handling.
- Available in factory pre-cut widths of 6", 9", 12", 18", and 39-3/8" rolls.
- High temperature resistance up to 240°F.
- Available in Winter and Summer Grade formulations.
- ICC-ES ESR-2260.

LIMITATIONS
- Membrane or primer must not be applied to damp, frosty or contaminated surfaces.
- Membrane must not be left exposed to sunlight for more than 30 days.
- Membrane must not come into contact with products containing coal-tar pitch.
- Best applied between the temperatures of 35°F and 90°F.

PRODUCT DATA*

Asphalt Modifier	SBS
Product Thickness	60 mil

Roll Width	Roll Size	Coverage per Ctn.	Rolls per ctn.
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39-3/8"	39-3/8" x 61'	200 sq. ft.	1 roll/wrapper

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Resistance to Soil Organisms (Fungi)	ASTM E 154	No effect (Permeability)

**% elongation to ultimate failure of rubberized asphalt membrane.

[1] Testing done using the procedure in ASTM D 1970 with adhesive side away from the mandrel.

TAMKO® TW-60
Self-Adhering Sheet Waterproofing Membrane

APPLICATION INSTRUCTIONS

SURFACE PREPARATION

Concrete-
The surface must be dry and have a smooth (not broomed) finish and be free of form release agents, voids and sharp protrusions. Forms should be removed as quickly as possible. On a horizontal deck do not apply membrane when forms are in place, unless the forms are vented. Concrete should be allowed to cure for a minimum of 7 days. Curing agents containing wax, oil, or pigment should not be used. Any holes or voids must be repaired with non-shrink grout. Cracks greater than 1/16" in width shall be cut out to a minimum of 1/4" with a minimum depth of 1/4" and sealed using a sealant suitable for use with rubberized asphalt per sealant manufacturer, prior to the installation of the sheet membrane. **Note: On masonry surfaces mortar joints must be flush to the face of the concrete block or brick and have a thorough parge coat.**

Expanded / Extruded Polystyrene (EXP/XPS) or Insulated Concrete Forms (ICF)-
Ultraviolet radiation in sunlight causes a rapid deterioration of the EPS surface which can create a chalky or dusty layer which could interfere with the membrane adhesion. If this occurs, or if the surface of the EPS is dirty, brush off the excess dirt and dust to provide a clean dry surface for the application of the membrane. Joints and voids in the surface over 1/4" should be filled with non-shrink grout, expandable foam or compatible crack filler.

Priming-
Priming is required on concrete and masonry surfaces, but may not be necessary on EPS/XPS and ICF surfaces that are clean and dry and have not developed a dusty layer due to sun exposure. Select either TWP-1*** Primer or TWP-2 Water-Based Primer, as appropriate, for the surface to be primed. DO NOT USE products containing solvents on EPS/XPS or ICF surfaces. Thoroughly mix the primer. Apply at recommended coverage rates with a sprayer or long nap roller and allow to dry as specified in the primer's application instructions. Drying times may vary according to weather conditions.

Flashing-
All penetrations and drains must be flashed with TW-60 membrane, extending the membrane a minimum of 6" on all sides. All cracks and joints must be sealed with a sealant suitable for use with rubberized asphalt per sealant manufacturer, and flashed with a 12" wide strip of TW-60 membrane centered on the axis of the corners.

HORIZONTAL APPLICATION
Starting at the low point of the surface and working to the high point, install TW-60 membrane by simultaneously rolling the sheet into place while removing the release film. Side laps should be 2 1/2", and end laps should be 5". Stagger all end laps. All terminating edges should be sealed with TWM-1 Mastic. Roll the entire membrane as soon as possible with a minimum 75 lb. garden roller wrapped with indoor/outdoor carpet.

If a flood test is required by the design professional, it should be conducted before the application of a protection layer. Check for leaks and make repairs immediately. Before flood testing be sure the structure is capable of withstanding the dead load of the water. Re-test after repairs have been made.

When TAMKO TW-60 is utilized as a waterproofing membrane in accordance with TAMKO Waterproofing Construction Detail TW-10 "Typical Balcony / Entry / Breezeway Outside Edge Detail" flood testing of the installation is considered good practice. The decision regarding necessity of a flood test is the responsibility of a design professional. When utilizing TW-60 as a waterproofing membrane on horizontal applications for balconies - the balcony must have a built-in positive slope away from the wall.

VERTICAL APPLICATION
Install TW-60 Sheet Membrane in lengths of 8' or less. Overlap edge seams 2 1/2". On walls above 8', apply in 8' sections, starting at the lowest point with the higher section overlapping the lower section 5". Use heavy hand pressure or a suitable roller to press membrane firmly against wall.

Terminations when applying to a concrete surface:
TW-60 sheet should be installed over the top of a wall or over the edge of a slab. If the membrane must terminate on a vertical surface, use a reglet or counter flashing. Press terminating edge firmly with a hammer handle or similar tool. Apply TWM-1 Mastic to all terminating edges.

TW-60 Sheet Membrane shall be installed on the base of the foundation wall, over the edge of the footing and the terminating edge pressed firmly against the vertical surface of the footing. Apply TWM-1 Mastic to all terminating edges including both vertical and horizontal.

Note: Failure to use adequate pressure at terminating edges will result in poor seal, potential leak and may affect coverage under the limited warranty. The use of mastic is not a substitute for a good seal.

Terminations when applying to EPS / XPS and ICF:
Apply a thick (min 3/8") bead of sealant suitable for use with rubberized asphalt and EPS / XPS and/or ICF per sealant manufacturer, at the termination of the waterproofing membrane and smooth with a putty knife to seal the termination. A non-deteriorating termination bar is required at the head of the waterproofing membrane.

MEMBRANE PROTECTION
Vertical surfaces must be protected immediately following installation of the membrane. Horizontal surfaces should be protected immediately. If a flood test is required the horizontal surface shall be protected immediately following the flood test. If the flood test is delayed, a temporary protection layer must be installed to protect the membrane from future operations and other trades. When TW-60 is utilized as a waterproofing membrane in accordance with TAMKO Waterproofing Construction Detail TW-10 "Typical Balcony / Entry / Breezeway Outside Edge Detail" flood testing of the installation is considered good practice. The decision regarding necessity of a flood test is the responsibility of a design professional.

***WARNINGS AND HAZARDS**
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TAMKO® TW-60

PRODUCT DATA

Self-Adhering Sheet Waterproofing Membrane

APPLICATION INSTRUCTIONS

(CONTINUED)

PROTECTION COURSE FOR USE WITH TAMKO TW-60 WATERPROOFING MEMBRANE

Horizontal Application Protection Course

For horizontal applications where membrane protection is required in TAMKO's application instructions, another manufacturer's protection course that is designed for horizontal installations may be used in conjunction with TAMKO's TW-60 waterproofing membrane, provided the minimum requirements shown below are satisfied.

Vertical Application Protection Course

For vertical applications where membrane protection is required in TAMKO's application instructions, another manufacturer's protection course that is designed for vertical installations may be used in conjunction with TAMKO's TW-60 waterproofing membrane, provided the minimum requirements shown below are satisfied.

Protection Course Minimum Requirements

Asphalt composition boards used as protection course shall comply with ASTM D6506 Standard Specification for Asphalt Based Protection Board for Below-Grade Waterproofing.

Cellular polystyrene insulation used as protection course shall comply with ASTM C578 Specification for Rigid, Cellular Polystyrene Insulation, Types IV, V, VI, VII, X, or XII.

Fan-folded extruded polystyrene insulation used as protection course shall have compressive strength exceeding 15 psi when tested in accordance with ASTM D1621 Test Method for Compressive Properties of Rigid Cellular Plastics and maximum water absorption of 0.4% when tested in accordance with ASTM C272 Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions.

Plastic drainage panels used as protection course shall have puncture strength exceeding 50 lbs when tested in accordance with ASTM D4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

BACK FILL

Back fill must be clean fill with no rocks, pails or wood. After back fill is in place, it must be tamped with a tamper to compress the fill.

REPAIRING MINOR DAMAGE TO THE TW-60 MEMBRANE

Patch Repair:

Minor damaged areas of TAMKO TW-60 Membrane that are no larger than 4" by 4" in size (e.g. tears, holes, fishmouths, and delaminations) can be repaired by installing a patch of TW-60 extending a minimum of 12" beyond the damaged area on all sides.

End Lap Repair:

Loose end laps no wider than 4" can be repaired by cutting and removing the loose material and applying a patch that extends 12" beyond the area on all sides.

A patch Repair or an End Lap Repair must begin with removal of dust, dirt, and other materials that may interfere with adhesion from the area receiving the patch. Remove or cut non-adhered, torn, or otherwise damaged membrane as necessary, creating a fully-adhered surface to receive the patch. The underlying substrate must not be damaged while performing a Patch Repair or an End Lap Repair.

Install the TW -60, applying sufficient pressure by hand or with a roofing seam roller to promote adhesion to the underlying material. Seal the edges of the patch by applying a 1/4" to 3/8" bead of TWM-1 mastic; smooth the bead with a trowel.

INSTALLATION OF TW-60 OVER PREVIOUSLY INSTALLED LAYER OF TW-60

A second layer of TAMKO TW-60 Self-Adhering Sheet Waterproofing Membrane may be applied over an existing layer of TW-60 provided that appropriate surface preparation of the existing material is successfully accomplished.

As required for direct installation to a substrate, the surface of the existing layer must be free of dust, dirt and other materials or conditions that could interfere with adhesion of the second layer. Irregularities in the installed TW-60 must be corrected prior to installation of the second layer; this includes removing or cutting non-adhered, torn , or otherwise damaged membrane or surface film. Take care to prevent damage to underlying substrates, such as insulated concrete forms, with these types of corrections. Side and end laps of the second layer must not coincide with side and end laps of the first layer.

The decision for surface suitability of the first layer is subjective and rests with the applicator; TAMKO assumes no responsibility for improper application (refer to TAMKO Waterproofing Limited Warranty) of the first or second layer, including improper application due to poor adhesion from an improper surface.

Upon installation of the second layer of TW-60, the first layer of TW-60 is recognized as part of the assembly substrate and considered "sold AS IS" and without warranty of any kind.

Failure to properly apply TAMKO TW-60 Self-Adhering Sheet Waterproofing Membrane according to the Application Instructions may affect coverage under the applicable 5-year limited warranty.

TAMKO® TW-60
Self-Adhering Sheet Waterproofing Membrane

CAUTION: This product contains crystalline silica. Crystalline silica has been classified as a "known" human carcinogen by the International Agency for Research on Cancer (IARC) and the National Toxicology Program. The National Institute for Occupational Safety and Health has concluded that the fumes of heated roofing asphalt are a potential occupational carcinogen. The physical nature of this product may help limit any inhalation or dermal hazard during application and/or removal. However, physical forces such as sawing, grinding or drilling during demolition work and heating or burning may increase the inhalation or dermal exposure hazard of this product. Take precautions to prevent breathing and contact with skin.

Information included in this product data sheet was current at time of printing. To obtain a copy of the most current version of this product data sheet, visit us online at tamko.com or call us at 800-641-4691.

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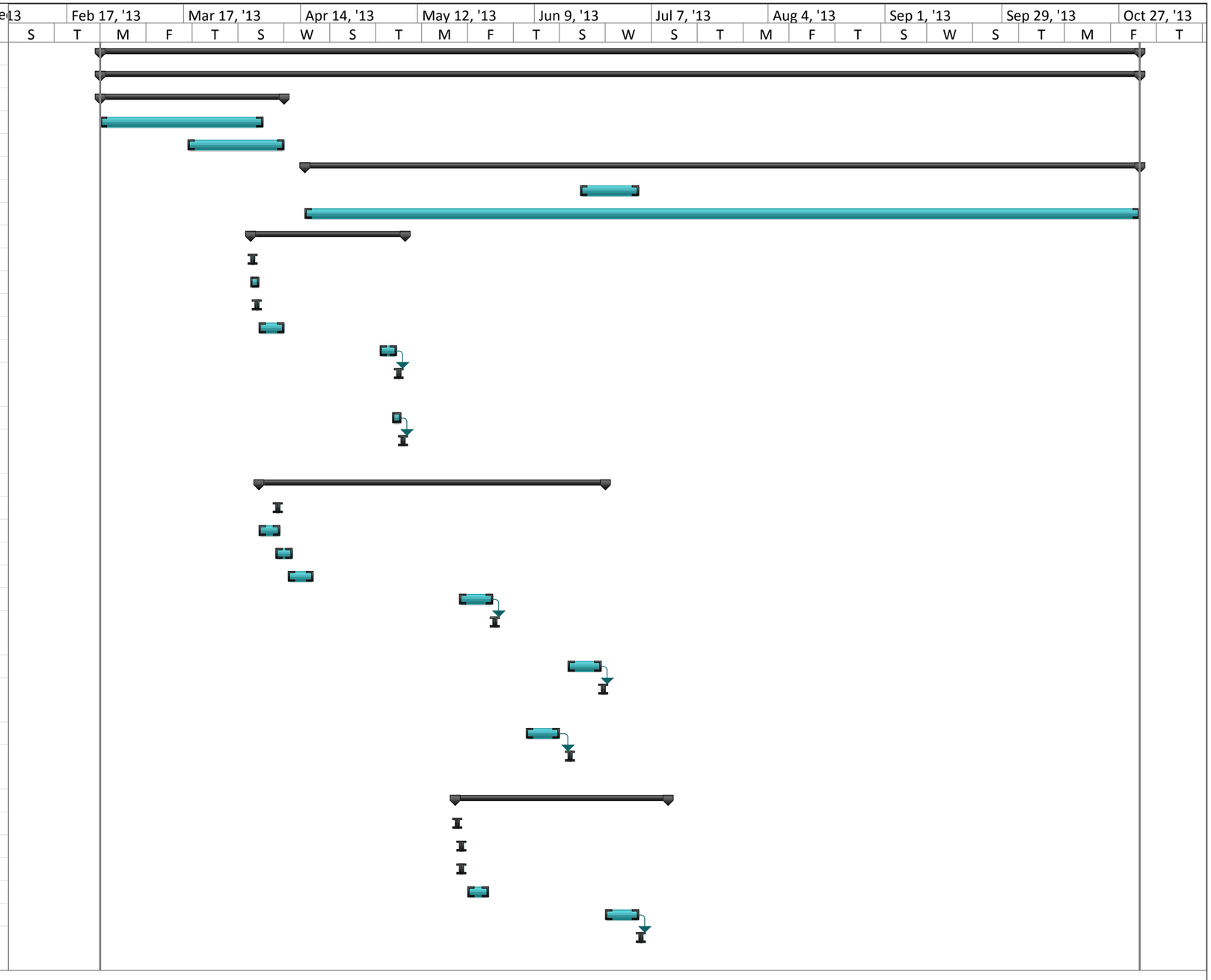
Western District	5300 East 43rd Avenue, Denver, Colorado 80216	800-530-8868

TAMKO® BUILDING PRODUCTS

Appendix C.4 – Updated Foundation Schedule

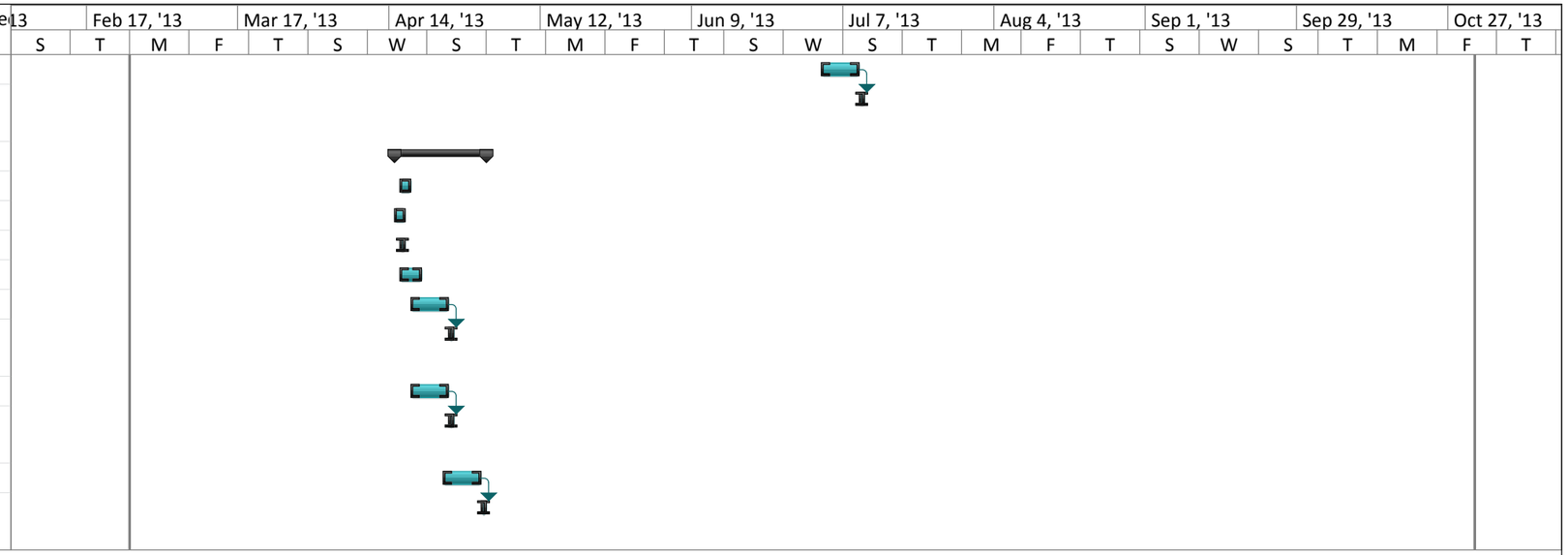
ID	Task Name	Duration	Start	Finish	Predecessors
1	**Building Caissons/Foundations**	**179 days**	**Mon 2/25/13**	**Thu 10/31/13**	
2	**Lab**	**179 days**	**Mon 2/25/13**	**Thu 10/31/13**	
3	**Caissons**	**32 days**	**Mon 2/25/13**	**Tue 4/9/13**	
4	Proof Coring Lab	29 days	Mon 2/25/13	Thu 4/4/13	
5	Caissons - Lab	17 days	Mon 3/18/13	Tue 4/9/13	
6	**U/G Plumbing Electrical**	**144 days**	**Mon 4/15/13**	**Thu 10/31/13**	
7	Install U/G Storm - Lab	10 days	Thu 6/20/13	Wed 7/3/13	
8	Install U/G Elect. Mains - Lab	144 days	Mon 4/15/13	Thu 10/31/13	
9	**N Line 1 - 6**	**27 days**	**Tue 4/2/13**	**Wed 5/8/13**	
10	Bituminus Seal	1 day	Tue 4/2/13	Tue 4/2/13	
11	Excavate Grade Beam	2 days	Tue 4/2/13	Wed 4/3/13	
12	Place Geo-Foam	1 day	Wed 4/3/13	Wed 4/3/13	
13	FRP Grade Beams	4 days	Thu 4/4/13	Tue 4/9/13	
14	FRP Walls N Line 1 - 3	2 days	Fri 5/3/13	Mon 5/6/13	
15	Install Sheet Waterproofing N Line 1 - 3	1 day	Tue 5/7/13	Tue 5/7/13	14
16	FRP Walls N Line 3 - 6	2 days	Mon 5/6/13	Tue 5/7/13	
17	Install Sheet Waterproofing N Line 3 - 6	1 day	Wed 5/8/13	Wed 5/8/13	16
18	**6 Line N - G**	**59 days**	**Thu 4/4/13**	**Tue 6/25/13**	
19	Bituminus Seal	1 day	Mon 4/8/13	Mon 4/8/13	
20	Excavate Grade Beam	3 days	Thu 4/4/13	Mon 4/8/13	
21	Place Geo-Foam	4 days	Mon 4/8/13	Thu 4/11/13	
22	FRP Grade Beams	4 days	Thu 4/11/13	Tue 4/16/13	
23	FRP Walls 6 Line N - L+	6 days	Wed 5/22/13	Wed 5/29/13	
24	Install Sheet Waterproofing 6 Line N - L+	1 day	Thu 5/30/13	Thu 5/30/13	23
25	FRP Walls 6 Line J - G	6 days	Mon 6/17/13	Mon 6/24/13	
26	Install Sheet Waterproofing 6 Line J - G	1 day	Tue 6/25/13	Tue 6/25/13	25
27	FRP Walls 6 Line L+ - J	6 days	Fri 6/7/13	Fri 6/14/13	
28	Install Sheet Waterproofing 6 Line L+ - J	1 day	Mon 6/17/13	Mon 6/17/13	27
29	**G Line 6 - 1**	**37 days**	**Tue 5/21/13**	**Wed 7/10/13**	
30	Excavate Grade Beam	1 day	Tue 5/21/13	Tue 5/21/13	
31	Bituminus Seal	1 day	Wed 5/22/13	Wed 5/22/13	
32	Place Geo-Foam	1 day	Wed 5/22/13	Wed 5/22/13	
33	FRP Grade Beams	3 days	Fri 5/24/13	Tue 5/28/13	
34	FRP Walls G Line 6 - 3	6 days	Wed 6/26/13	Wed 7/3/13	
35	Install Sheet Waterproofing G Line 6 - 3	1 day	Thu 7/4/13	Thu 7/4/13	34



Project: Updated Foundation Sche
Date: Tue 4/1/14

Task	Project Summary	Inactive Milestone	Manual Summary Rollup	Deadline	
Split	External Tasks	Inactive Summary	Manual Summary	Progress	
Milestone	External Milestone	Manual Task	Start-only		
Summary	Inactive Task	Duration-only	Finish-only		

ID	Task Name	Duration	Start	Finish	Predec
36	FRP Walls G Line 3 - 1	5 days	Wed 7/3/13	Tue 7/9/13	
37	Install Sheet Waterproofing G Line 3 - 1	1 day	Wed 7/10/13	Wed 7/10/13	36
38	**1 Line G - N**	**13 days**	**Mon 4/15/13**	**Wed 5/1/13**	
39	Place Geo-Foam	2 days	Tue 4/16/13	Wed 4/17/13	
40	Excavate Grade Beam	2 days	Mon 4/15/13	Tue 4/16/13	
41	Bituminus Seal	1 day	Tue 4/16/13	Tue 4/16/13	
42	FRP Grade Beams	4 days	Tue 4/16/13	Fri 4/19/13	
43	FRP Walls 1 Line G - K	5 days	Thu 4/18/13	Wed 4/24/13	
44	Install Sheet Waterproofing 1 Line G - K	1 day	Thu 4/25/13	Thu 4/25/13	43
45	FRP Walls 1 Line M.2 - N	5 days	Thu 4/18/13	Wed 4/24/13	
46	Install Sheet Waterproofing 1 Line M.2 - N	1 day	Thu 4/25/13	Thu 4/25/13	45
47	FRP Walls 1 Line K - M.2	5 days	Wed 4/24/13	Tue 4/30/13	
48	Install Sheet Waterproofing 1 Line K - M.2	1 day	Wed 5/1/13	Wed 5/1/13	47



Project: Updated Foundation Sche
Date: Tue 4/1/14

Task		Project Summary		Inactive Milestone		Manual Summary Rollup		Deadline	
Split		External Tasks		Inactive Summary		Manual Summary		Progress	
Milestone		External Milestone		Manual Task		Start-only			
Summary		Inactive Task		Duration-only		Finish-only			

Appendix C.5 – Mechanical Breadth

Land & Water
Conserving Natural Resources in Illinois
University of Illinois Extension • College of Agricultural, Consumer and Environmental Sciences

Sizing Up a Sump Pump

Water World

It's every homeowner's nightmare—a basement under water. Carpeting ruined. Belongings water-logged.

In the ongoing battle for dry basements, sump pumps play a pivotal role. A pump typically has to be replaced every few years. But if you size it correctly, you can extend the life of your pump. What's more, you can ensure that you have the right pump for the job.

When you're selecting the size of a sump pump, you need two pieces of information:

- System Capacity
- Total Dynamic Head (Static Head plus Friction Head)

Determine System Capacity

It's important that your pump can draw water out of the basin (or "sump pit") faster than water flows into it. Therefore, the first thing you need to measure is the amount of water that drains into the basin during a high-flow period.

During a heavy rain, stick a ruler in the basin and measure how many inches of water flow into the basin in 60 seconds. This will tell you how many gallons flow into the basin per minute, which is the System Capacity.

If you have an 18-inch-diameter basin, 1 inch of water is equal to 1 gallon. If you have a 24-inch-diameter basin, 1 inch of water is roughly equal to 2 gallons.

If you find out that more than 30 gallons of rainwater flow into the basin per minute, you're better off with a 24-inch-diameter basin. Also, the water level should never be allowed to go higher than the bottom of the inlet pipe of the foundation drain tile.

But what if you're building a new home and don't have a system installed yet? In that case, there are some general guidelines.

If you're building on sandy soil, plan for a system capacity of 14 gallons per minute for every 1,000 square feet of home.

If you're building on clay soil, plan for a system capacity of 8 gallons per minute for every 1,000 square feet of home.

Example: Using a ruler, you find that 18 inches of water flow into your sump pump basin in 60 seconds. Because you have the smaller diameter basin, each inch equals 1 gallon. Therefore, your System Capacity is 18 gallons per minute.

Determine Static Head

Total Dynamic Head is equal to Static Head (or "vertical lift") plus Friction Head.

Static Head is the vertical height that the water rises through the discharge pipe. Begin measuring from the point where water enters the sump pump. Then measure up vertically to where the pipe becomes horizontal (see Figure 1).

Example: Assume that the height from the sump pump to the point where the discharge pipe becomes horizontal is 13 feet. This is the Static Head.

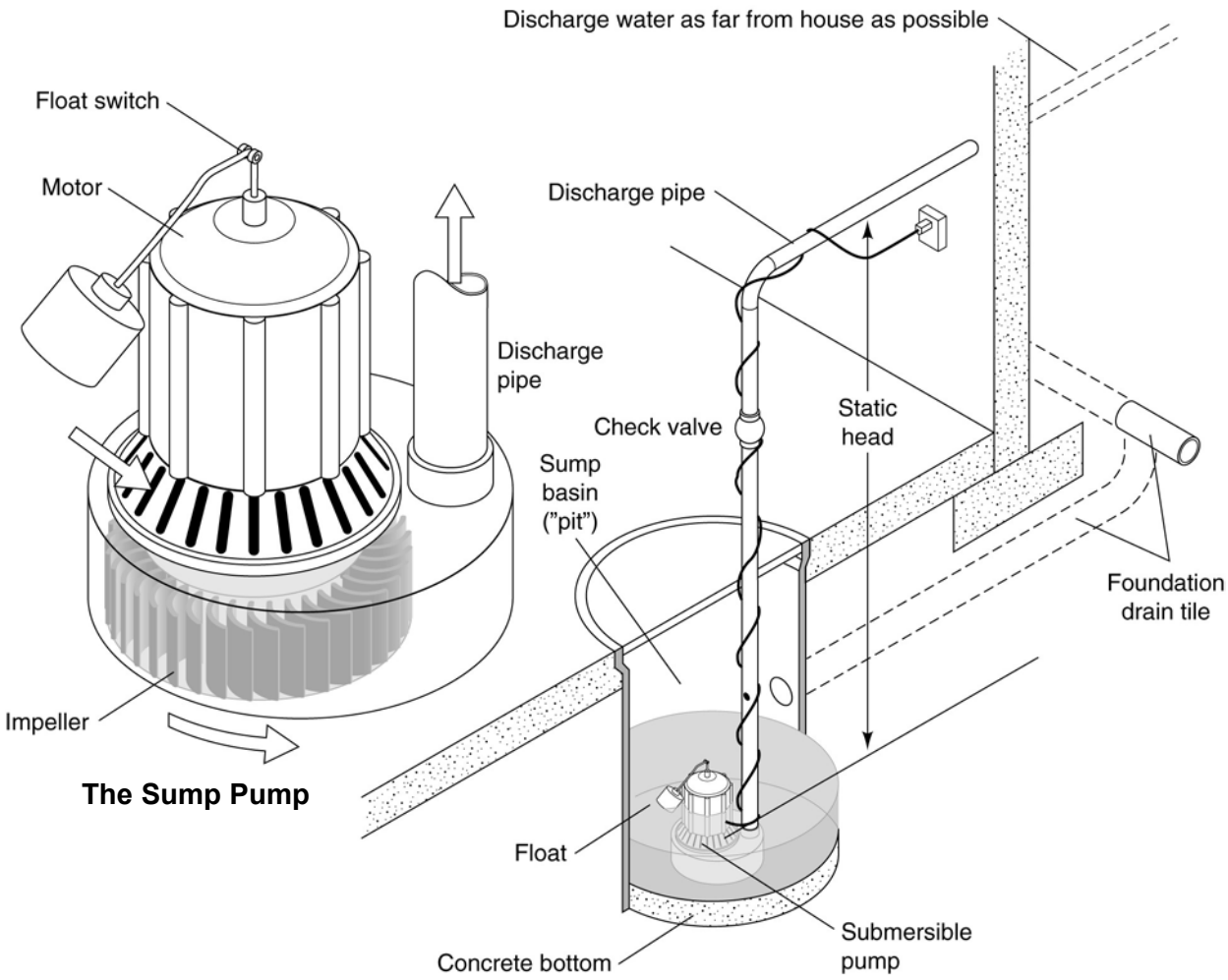


Figure 1. A Sump Pump System

Determine Friction Head

Determining Friction Head is more involved than finding out the Static Head. Friction Head is "the equivalent length of pipe" plus the actual length of pipe multiplied by the "friction loss" divided by 100.

What follows are four steps in figuring out Friction Head.

Step 1. Determine Equivalent Length of Pipe

The equivalent length of pipe is determined by how many pipe fittings are required for your system. Table 1 shows the equivalent length of pipe for various fittings, based on pipe size.

Example: Assume you're using 1¼-inch pipe, with three 90-degree elbows and 1 check valve. According to Table 1, three elbows add 10.5 feet of equivalent pipe, while the check valve adds 11.5 feet. The total equivalent feet of pipe is 22 feet.

Step 2. Determine the Actual Pipe Length

The actual pipe length is the length of pipe running horizontally out of the house. You should be able to see where the pipe discharges outside of the house.

Example: In our example, the length of discharge pipe is 100 feet.

Step 3. Determine Friction Loss

Friction loss is how much friction slows the flow of water moving through the pipe. Table 2 shows what friction loss occurs for different pipe sizes, depending on how many gallons of water per minute move through the pipe.

With Table 2, use your System Capacity number as the "gallons per minute."

Example: If 18 gallons per minute flow through your 1¼-inch pipe, it would create a friction loss of 5.25 per 100 feet of pipe.

Table 1. Equivalent Length of Pipe Due to Fittings

Pipe size	90˚ elbow	45˚ elbow	Check valve (swing pipe)
	⟵ (*feet*) ⟶		
1-1/4 inch	3.5	1.8	11.5
1-1/2 inch	4.0	2.2	13.4
2 inch	5.2	2.8	17.2
2-1/2 inch	6.2	3.3	20.6
3 inch	7.7	4.1	25.5

Step 4. Put it All Together

To figure out Friction Head, add the actual length of the discharge pipe to the equivalent length of pipe from fittings. Then multiply by the friction loss and divide by 100.

Example: Add the actual length of the discharge pipe (100 feet) with the equivalent length of pipe from fittings (22 feet) to get 122 feet. Then multiply this by the friction loss per 100 feet of pipe (5.25) and divide by 100.

122 x 5.25 ÷ 100 = 6.40 feet

6.40 is the Friction Head

Determining Total Dynamic Head

Now that we've determined Static Head and Friction Head, we simply add the numbers to get Total Dynamic Head.

Example: Add the Static Head (13 feet) to the Friction Head (6.40) to get a Total Dynamic Head of 19.40. Round up to 20 feet.

Table 2. Friction Loss Per 100 Feet of Plastic Schedule 40 Pipe

Gallons per minute (GPM)	Size of pipe				
	3/4"	1"	1-1/4"	1-1/2"	2"
4	3.7	1.2	.34		
6	7.9	2.4	.71	.33	
8	13.4	4.1	1.19	.56	
10		6.3	1.78	.83	
12		8.8	2.48	1.16	.34
14		11.7	3.29	1.54	.45
16			4.21	1.97	.58
18			5.25	2.41	.72
20			6.42	2.96	.88
25			10.39	4.8	1.38
30			13.6	6.27	1.81
35			19.2	8.82	2.4

Selecting the Pump

You now know your System Capacity (18 gallons per minute) and you know the Total Dynamic Head (20 feet). So you're ready to select a pump.

Most sump pumps have charts or curves that show how many gallons per minute they can pump for different lengths of head (See Figure 2). You've already determined how many gallons per minute must be pumped out. So look at these charts and make sure that the pump can handle that many gallons per minute.

You don't want a pump that is either too small or too powerful. If the pump is too small, it won't be able to keep up with water flowing

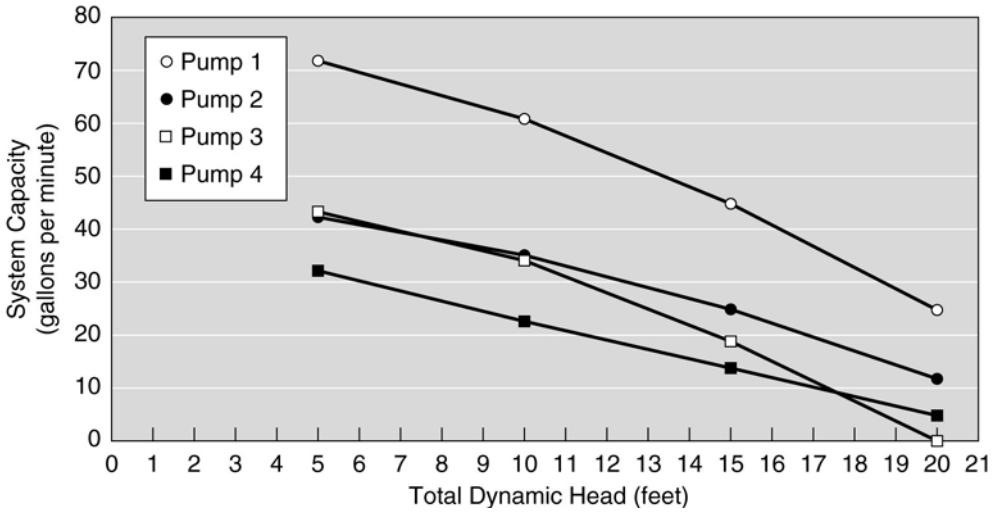


Figure 2. Sample Sump Pump Performance Curves

into the basin. If the pump is too powerful, it will "short cycle." This means the pump will start and stop frequently, which can cause premature pump failure.

Example: If the Total Dynamic Head is 20 feet, you have only one choice among the four pumps shown in Figure 2. Only Pump 1 will be able to handle 18 gallons per minute. The other three pumps can't handle any more than 12 gallons per minute.

Note that changing to a larger size of pipe in this case might lower the friction head enough to enable you to use a different pump (Pump 2 on the chart).

Maintaining the Pump

Periodically maintain your pump by doing the following:

- Check the operation of the float to make sure that its up-and-down movement is not restricted.
- Check the outside pipe when the pump is running to make sure it is discharging water. Several things can cause water not to be discharged, including a stuck check valve, the impeller loose on its shaft, or a plugged water pipe.
- If the pump has not had to run for several months, put enough water in the sump pump basin to trigger the float switch. That way, you ensure that the pump is still operating properly.

Other Considerations

Basin Size. Most residences have an 18-inch diameter basin—or sump pit. Basin size plays a part in how long the pump runs and how long it takes to fill up. If your existing basin is undersized and fills too quickly between pumping cycles, it may be worth installing a wider basin to accommodate the flow.

A cheaper option may be installing an adjustable float switch that allows the water to rise to a higher level before turning the pump on. Most pumps depend on having water in the pump at all times to lubricate and cool pump seals. So make sure the float switch is positioned to prevent the pump from running dry. Pedestal-type pumps have floats that can be adjusted to different lengths for operation.

Check valve. Select a swing-type check valve of the same size as the discharge pipe. Install it just above the sump pump. The check valve keeps the water in the discharge pipe from flowing back into the basin between pump cycles.

Electrical Circuit. The sump pump must be supplied with its own dedicated motor control circuit and breaker. Be sure to observe all applicable local electrical codes and ordinances when installing electrical circuits.

Land & Water

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Sources
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Appendix D – Analysis 4

Appendix D.1 – Facility Management Outline

I. Introduction

The goal of this guideline is to assist owners and facility managers with receiving and managing information that is required for maintaining and operating their buildings. This guide is geared more towards facility managers that have yet to implement BIM and the BIM process to a significant degree. The suggestions in this guide are based on the results of the research gathered from BIM Planning Guide for Facility Owners, Massaro, the University and Dr. Ed Gannon. For further information regarding the BIM process and the BIM guide, it is available for download at http://bim.psu.edu/Owner/Resources/contact_info.aspx.

II. Design Phase

a. End User Integration

For commercial building projects, the owner and/or facility manager will not be the only end user of their building or even use their building. When designing with the end user in mind, minimizes the number of post turnover issues with building tenants and maintenance personnel.

The first thing to do when designing the building is to determine who the all of the potential end users are for the building.

Example: The University Engineering Building

> *End Users: Undergrad. & Grad. Students, Faculty Members, Janitors, Maintenance Personnel, Department Heads, Potential Students and Academic Professionals, Alumni and Construction/Facility Management Employees*

End-users can provide input that will maximize the efficient use of space in the buildings and having this input early during design before anything is finalized will decrease the number of changes during construction. Depending on the building's function, the end users input will be more beneficial.

Example: The University Engineering Building

End User	***Input***
Faculty Members	*Laboratory space layout to create efficient usage of the space*
Grad. Students	*Office desk layouts and Laboratory space layouts*
Maintenance Personnel	*Storage space, finishes and other factors that make their jobs more efficient*
Clean Room Occupants	*Clean Room is properly laid out and sealed so that research can be conducted without any interruptions/issues*

b. Determination of Necessary Information

Prior to meeting with and determining a CM/GC, the facility manager/owner must know what information they need in order to operate their building after construction. In order to determine what information is necessary, certain factors must be analyzed, which are building function, systems, equipment and finishes. After finalizing these factors the information can be determined. If the building is MEP intensive then the focus should be on those systems and MEP equipment for maintenance. An architecturally intensive building with the focus on aesthetics, then the information should focus on finishes and cleaning and materials.

Example: The University Engineering Building

> *The UEB is a laboratory/research building with a heavy focus on the mechanical system. The information that the University should be focusing on includes how the mechanical system works, all the literature on the different air-handling units and other equipment and the layout of the MEP systems to better understand the layout of the building and where things are. The main feature of the UEB is the clean room, which should also be the focus of required information. Clean rooms are also very technical spaces with requirements different from standard lab spaces.*

III. Preconstruction Phase

a. Owner/FM – CM/GC Relationships

As with any construction project, the key to it being a success from both the owner/FM perspective and the CM/GC perspective is based on the relationship between the two parties. Delivering a completed building to the owner is one thing, but working together and providing what each party wants makes a project successful and leads to other future projects. In terms of information delivery, this relationship is even more important because the flow of that information between parties occurs more frequently.

Example: Penn State OPP

> *Penn State OPP uses a different kind of approach with their projects and their relationships with CMs. Penn State takes a more grass roots approach, according to Dr. Ed Gannon, where the facility management personnel acts a member of the project team, sharing information and taking part in meetings and working with the team. OPP's BIM Facilitators work closely with the project team helping to create and maintain the 3D building models. Penn State looks*

to have open relationships with the CMs allowing for CMs to provide feedback, positive or negative, on the FM process and help Penn State improve.

b. Front-End Planning

Along with having a positive relationship with CM/GC, performing as much front-end planning as possible can solve future problems before they occur. Once the CM/GC is picked having a kick-off meeting is necessary to get every member of the project team on the same page. At this meeting is the best time to lay the groundwork for what information the owner/FM needs when the building is completed. Giving the CM/GC notice at the beginning of the project, allows them time to make any plans and set goals to reach in order to provide the owner what is asked for.

c. Technology Implementation

In relation to the front-end planning, the decision to implement BIM is just as important. The decision to implement BIM depends on whether the owner and the CM/GC are familiar with the concept and a BIM execution plan has been created based on the specific project. The benefits of using BIM processes include having a 3D model that can store data for future use, coordination between trades to minimize issues and can streamline the construction process by planning and solving problems before they occur. If BIM is new to the owner, then the best thing to do is to slowly different aspects of the process and research it more. The best starting point is Penn State's BIM Planning Guide for Facility Owners to learn about the process and ways to begin implementing it.

Example: The University

Currently the University has not implemented BIM on their projects. At this point they are beginning to rewrite guidelines and standards to begin requiring contractors provide 3D models for use in information storage. Only through research and discussions with contractors has the University decided that BIM has enough benefits to begin the process of implementing it on projects. The key, that the University representative sees, as was discussed by Dr. Ed Gannon, is that BIM is not the information but a means to getting that information.

For those facility managers that don't have the means or the understanding of the BIM process, there are other alternatives in terms of implementing technology to aid in managing their buildings. Programs exist that have been designed specifically for facility management and some of those include Maximo, COBie, faciliCAD and others. Enough research must be conducted into which software would be most beneficial to use. A key to look at is, if there are multiple buildings to maintain, such as universities, then using software that has the capabilities to store information on all the buildings in one central location is the most efficient. Mobile integration is another aspect to research. Tablets

and smart phones have begun to dominate the public conscious and with this growing trend, the abilities of these devices have grown. Linking mobile devices to computer software has the means to save time and money for the facility manager.

IV. Construction Phase

a. Updates and Progress

Enough preparation during preconstruction makes information delivery less of an issue during construction. At this point, the owner should be meeting with the CM/GC on a regular basis to check progress and receive updates. This is also the perfect time for communication between the two parties if questions arise, they can be answered. Depending on the software used by the owner, Maximo, etc., the CM/GC might have to spend the entire construction process preparing documentation for the owner during the turnover process.

Example: Massaro on the University Engineering Building

> *According to the project manager, the project team is collecting necessary drawings, equipment information, warranties, etc., throughout the construction process so that the information is easily available when the O&M Manuals will be created. Also Massaro created a 3D model of the MEP and structural systems for coordination purposes with the subcontractors.*

V. Commissioning and Turnover

a. Training

Depending on the building systems and their complexity, the need to train operations personnel is apparent. Mechanical equipment can be some of the most crucial and at the same time difficult equipment to fully understand. Training sessions must be scheduled in advance of building turnover, because vendors and subcontractors must be coordinated along with operations personnel to educate them on the equipment and systems and train them to properly operate and maintain said items. Providing the right training and education for the facility management personnel in conjunction with the right facility management software will expedite future maintenance work orders.

Example: The University Engineering Building

> *After speaking with both the University representative and Massaro's project manager, both discussed the training policy used by the University. All training sessions are the obligation of Massaro to schedule and coordinate subcontractors and vendors. The vendors are brought in to show personnel how to operate the equipment and different typical maintenance procedures. One of the main training sessions will be for the air-handling units, with all the units being custom made to handle the two separate mechanical systems. At this*

point Massaro has begun the early stages of determining the training required and tentatively scheduling sessions.

b. Information Delivery

This occurs during the actual turnover process. The culmination of all the planning and information gathering will be condensed to either hard copy binders or digital formats. With the growing reliance on technology, facility managers should require digital copies of all the O&M manuals and other information. If BIM was implemented and a 3D model was created, the model would be given to the owner/FM based on the terms of the contract between the CM and owner. Once the FM has the information it is up to them, or the CM, again depending on the contractual language, to input the data into whatever software is used for access by operations personnel.

Example: Penn State University

Penn State uses IBM's Maximo Asset Management software for the operation and maintenance of their buildings. Part of the building turnover and early lifecycle process is to input all of the information received from the CM into Maximo. From this point, data collection on new buildings can begin and the building lifecycle can continue.

c. Building Maintenance and Operation

Part of the building lifecycle process is maintenance and operation. The expectation from the owner, end users and facility management is that the building will function with as little need for maintenance as possible. Since this is not possible and nothing is built perfectly, managing the maintenance to make it as efficient as possible is the next best expectation. The combination of all the steps taken prior to this stage will put systems in place that create efficiency and make the building lifecycle as profitable as possible.

Appendix D.2 – Massaro Project Manager Interview

Q: ***Have you had conversations with WVU about certain things they expect of Massaro when the building is turned-over, if so what are those things they are looking for?***

A: *So far, not really. This is mainly a topic that we will discuss with the University closer to the end of the project. Massaro does have a system in place that we follow when turning over any project. That includes making hard copy binders of all O&M material, warranties, manuals, all drawings and emergency contacts, etc.*

Q: ***Do you plan on allowing the University to have access to the 3D model for maintenance purposes after construction?***

A: *Actually, at first the University didn't want the model or have to pay for it, but I just recently gave a presentation to them on BIM and 3D modeling in general and they now interested in working towards integrating more technology within their facility management process. If they were to want the model for use it would have to be cleaned up and have more added to include the rest of the details of the UEB.*

Q: ***Do you implement any facility management software early during construction based on an owner's needs, not AERB specific?***

A: *We don't use any software, this would be something that a specific owner asks for as a service, but most of the clients we work with have not asked us to do anything like that.*

Appendix D.3 – University Project Manager Interview

Q: ***When beginning a new project, does the University meet with the CM or GC and discuss expectations of what information that needs to be turned-over with the building?***

A: *The University uses only GC's on our projects, but there is a kick-off meeting at the beginning of the project to go over anything from questions to concerns and expectations for the project as a whole, not so much what we expect at the end information-wise. We typically save those discussions for later during the project.*

Q: ***In the case of the UEB, or other lab/research type buildings, do you consult faculty and other end users for their input of space layout and other design choices?***

A: *Yes, we believe that having some faculty input in terms of things that would work and don't work in terms of them performing their job, but in terms of office space and things like that, we have set design standards that certain faculty offices can only be so big, SF-wise. We also have maintenance and facilities personnel look at things like storage, equipment needs, floor finishes and ask for their input on how to make their jobs more efficient and allow the building to operate smoothly.*

Q: ***Is there an official guideline that mandates the information and expectations that a GC must deliver/meet?***

A: *Yes, this is posted online and made available to all contractors on any given project, so they know what they must do.*

Q: ***Is there a training protocol for operations personnel to be able to navigate and find information as needed?***

A: *Formal training on any equipment and systems is the responsibility of the GC on the project. They go through scheduling with us and vendors to coordinate times and we expect any manuals and such with the rest of the building info at the end of the project. We are currently working on ways though to improve are training guidelines and to find ways to make the training more beneficial.*

Q: ***What is one thing that you would prefer GC's do in terms of info delivery that they don't already do?***

A: *Mainly, improve training and quality control throughout the whole building process. It's the little things at this point and delivery is pretty standard.*

Q: ***Has the University thought of incorporating the BIM process, to any degree, for building projects?***

A: *We actually just had Massaro give a presentation on the potential of BIM and use of technology so it is something we are currently looking into, but will slowly begin to incorporate certain aspects.*

Appendix D.4 – Dr. Ed Gannon Interview

Q: ***Does OPP work with contractors early to determine what information/deliverables you want?***

A: *We mostly use CMs now and we bring them on for preconstruction services. That way we have the CM and the designer work together and we have been using lean, to determine what info Penn State needs. We do this by pulling the info that we need and by doing that we eliminate what we don't need because we don't have the CM or designer pushing information on us, that doesn't move anything forward.*

Q: ***What Facility Management software does OPP use?***

A: *We use Revit and Autodesk Suite mainly for the modeling side of things and Maximo Facility Asset Management Software to handle the information gathering and sorting. We are currently trying to develop a link between the two to allow us to access information on one model from another have the information only one click away, rather than having both programs running and switching between the two. We want to be able to store the data on the models so that only the model needs to be looked at.*

Q: ***When it comes to lab/research buildings, do you have faculty provide input for space layout and other things?***

A: *Definitely, having faculty give input is extremely important. Up to this point they were given 2D drawings to look at and provide feedback on feasibility but a lot of them had difficulty taking that 2D drawing and picturing a 3D image, so we had lots of owner requested change orders. Now that we have these 3D models, with entire layouts and finishes modeled, we can walk them through the model and now the number of change orders has decreased.*

Q: ***How often do you meet with CMs during a project's duration to go over final items?***

A: *Before we would meet often, but now that OPP has shifted toward hiring CMs, we go for the best possible one that we can form a relationship with that goes past whatever project they are working on. We want to have an open relationship where collaboration increases and the CMs feel more comfortable working with us and have that back and forth mentality when working together. We have BIM facilitators on each project that are almost just another member of the project team. We are trying to get things on a grass roots level and hope that the relationships we build lead to repeat work and that makes the overall process easier.*

Q: ***Is there anything you wish CMs would do, that they don't already do?***

A: *Speaking of the open relationship mentality, I wish that CMs would give more valid criticisms on how we are doing our job. We want to know if we can do something better or if something we are doing just flat out does not work. We want to move towards Integrated Project Delivery.*

Appendix D.5 – Maximo Brochure

IBM Software

Understanding the impact and value of enterprise asset management

Implementing IBM Maximo Asset Management to enable your smarter physical infrastructure

IBM

Highlights

- Collect, consolidate and analyze essential information on all types of assets
- Improve operations through better asset availability, reliability and asset utilization
- Significantly extend the value of assets and increase flexibility
- Extend the useful life of all assets or equipment, improve return on investment and defer new purchases
- Unify processes for wide-ranging asset management functions across multiple sites

Introduction

Perhaps one of the biggest challenges in asset-intensive industries is how to effectively manage all their different types of assets—without creating a huge management workload that erodes the bottom line. Enterprise asset management (EAM) processes and solutions are big business due to the inherent complexity of this problem.

In developing or manufacturing a product, or delivering a service for a market, asset-intensive organizations must constantly track, assess and manage an extraordinarily wide range of physical, technology and human assets. Organizations in asset-intensive industries must manage both inventory and production; repair machinery; hire and schedule employees; deploy and manage their IT infrastructure; and maintain physical plants, their linear infrastructure or rolling assets. To further complicate matters, technology infrastructures are tremendously complex, typically running applications and data in silos that can limit the effectiveness of cross-organizational operations and efficiencies.

These organizations must deal with continually aging physical assets—from power plants to railroad bridges to sewer systems, or from generators to electronic devices such as handheld computers—that require ongoing maintenance and repair, since asset performance and the resulting quality of the company's products are impacted by the reliability of the asset or equipment. The increased need for asset maintenance and its management therefore can have a direct impact on customer satisfaction. This applies to processes, as well—as production, maintenance or service processes age and erode, end goods or service output may not be produced or delivered to the quality standards that were originally specified.

Managing human resources—the most valuable asset of all—comes with its own special set of challenges. Long-term employees, for example, are continually edging toward retirement, which can mean a loss of knowledge and skills—and the expense of training new employees.

Despite these challenges, an organization's products or services must constantly evolve to meet customer demands. Issues such as increased globalization; commoditization and competition; compliance with industry and government regulations; green and sustainable operations; health and safety in the workplace; eroding margins; and the resulting higher costs of doing business all contribute to this phenomenon.

So, how can an organization hope to both control assets and remain profitable? Successful organizations adapt to change by improving their operations and enabling flexibility and agility. And asset management can be a significant factor in their success. One critical step in rising to the challenge of change, and in controlling the complex asset environments necessary for bottom-line results, is to unify processes that manage wide-ranging functions across an organization's multiple sites—while optimizing production and service systems within each site.

It is clear that enterprise asset management is critical to the health of an organization. If handled correctly, it can be the key to continued operations in times of reduced budgets. It can help extend the useful life of equipment, improve return on investment and defer new purchases.

On today's smarter planet, where assets are becoming more and more *instrumented*, *integrated and intelligent*, an effective asset management solution can help organizations reach these goals by collecting, consolidating and analyzing information—and then putting information to use—across assets.

Introducing the IBM Maximo® Asset Management solution, which provides the key to better managing your physical infrastructure assets. This brochure offers insight you can leverage to make better decisions around all aspects of asset management, and describes how the Maximo Asset Management solution can move you toward this goal.

Defining asset management

The term *asset management* is defined by the PAS 55 industry standard as " … systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan."

There are different levels at which critical or strategic assets can be identified and managed—ranging from discrete assets to more complex functional asset systems, networks, sites or portfolios.

Asset management focuses on all types of assets, varying from critical or strategic physical assets to human assets.

Figure 1: Enterprise assets encompass many different types.

Physical assets, which are part of an organization's infrastructure, are positioned in the following four classes:

- Plant and production (occurring, for example, in industries such as oil, gas, chemicals, mining, manufacturing, pharmaceuticals, food, electronics and power generation)
- Infrastructure (including railways, highways, telecommunications, water and wastewater, and electric and gas distribution networks)
- Transportation (for military, airlines, trucking, shipping, rail and other use)
- Real estate and facilities (for example, in offices, schools and hospitals)

The human asset perspective provides a broad view of personnel motivation, expertise or skills, roles and responsibilities, as well as insight into leadership teams within the organization.

Maximo Asset Management provides an integrated approach to managing these discrete or complex assets, to help organizations overcome challenges rooted in their aging infrastructures or human assets and in their siloed or disconnected systems. By breaking down multiple silos of non-standard, non-integrated systems, an *integrated approach* can help align operations with overall business objectives.

Such an integrated approach can also support long- and short-term planning—controlling inventory, for example, to better meet demands. It can enable preventive and condition-based asset maintenance. It can help manage vendors with comprehensive support for a full range of contracts and full support for managing service agreements.

Building on the enterprise asset and facilities foundation

There are many reasons for the increasing demand for better asset management. When organizations raise the importance, risk, quantity and/or cost of their corporate critical or capital assets, they often see a corresponding rise in interest by management to better maintain control and visibility of all these assets.

In addition, governments, regulatory bodies, shareholders and other key stakeholder groups have increased the pressure on organizations in both the public and private sectors to be able to locate and track asset whereabouts. The higher the risk or opportunity cost in not knowing where an asset is located, the greater the incentive for management to implement an asset tracking system. Enterprise asset management can provide real-time insight or visibility into all physical assets, as well as across the maintenance, repair and overhaul (MRO) supply chain.

EAM foundational capabilities—such as tracking, monitoring and managing information around asset reliability, asset utilization and performance, as well as information around the services to execute this type of information—should be integral in managing a company's smarter physical infrastructure.

These capabilities are included in two categories of activities: asset management and facilities management. The following diagram depicts the points of focus within these categories which are supported by the Maximo Asset Management solution portfolio.

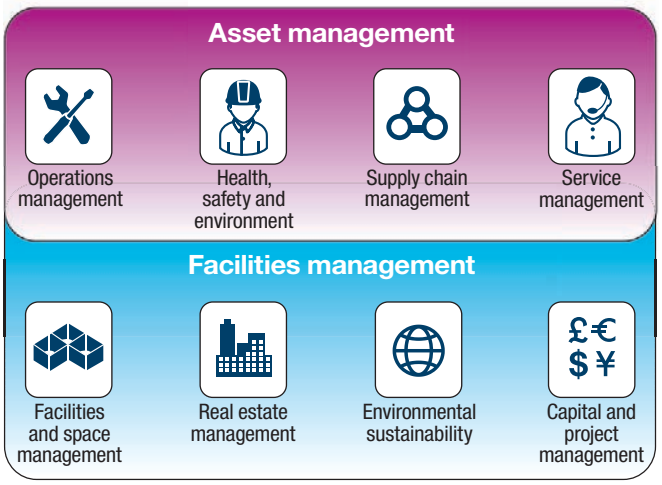

Figure 2: A robust set of enterprise capabilities is designed to meet the demanding needs of asset-intensive organizations.

Asset management

- **Operations management**—An effective enterprise asset management solution must manage and optimize the use of all assets to achieve greater asset availability, reliability and performance. The result is the ability to extend the asset's life because assets are better maintained. The ability to gather and analyze data about asset operations allows an organization to move from corrective (repairs made after a problem occurs) to preventive (maintenance dictated by a schedule based on past experience) to predictive maintenance (performed because data for a particular asset indicates that a failure is imminent).
- **Health, safety and environment**—The primary objective of health, safety and environment initiatives is to reduce overall risk, to comply with appropriate regulations and to create a safe yet efficient operating environment in which assets are used. Achieving this objective is as much about standardizing health, safety and environmental practices and integrating these practices with day-to-day operations management.
- **Supply chain management**—As traditional business assets become more technology-enabled, operations and IT functions are increasingly converging in today's changing business and technology environments. As a result, one way to manage operational applications more effectively and efficiently is to consolidate them. Companies seeking to better manage their supply chains must:
  - Find support that is able to manage all types of assets and asset maintenance information
  - Establish a single technology system to manage all types of assets and asset information—production, linear, facilities, transportation and IT—including calibration support and use of mobile capabilities
  - Have an integrated asset management solution that enables optimal return on assets, complies with regulations and helps minimize risk
  - Be able to develop smarter processes and to provide users with an innovative, fully integrated supply chain management system designed for asset-intensive industries
- **Service management**—Service management enables end users to submit new service requests for the deployment or use of assets, as well as track and update open service requests. This supports service management best practices through service desk capabilities. And it can align asset management goals and priorities in a manner that best supports overall business objectives. By infusing comprehensive service level management into an asset management practice, organizations can:
- Define service offerings to help improve organizational communication and verify that the services provided are those required to support the business
- Establish service level agreements (SLAs) to help increase communication between the organization and the business units or external customers, helping to align service levels with business objectives
- Monitor service level delivery proactively against metrics to avoid missing service level commitments
- Implement escalation procedures to properly manage resources to achieve service level commitments

It is also recommended that organizations have enhanced control over the service contracts they have with vendors, suppliers or customers. Integrated contract management provides comprehensive support for purchase, lease, rental, warranty, labor rate, master, blanket and user-defined contracts. Contract correlation links SLAs to vendor contracts, helping organizations identify unreliable vendors and low-quality products. It also enables them to reference SLA performance metrics when renegotiating vendor terms.

> *" IBM Maximo Asset Management helps us better plan and find the optimum balance between maintenance and operations. This will help us increase the uptime of our assets and reduce inventory costs to increase our profits."*
>
> —Marc Boer, manager, plant and management support, Royal Boskalis Westminster, The Netherlands

Facilities management

- **Facilities and space management**—This type of management refers to maintaining sustainable building operations by improving planning to ensure optimal use of space for offices, production floors, data centers, research laboratories and other physical spaces to enhance worker productivity. Facilities and space management can provide aggregated and processed information that includes a broad range of data to solutions for monitoring building conditions and maintenance from specific pieces of equipment operating at specific physical locations.
- **Environmental sustainability**—Managing assets for environmental sustainability can help an organization meet cost and regulatory drivers for energy efficiency by providing advanced abilities to analyze the energy usage of building systems in real time. The facilities management components of an EAM system can include automated solutions that can identify and suggest opportunities for energy savings in areas such as energy consumption, carbon management and greenhouse gas emissions.
- **Real estate management**—This type of management provides a clear view of strategic real estate objectives through portfolio plans and streamlines the implementation of these plans through integrated life-cycle processes. It tracks and manages real estate contract obligations, critical lease information required for reporting against federal guidelines and regulations, and provides real-time information about the real estate life cycle in one centralized location.
- **Capital and project management**—This standardizes and streamlines project portfolio management, project schedules and project vendor management. Business analytics help identify under-performing projects, resources and project management processes. It improves project planning and accelerates project schedules. It can also identify high return projects, reduce project schedule overruns and streamline project cost accounting processes.

Gaining asset management benefits with visibility, control and automation

In order to manage the full asset life cycle and better address business imperatives, asset-intensive organizations require integrated *visibility*, *control and automation* across their business and technology assets. This can help them better achieve their business objectives and maximize the value from all assets supporting the operation.

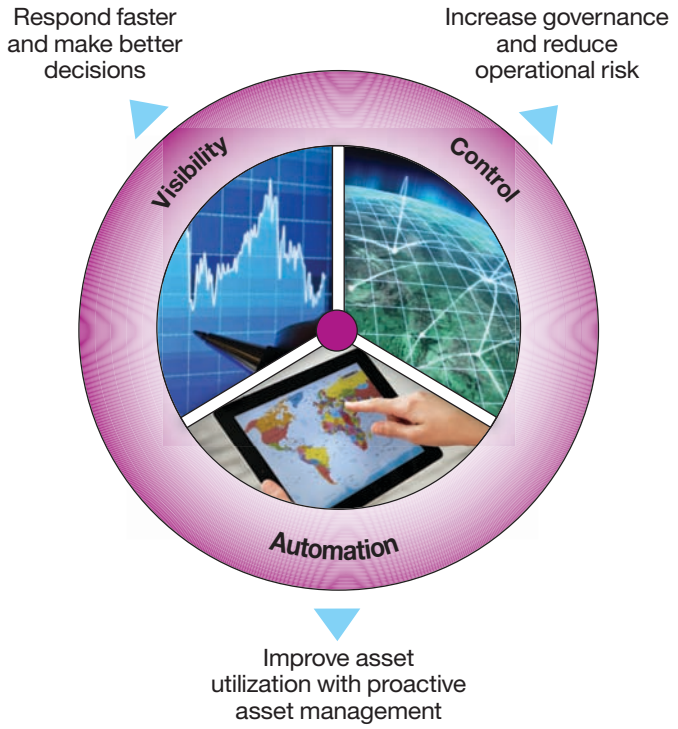

Figure 3: A comprehensive enterprise asset management solution provides increased visibility, control and automation.

This increased visibility of all assets across the enterprise allows organizations to respond faster and make better decisions. Visibility provides an enterprise-wide view of asset details and processes from across the organization—including visibility into asset service processes across the enterprise supply chain.

With better control of their assets and asset-related data, organizations can:

- Better manage and secure their investments
- Increase governance and reduce operational risk
- Extend asset life, reduce inventory costs and control spending
- Mitigate compliance issues and risk
- Improve health, safety and environment, and security

In addition, increased automation enables organizations to:

- Build agility and flexibility into their operations
- Improve asset utilization with proactive asset management and consolidation of their systems
- Enhance operational capabilities by automating workflow, reporting through key performance indicators and dashboards, and improving inventory data reliability

In order to manage the full asset life cycle and address these business imperatives, asset-intensive organizations can derive great value by implementing and using the Maximo Asset Management solution.

“Prior to implementing Maximo software, we were using many contractors to support our day-to-day operations, with little coordination. Using Maximo to plan our maintenance has significantly improved the efficient use of contractors here at PWCS.”

—Greg Harrap, specialist advisor, maintenance systems, Port Waratah Coal Service Ltd. (PWCS), Australia

Adding value through improved enterprise asset management

Increased asset availability and greater asset reliability provide a basis for *improving service delivery* and *growing more revenue* from the same asset base. As organizations tune their supply chains to meet specific supply levels, their asset or equipment uptime and availability must align to these demand schedules.

Asset management has a direct impact on profitability, since it affects the quality of the product or service produced or delivered. It can be a significant component toward justifying the price, and ultimately, determining profitability. The quantity of goods produced or services delivered directly contributes to the top-line revenue for any organization, whether in energy, utility, manufacturing, transportation, logistics or public sector—whether that good produced is a hard asset, such as an engine component, or whether the good produced is a service delivered to a customer.

Asset management also has a logical impact on operational costs. Efficiencies realized by effectively managing labor, inventory and other support services directly impact the bottom line by helping to control costs. More timely and precise user intervention can improve productivity and reduce materials use and, in turn, overhead.

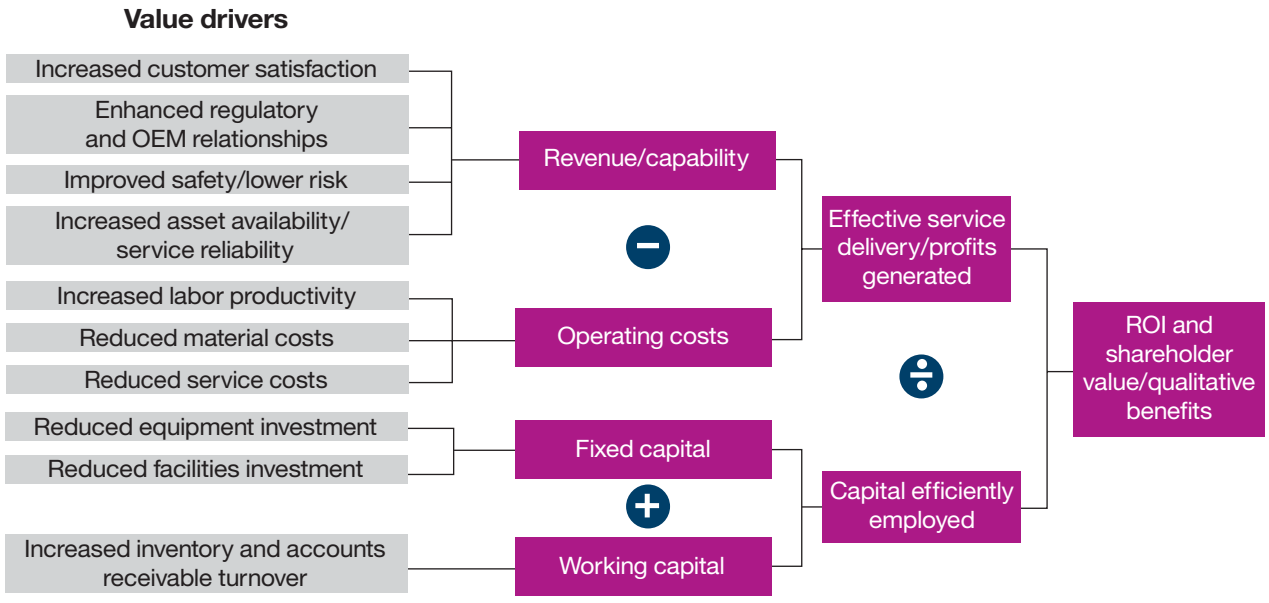

Figure 4: Certain value drivers contribute directly to ROI and shareholder value.

A significant challenge for organizations today is to balance the utilization loads of their asset portfolios effectively to meet customer expectations with the lowest operational cost. It's common practice, as a result, for organizations to overstock equipment and fleets to make sure they always have the assets they need. Other companies stockpile spares and inventory to shorten repair times by eliminating delays caused by an inefficient supply chain. Each of these "insurance policies" comes with high premiums associated with constant upkeep, refurbishment and financial carrying costs that will never go away.

These strategies can increase, rather than decrease, costs. Using Maximo Asset Management, however, helps control or eliminate overstocking and stockpiling, and can also help reduce the organization's fixed capital investment and contribute to positive, bottom-line results.

"IBM Maximo software gives us insights that we didn't have before, letting us focus on individual processes and identify possible improvements."

—Brian Urbanek, business systems analyst, Lower Colorado River Authority, USA

Choosing a solution that can increase revenues and decrease costs

With Maximo Asset Management, organizations are better able to meet today's business, operational and technology challenges, as well as more efficiently address the complete life cycle of resources. This solution enables companies to:

- Manage an aging infrastructure by:
  - Implementing and enforcing standard processes for asset management
  - Supporting real-time data collection, diagnostic and analysis tools that closely monitor aging assets to extend the useful life while improving overall maintenance best-practices, as well as meeting increasingly complex health, safety and environmental requirements
- Control the "brain drain" among employees facing retirement by:
  - Responding to global price pressure by enabling a reduced workforce to work more efficiently and cost-effectively
  - Putting into place proven workflows and enforced best practices that capture the knowledge and critical skills of long-time employees
- Consolidate operational applications by:
  - Standardizing asset management best practices across all asset types across the entire enterprise
  - Supporting global operations by leveraging a wide range of languages
- Provide a lower cost of ownership by using one global enterprise application instance, consistent metrics and best-in-class practices that are enforced with the same standard asset management solution at all of the organization's sites
- Enable asset-intensive organizations to optimize their maintenance and repair supply chain with management of materials and spare parts inventory that is fully integrated into the asset management solution
- Leverage easy-to-use, integrated capabilities for integration with other systems for enterprise resource planning, operational systems, financial management, reporting and analysis to support better quality decision making overall

Implementing a solid enterprise asset management solution can directly contribute to the way organizations in asset-intensive industries increase revenues and decrease costs.

IBM Maximo Asset Management

The IBM Maximo Asset Management solution offers the required visibility, control and automation of key information an organization needs to achieve greater efficiency in asset management by managing all asset types, from traditional IT, physical and emerging smart assets, on a single technology platform.

Maximo Asset Management can support the maintenance of an organization's smarter physical infrastructure and improve customer service, increase return on assets, enable greater compliance, improve asset performance and reduce risk. And it can do it in a shorter time period, while providing better visibility and control of all required information to better align with an organization's overall business goals and objectives.

The IBM solution for an integrated enterprise asset management approach is designed to naturally align with asset management best practices across an organization or in an industry. Maximo Asset Management software provides industry-leading capabilities and functionalities that allow capital, asset-intensive industries to leverage the benefits of an integrated enterprise asset management system to manage all critical assets and facilities within the organization.

Maximo Asset Management software unifies comprehensive asset life cycle and maintenance management activities, providing insight into all enterprise assets, their conditions and work processes to achieve better planning and control, leveraging the business function within an organization.

Maximo Asset Management is available for and can be tailored to the following industries:

- **Government**—Addresses requirements unique to federal and local governments, including municipalities managing contracting and personal property
- **Utilities**—Provides smarter work and asset management activities for transmission and distribution in water and wastewater, as well as gas and electric power distribution
- **Oil and gas, mining and metals**—Focuses on operational excellence by improving safety, reliability, compliance and performance while reducing costs through standardization, collaboration and the adoption of better operational practices
- **Manufacturing**—Helps industries such as automotive, aerospace and defense, electronics or industrial products, food and beverage, or consumer products manage all their assets and maintenance activities; leverages concepts such as Lean/Six Sigma; and complements product life-cycle management requirements
- **Life sciences**—Helps monitor, track and manage equipment, facilities, mobile and IT-enabled assets; integrates with IBM Maximo Calibration to help meet complex compliance requirements from the FDA and to provide support in validation projects
- **Healthcare**—Tracks and locates all critical assets, monitors facility conditions, complies with reporting requirements and integrates with operational health information systems
- **Nuclear power**—Helps nuclear organizations manage all work and asset management activities and address stringent regulatory requirements on compliance, health, safety and security
- **Transportation**—Provides best practices to help improve the availability and utilization of critical transportation assets in companies operating rail, road and air traffic or logistics
- **Service providers**—Helps manage SLAs and all related service management activities for multiple customers in a single deployed instancee

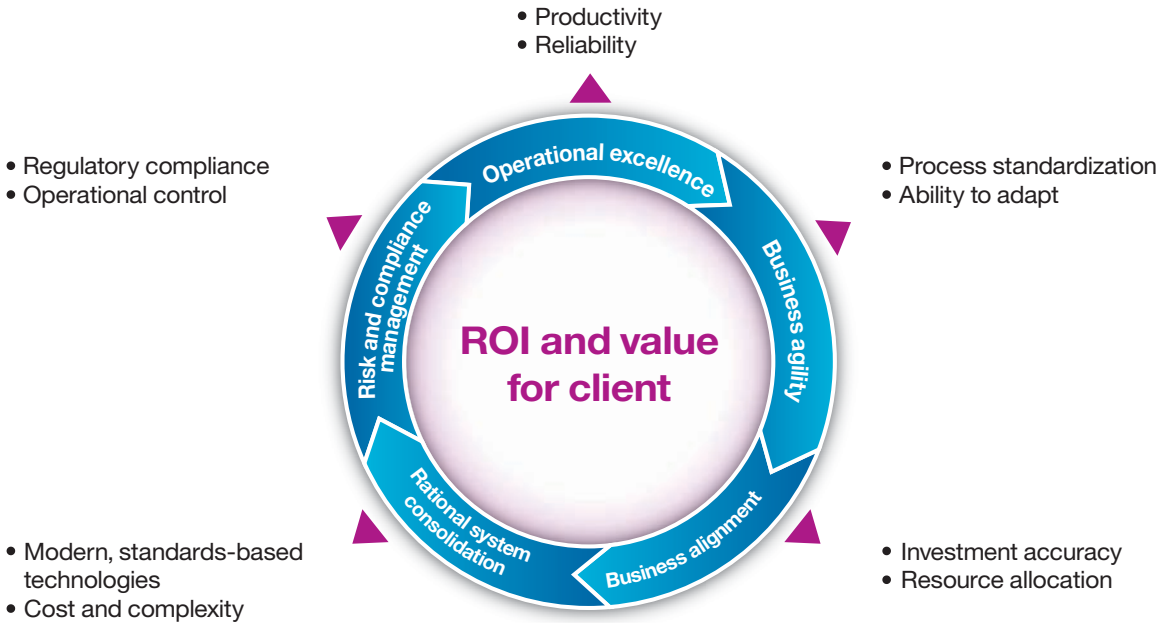

Figure 5: IBM Maximo Asset Management provides a core business solution.

In addition, Maximo Asset Management solutions can leverage the following key aspects of enterprise asset management to their advantage:

- **Asset maintenance management**—Optimized at the *process* level. Examples include reactive, preventive and planned maintenance combining materials and service management. Maximo asset and work management modules in general address this requirement.
- **Asset risk management**—Optimized at the *asset performance* level. For example, asset reliability, service and performance management, Maximo Calibration and key performance indicators and metrics, such as mean time to repair and mean time between failures, address such requirements.
- **Infrastructure management**—Optimized at the *service performance* level. Examples include utilities and facilities management. Spatial and linear asset management, facilities and integration with intelligent building management systems address these requirements.
- **IT asset management**—Optimized across the enterprise. This aspect is important in today's asset management environment to integrate specific requirements from the shop floor to the corporate office. Examples include management of data repositories, servers, telemetry and database connection services. Maximo IT Asset Management addresses these capabilities.

According to ARC Advisory Group, "IBM Maximo solutions are well proven in the industry, as they have had the leading overall market share in their class for the past five years. Specifically, IBM holds the leading market position in the following segments: EAM worldwide and in North America, EAM software revenues and service revenues, EAM for oil and gas, pharmaceutical and biotech, electric power, water and wastewater, automotive, logistics, government and independent maintenance service providers."[1]

For more information

To learn more about how IBM Maximo Asset Management solutions can help you manage your enterprise assets more effectively—and help to bolster your bottom line—contact your IBM representative or IBM Business Partner, or visit: http://www-142.ibm.com/software/products/us/en/category/SW222, where you'll find white papers, data sheets and more.

Additionally, IBM Global Financing can help you acquire the IT solutions that your business needs in the most cost-effective and strategic way possible. We'll partner with credit-qualified clients to customize an IT financing solution to suit your business goals, enable effective cash management, and improve your total cost of ownership. For more information, visit: **ibm.com**/financing

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[1] ARC Advisory Group, "Enterprise Asset Management and Field Service Management Worldwide Outlook, Market Analysis and Forecast Through 2015." ARCWeb.com, April 4, 2011

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