JSNN

The Joint School of Nanoscience and Nanoengineering

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Construction Management

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The Joint School of Nanoscience and Nanoengineering
Gateway University Research Park
2907 E. Lee Street
Greensboro, NC 27401

9th, April 2014

Final Report

The Joint School of Nanoscience and Nanoengineering

A collaborative project of North Carolina A&T University and the University of North Carolina Greensboro

Gateway University Research Park

2907 E. Lee Street, Greensboro, NC 27401

Building Information

Size: 92,337 GROSS SQ. FT.
No. of levels: 3 stories above grade
Cost: $47 M
Dates of Construction: Mar 2010—Dec 2011
Delivery Method: CM at Risk, GMP
Owner: UNCG and A&T
Architect, MEP, Civil: HDR and CUH2A
CM: Samet. Barton Malow. SRS
Structural: Stewart

Lighting/Electrical

- **A majority if the lighting in the building is fluorescent lighting. In the clean rooms, it is prismatic lighting with rust-free resistance.**
- **There are 11 set-up transformers that feed different equipment in the lab areas to provide the correct amount of voltage. There are several future utility transformers placed out side of JSNN for the next phases of Gateway University Park.**

Mechanical/ Chemical

- **Based on the needs of a science lab, several inert gases must be piped into the building from the tanks stored inside and outside the building depending on storage temperatures.**
- **The building is using 100% OA Heat Recovery system for 3 out of the 10 air handling units.**
- **The clean rooms have separate HVAC systems from the rest of the building due to stringent requirements of air particles in the building.**

Structural

- **Steel framed construction with light-weight concrete steel on composite decking.**
- **Due to the limited amount of steel allowed in the clean rooms, the first floor hallways have added W8x24 beams spaced closely together to support the lateral loads from the clean rooms.**
- **Steel joists are the roof structure in the penthouse and clean room plenums.**

Architecture

- **Prototype for the other eight buildings that are to be constructed on campus. The façade is made up of masonry brick and curtain wall systems. The front facing wall has glazed windows in its curtain wall.**
- **The west side is 66% aluminum louvered screening to protect the exhaust fans and refrigerant systems on the roof.**

Executive Summary

Through the 2013/2014 school year, the Joint School of Nanoscience and Nanoengineering (JSNN) was analyzed to denote areas during the construction process, design, and facility management of the laboratory that would enhance their functions. Feedback from the project team, owners, and facility managers helped to pinpoint topics that are relevant to JSNN. The following represents the three analyses performed as part of the final senior thesis project for the undergraduate architectural engineering program at Penn State University. It is important to note that the purpose of this thesis is strictly educational and is not intended to critique the project team, owner, and facility managers in anyway.

Analysis 1: Aquatherm

Aquatherm is a type of piping with a built in R-value of 1. This allows for no insulation to be wrapped around the pipe on certain types of lines such as the domestic cold water line that was analyzed in this report. The Aquatherm piping material was able to reduce the cost against copper piping by $4,777.52. Since the copper line required a worker to go back and insulate the pipe, a savings of roughly $1,400.00 per 300 linear feet of can be achieved through Aquatherm. The Aquatherm system can outlast the copper piping by reducing head loss on the system (Mechanical Breadth). The chemical make-up of Aquatherm reduced the time span on buildup of scales in the pipe and can reduce the power output on the pumps by 22%.

Analysis 2: On-Site Material Storage Warehouse

Within the building are level 5 clean rooms that require heavy protocol when constructing them. The goal is to reduce the amount of debris accumulated in them. Have a facility on site where prefabrication can take place can improve the quality of the construction performed for a highly sensitive laboratory. In addition to having a warehouse to prefabricate piping and general trades work in, there is a need to house the laboratory equipment for temporary purposes until they are ready to install. The heaviest piece of equipment is the MRI. Due to the weight of the MRI, the slab on which the warehouse rests must increase in size (Structural Breadth). The slab must be designed to 0'-8" and the slab must be outside of the building footprint so that the construction schedule is not interrupted.

Analysis 3: Wetland Preservation

Upon the start of the project, the project team was told by the NCDENR to repair the erosion damage from the previous job costing approximately $18,000.00 by the end of the project. The suggestion is to install a sand filter at the 15'-0" encroachment area around the wetland. The cost of installing the sand filter is $34,500.00. While the cost may seem high, the investment will eliminate the need for erosion control on the future facilities of JSNN. Based on geographical and climatical data, the sand filter will not be experiencing flooding of any sorts.

Analysis 4: Total Cost of Ownership for Magentom MRI

JSNN is a unique development from two universities desires to want to come together for research and development with, what seems to be, low political issues involved. It is recommended that Gateway become a staple for how two universities interest become one effort to improve the strengths of the other.

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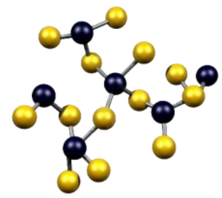

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Architectural Engineering Class of 2014

God

Thank you to all who assisted in my research! I am very appreciative of willing facility and industry members to help students in their communities grow.

Project Background

Figure 1 Provided by Karen Ryan

Figure 2 Provided by Google Maps

The Joint School of Nanoscience and Nanoengineering (JSNN) is a product of two North Carolina universities coming together to establish Gateway University Research Park. The schools, UNCG and North Carolina A&T, both offer programs related to nano-research. UNCG offers a nanoscience program while A&T offers a nanoengineering program. The two universities saw strength in bringing together their research programs and decided to call the new program the Joint School of Nanoscience and Nanoengineering. The research conducted poses certain difficulties in attracting researcher to the facility. UNCG and A&T decided to set up Gateway University Research Park as the solution. Gateway is a non-profit organization that is designed to manage the facilities and operations of the research park. JSNN is the first of eight buildings that are planned for the research park. The land that Gateway acquired was originally owned by A&T for agricultural purposes. JSNN is located in Greensboro, NC where East Lee Street and Florida Street meet (See Figure 2 for mapped location). JSNN has high hopes of bringing in the revenue and research that will continue to grow the facility. The students are able to conduct highly advanced research at the facility with the state of the art equipment available to them. The 92,000 square foot facility provides several bio and chemical labs as well as a series of level 5 clean rooms otherwise classified as ISO Class 8 clean rooms. In addition to the laboratories, the facility also houses its own Magnetic Resonance Imaging (MRI) and Nuclear Magnetic Resonance (NMR) for the students to work with.

Project Team Selection

Typical construction in Greensboro, NC does not normally entail building a nanoscience and nanoengineering lab. In order to build JSNN, Gateway had to select the right talent for the job. A joint venture was considered for the strengths that the two players, Barton Malow and Samet, brought to the table. Barton Malow had the experience in building science laboratories, but they did not have affiliation with local subcontractors and vendors. To help with local ties and connections, Samet was chosen as the joint venture partner for its strength with the local subcontractors. In Southern State a minority representative must be present on the job.
In order to fulfill this requirement, SRS was asked to join the board as the minority leader. The risk and liability was then divided into a 50-40-10 percentage distribution. Because Barton Malow had experience with science laboratories they held fifty-percent of the risk, while Samet took on forty-percent of the risk.

Site Conditions

Since JSNN has been planted on what use to be a farmland of the North Carolina A&T School, it also rests on silty soil. Sitting a couple of hundred yards back are natural wetlands that the team is expected to preserve and protect during construction. Construction of JSNN was delayed from its initial start date because of damage that was done to the wetlands from the previous contractor. The North Carolina Department of Environment and Natural Resources (NCDENR) postponed any construction on the property until the issues with the wetlands and preservation were resolved. JSNN ended up spending an extra $13K-$14K to resolve the erosion control issues. Once the issues were resolved, the project team was able to finalize their civil drawings and move forward with construction.

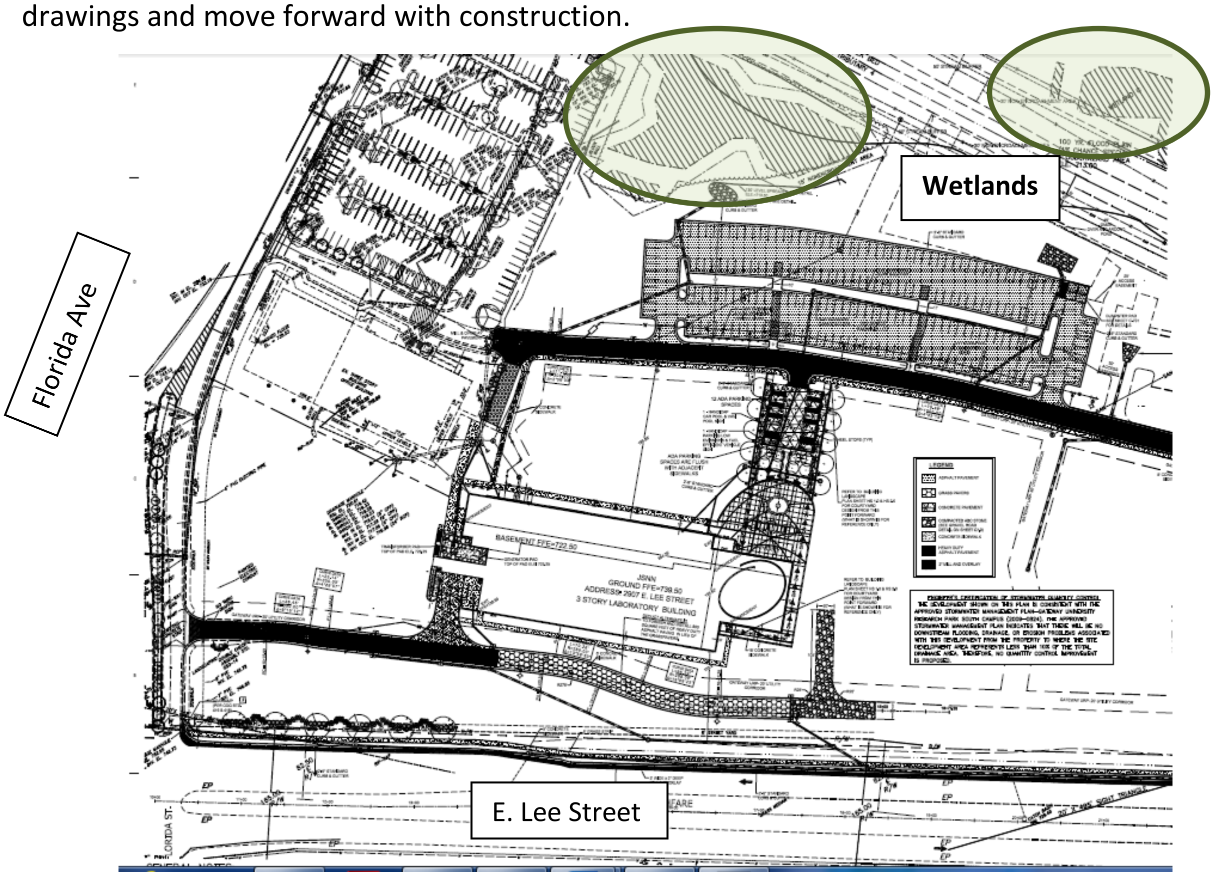


Figure 2.1 Civil Plan C-300

Aside from construction issues with the site, the logistics and planning for the building were no issues with the team. The project team was fortunate enough to have a site that was wide spread and offered room for storage and mobilization during construction. Even a site fence was not required. The only fencing that was erected was a silt fence to prevent run off from building up on Florida Ave and E. Lee Street. The location of the building also had its disadvantages. Since Greensboro, NC is 1.5 hours from the closest city, Charlotte, NC, there were some troubles in getting the right contractors out to do the job. Several different specialty subcontractors had to be brought in to install process piping and toxic gases. The job was not unionized, but it did bring in subcontractors from cities and towns further out from Greensboro.

Geotechnical Analysis

Sections of the geotechnical report that will be discussed are found in Appendix A. The boring location plan shows the location of 25 different bores that were done. The bores of highest concern were the bores that were taken directly below where the MRI and NMR were to be located. Figure 2.3 shows the boring plan and the number of bores that the geo-technician made. Location of bore 25 has a concentration of four different bores that were taken relatively close to each other. The location of bore 25 is the place in the building where the NMR is to be located. Bore 25 reached bedrock at 6’-0” confirming its suitability for the NMR. The NMR has a large magnetic field that is embedded into the reinforced fiberglass concrete that surrounds the machine. Bores 17 and 18 are the deepest bores on the plan because this is the location of the MRI. Bore 18 finally reached auger refusal at 58.5’ below grade. The MRI purchased from Siemens is 10 tons and can easily cause depressions to the foundation if it is not properly supports. The early design documents did not included an MRI because the owner was unsure about the type of MRI they were going to be purchasing. The structural design to support the MRI is show in Figure 2.2

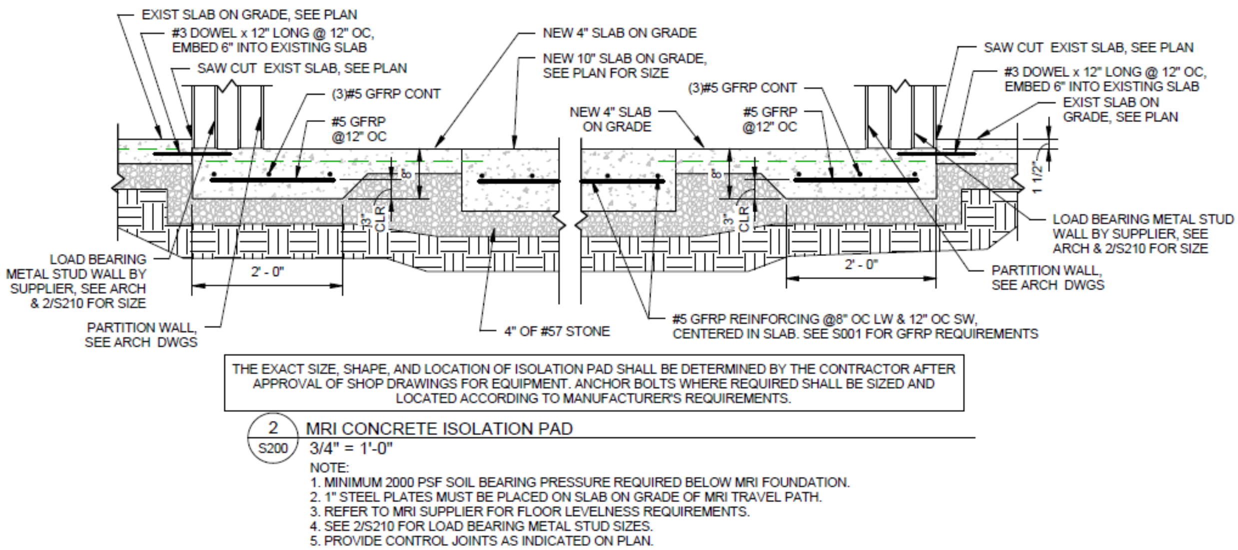


Figure 2.2 MRI Isolation Pad Detail S-200/2

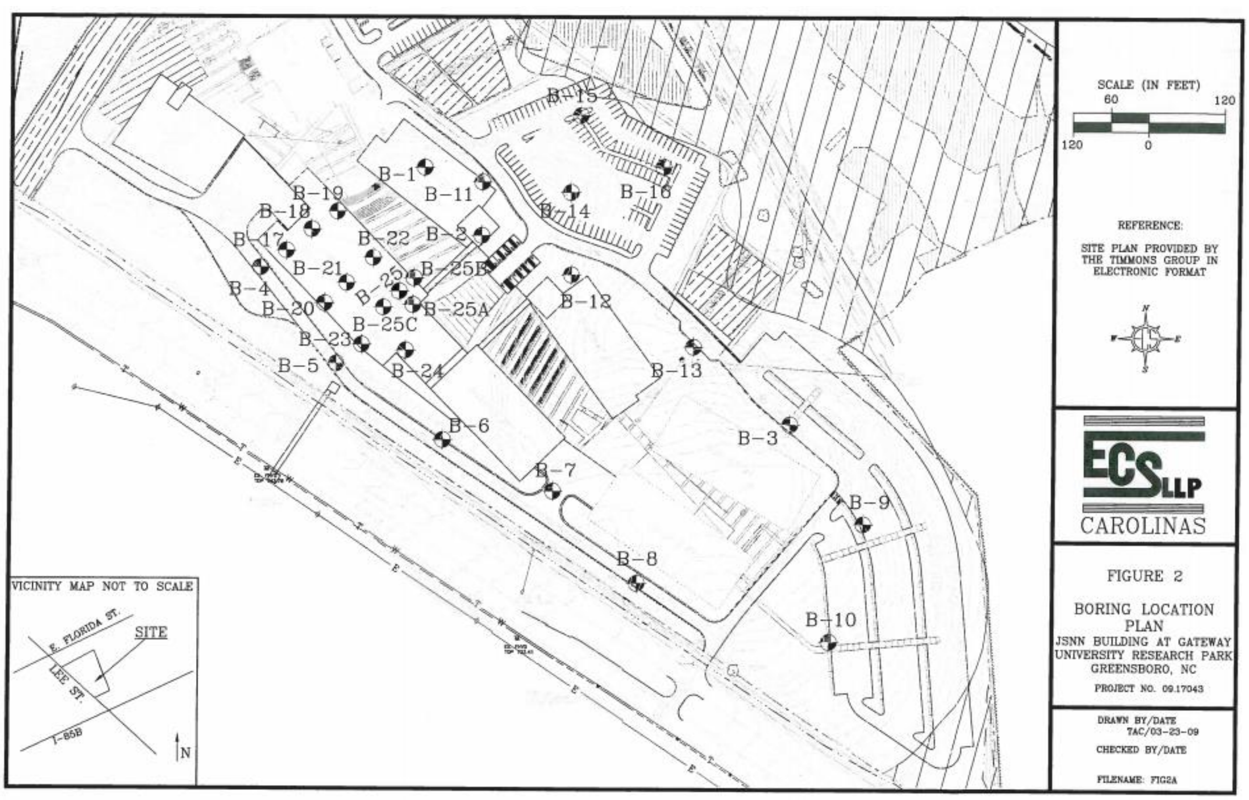


Figure 2.3 Boring Location Plan for Geotechnical Report

Construction Management Data

Contract Type

The contract implemented for the Joint School of Nanoscience and Nanoengineering (JSNN) is a construction manager at risk contract between the construction manager and the subcontractor, also referred to as CM at risk. As mentioned earlier, the risk and liability break down is a 50-40-10 split between Barton Malow, Samet, and SRS respectively.

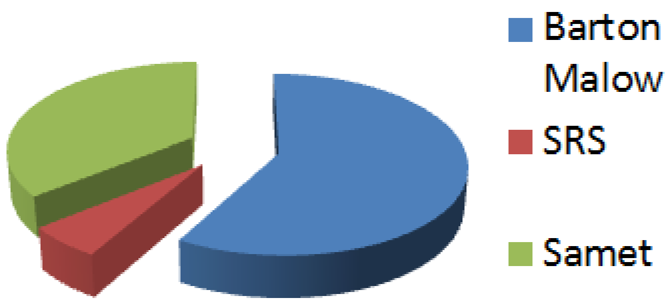


Figure 3.1 Risk and Liability Chart 1

While under a CM at risk contract, several items were not a liability to the project team such as the laboratory equipment. The laboratory equipment, MRI and NMR used in JSNN are a responsibility of the owner to furnish and install. It was up to the project team to have the appropriate connections and structure in place for the equipment to be housed in.

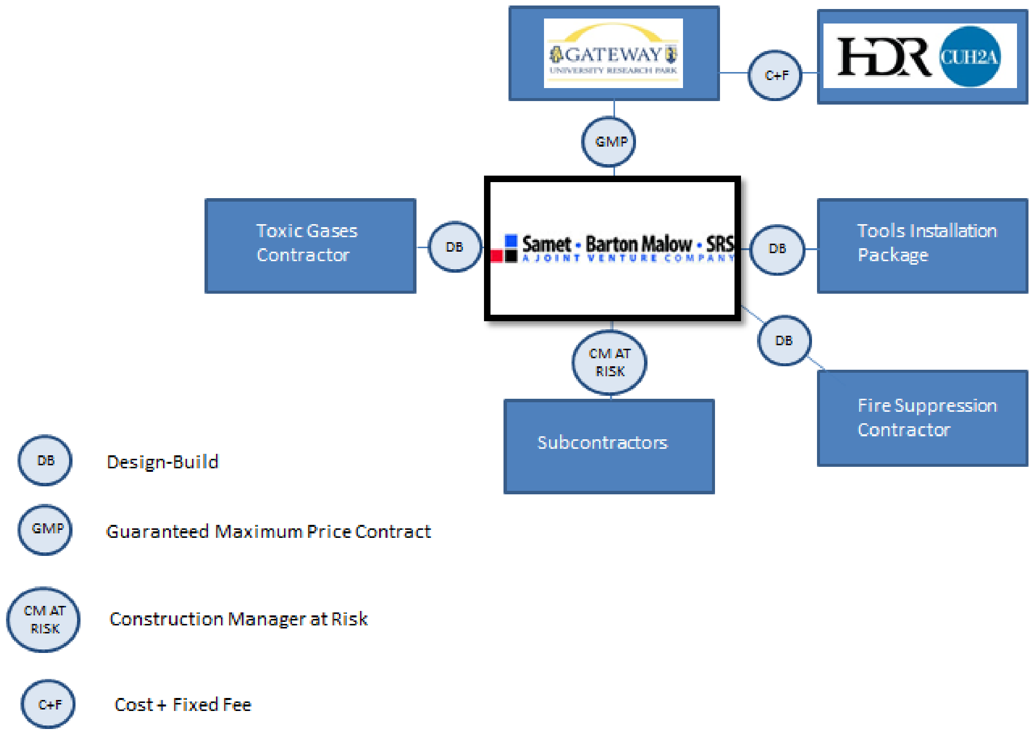


Figure 3.2 Contract Type Breakdown 1

The contracts between all other parties are show in Figure 3.2. Design-Build type contracts were used between the specialized contractors for process piping, inert gas piping, and tool installation in the building. By using a design build contract, it allowed for these systems to have the flexibility in altering the design to fit the needs of Gateway to ensure that the systems would operate in the most efficient means. The tools installation contractor needed a design build contract type because of the type of machinery and equipment that was being places in the building. 158 different tools were placed in the building from microscopes to MRIs. The risk and liability for these pieces of equipment were not going to fall on the responsibility of Barton Malow and Samet. Gateway was responsible for the selection of the equipment and Barton Malow and Samet were responsible for the management of the tools installation contractors once the equipment was delivered on site.

Schedule

The construction of the Joint School of Nanoscience and Nanoengineering is a 25 month schedule. Preconstruction for JSNN began in March of 2009 after the selected CM was awarded the project in June of 2009. The turnover date was expected to be the 29th of November in 2011. The team successfully delivered the project on time to Gateway. The critical path for the project fell on the delivery and installation dates of the tools that were being set in the building. Some of the tools required special preparation in order for them to be installed. In addition to the installation of the tools, the building needed to be water tight since the construction of the clean was separate from the rest of the building and required a separate protocol to be followed according to specification 13 60 16.

A unique schedule was made to accompany the clean room construction and tool installation. Excavation and superstructure followed the typical construction of a new facility. The foundation was completed and the steel construction went from the ground floor up to the penthouse. The MEP and interiors work began in the penthouse and worked back down the structure from penthouse to ground floor. Since the clean rooms required that the MEP needed to be in operation in order to begin filtering particles out of the area where the clean rooms were to be built, the rough ins and interior structure had to be in place before the HVAC equipment were to be fired up.

The auditorium and lobby area have a lot of architectural features that do not require any sort of immediate attention in comparison to the clean rooms and the tool installation. This means that the auditorium and lobby which have led them to be the last items in the schedule constructed.

Systems

Mechanical and Piping

The mechanical and piping systems for JSNN are the most complex systems in the building. There are two separate HVAC systems: one to feed the building and one to feed the clean rooms. The clean rooms require a particular level of filtration that the rest of the laboratory does not require. The clean rooms are classified as ISO 8 or class 5, which means that there are only going to be 100,000 particles/ m^3 compared to the typical 35,000,000 particles/ m^3 that people breathe on a daily basis. Ten air handling units are serving building, and three of these air handling units are 100% Outdoor Air supplied. The louver that draws in the outdoor air is on the north side of the building.

In addition to the typical hot water supply and return, cold water supply and return, and other necessary plumbing JSNN requires process piping for the tools that are installed in the building such as utility nitrogen, vacuum piping, industrial cold water, etc. Storage tanks for these liquids and gases are stored outside the building and in the basement for distribution to the laboratories; where the equipment is located. A process piping contractor should be selected to furnish and install the piping required since it needs different pipe coatings for the type of liquid or gas running through it.

The last piece of piping that is unique to JSNN, but not abnormal for a laboratory, is inert gas piping. The inert gas piping distributes gases such as oxygen, hydrogen, helium, nitrogen, and krypton to name a few. The toxic gas contractor is responsible for the furnishing and installation of the piping. They will also need to coordinate with the MEP contractors in order to know which days and times the testing and start up can be completed for the rest of the building systems.

Electrical and Lighting

Feeding the appropriate amount of electricity to each piece of equipment and the building will require an extensive set up. The utility transformer for the building is fed from the local power plant's distribution. The system is a 4 wire, 3 phase of 480Y/277 voltage. A backup generator is installed so that the building is continuously fed electricity. Once the electricity is in the building it is sent to a switchboard, which is then sent out to the rest of the building. There are 14 step-up and step-down transformers placed in the building to supply the voltage and amperage needed for the equipment. The total KVA begin supplied is 1870.5. The total KVA includes miscellaneous loads and future loads from the MRI and NMR. 18% of the load is due to the amount the air handlers need to run and operate.

The lighting elements in the building have unique features to them. In the clean rooms, there is a mixture of rust-resistant prismatic lens for the lighting fixtures in addition to rust-resistant clean room flow-thru fixtures. A majority of the lighting, in the building, is fluorescent. In the flammable gases room, corrosive liquids, chemical waste lab, and toxic gas lab, the lighting is explosion proof class. In areas that are applicable, such as the canopy on the exterior of the entrance, there are LED spot lights used for aesthetic appeal.

Structural

The structure of JSNN is a cast-in-place concrete foundation system with structural steel and concrete beam combination. The foundation system is a mesh of retaining walls and concrete piers intertwined on the slab on grade for the basement. There are four different slabs on grades due to the type of facility that is resting on it. The southern side of the building has a 0'-4" slab on grade that continues over to the auditorium and lobby section of the first floor. The

clean rooms have a 1’-0” thick slab on grade. The basement, where several different types of laboratories are housed, varies in size from 0’-6” to 0’-10” in thickness.
The MRI, the heaviest tool that will be installed in the building, has a specific slab that the equipment must rest on to support its 10 ton weight. Figure X.X shows the detail for the MRI slab.

The roofing structure is composed of steel joists and beams running along the top to make a flat roof. The roofing materials are a light gauge metal decking with insulation covered by 0’-2”of cellular lightweight concrete. To have suitable drainage, the roof is sloped at 5/16 for drains located towards the middle of the roof.

Architectural
The building is composed of a brick exterior façade with a curtain wall system attached to the front of the building. The entrance to JSNN is a clear curtain wall system that allows visibility into the lobby and auditorium. A cyclone-like mass extrudes from the curtain wall boxed entrance. The mass is the auditorium enclosed in plaster. The construction of the auditorium is a sound proofing, gypsum wall system backed on metal studs see Figure 4.1 for the detail on the auditorium enclosure.

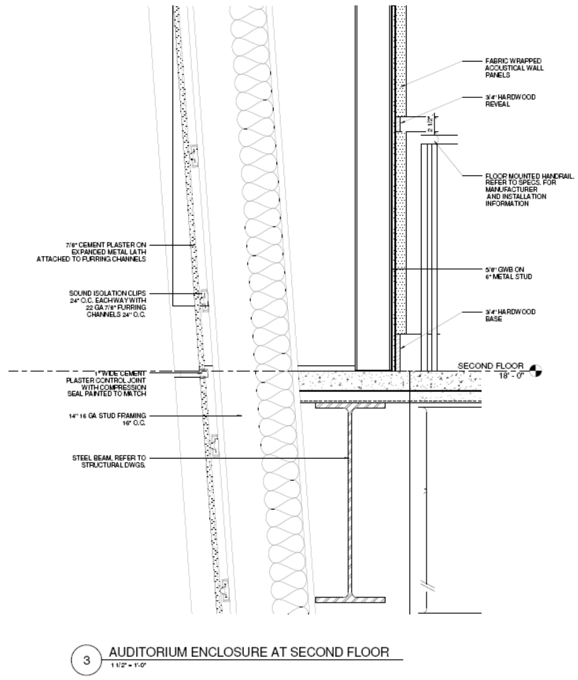


Figure 4.1 Auditorium Enclosure Detail 3/A-552

On the west side of the building, screens cover one third of the building in order to block the view of the mechanical equipment. The remainder of the west façade is exterior brick. From the west side, the grade of the building is provided to show the differences in the depths of the basement and first floor grades.

The East façade is encompassed by the curtain wall entrance. The curtain wall glass is composed of elements that make it either heat strengthened, tempered, colored, or insulated glass depending on its location in the building. The information of the types of glass per the ASTM standards can be located in specification 08 81 02.

The main entrance to the building is located on the north face of the building and it rests under an aluminum canopy with the JSNN name above it. On the majority of the face, the brick encompasses a glazed curtain wall system. The architecture on this part of the building puts blue and gray glazed windows in the middle of the system. To obtain some of the LEED points required for the project, the brick is a clay brick manufactured locally. The southern elevation is similar to the northern elevation. The additional piece on the southern elevation is the ability to see the loading dock, which is a concrete structure with a flat aluminum roof.

Aquatherm

Analysis I: Aquatherm

PROBLEM/ TOPC:

During the coordination efforts for JSNN, there were several design issues, on the MEP side, that arose due to the amount of different types of plumbing. Ceiling plenums were packed with piping that was in the duct works and sprinkler piping. While 3D coordination was conducted on this project, it was still a cumbersome task to get the MEP equipment installed in the ceilings. Post construction, a design issue slipped through that was not caught in the developmental stages of the project. In the plenum space above the clean room, there are p-traps connected to the floor drains in the penthouse that collect condensation from the mechanical equipment (see Figure 2.2). The red circles in Figure 2.2 represent the location of the floor drains in the penthouse. In the design and specifications, the p-traps were never given insulation. The condensation would form on the outside of the traps causing the water to drip down into the ceiling of the clean room. The water drips down over fan filters that have rusted overtime. The owner has had to replace the fan filters multiple times since the building has been turned over.

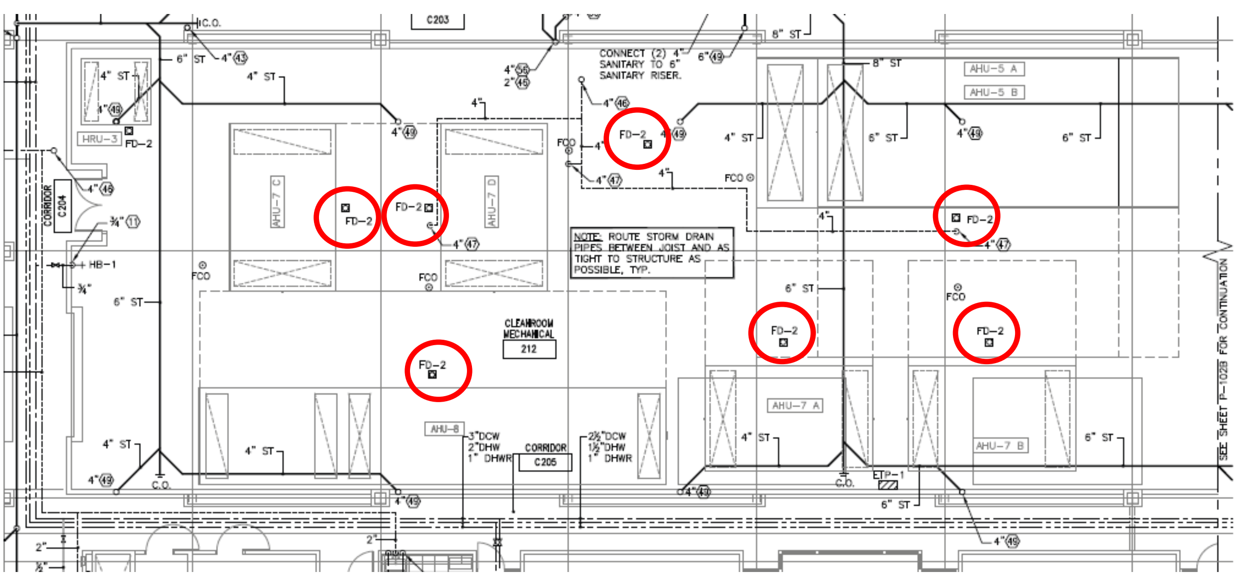


FIGURE 2.2 LOCATION OF FD-2 DRAINS OVER CLEANROOM PLENUM, P-102A

Background of Aquatherm

Aquatherm, founded in 1973 by Gerhard Rosenberg in Germany, has become one of the most innovate and green piping systems developed and is considered to be the best polypropylene pressure piping. The Rosenberg's have developed a piping system that can fit almost any piping system in commercial buildings. There are five types of piping that Aquatherm has developed to meet the needs of the different systems in place as shown in Figure 5.1. The Aquatherm green pipe is used for potable and food-grade applications. It has also been used in residential homes for sprinkler systems. The Aquatherm blue pipe, formerly called climatherm, is often utilized on Aquatherm based projects. It can be used in scenarios where the green pipe, with the addition of the blue pipe, is engineered to have an 'R' value of 1. It is best used for hydronics, compressed air and other industrial and commercial applications. For the recycled, reclaimed, and rainwater applications, Aquatherm lilac piping is designed to increase the laminar flow through the pipe and is colored to demarcate the pipe.

Aquatherm also has specialty piping that is used in certain instances. For instance, the Aquatherm red pipe is designed for fire sprinkler systems in the commercial and industrial settings. The piping has an inner and outer lining that make it fire resistant. The most unique system Aquatherm has on the market is its black system piping. The Aquatherm black system piping is used on radiant heating and cooling. Radiant panels can be constructed using a series of the black piping to make panels that fit the space that previously had copper piping.

Figure 5.1 Aquatherm Products provided by Aquatherm Product Catalog

Engineered Design

Aquatherm is a unique product because of its chemical make-up and design. All of the piping is composed of a thermoplastic material, a type of polymer called polypropylene-random (PP-R). PP-R is a series of carbon and hydrogen chains. The chains are random lengths and combinations, which in turn gives the piping its unique structural properties. When heated the bonds between the carbon and hydrogen weaken and make the PP-R material malleable enough to be remolded. Upon cooling, the hydrogen and carbon bonds re-strengthen forming bonds much like the original material.

Heat Fusion

In order for this piping to be used in commercial, industrial, and residential applications Aquatherm developed the heat fusion method to join the piping though socket fusion, fusion outlets, and butt welding. Typically, the weld or joining method for any type of piping is the weakest point in the system. It is expected that if a system or line should fail, it will fail at the joints and welds. Heat fusion chemically alters the carbon and hydrogen bonds in the pipe causing them to bond with the fitting, or pipe that it is attaching to, so that no weakened areas exist in the line. The heating iron, as shown in Figure 5.2, does not require any special electrical set up for the heating iron to work. The device will require 10-30 minutes to heat up depending on the size of the pipe that is being fused together. The iron must heat up to 260 degree Celsius, or 500 degrees Fahrenheit, to reach the desired temperature for the fusion. Heat fusion methods reduce the number of products that a contractor needs to purchase for the workers.

Cost Benefit of Heat Fusion versus Soldering

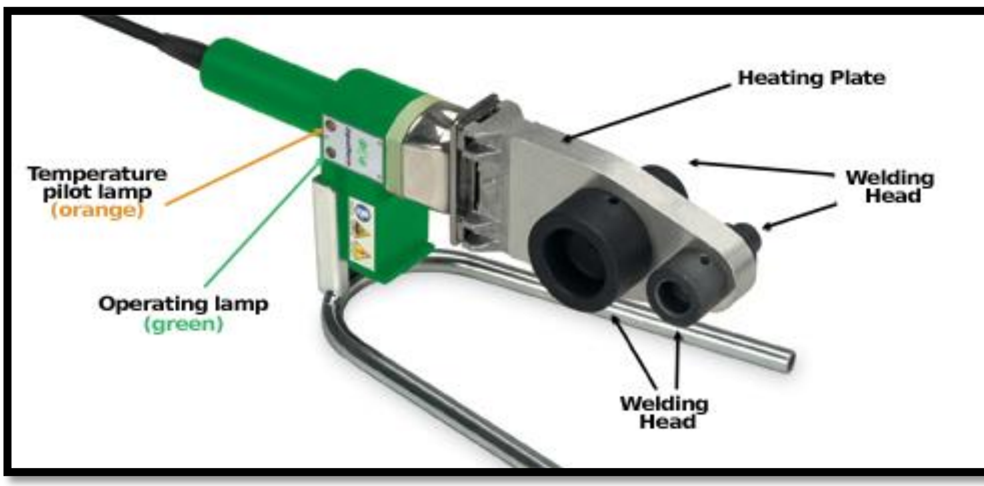


Figure 5.2 Heating Iron provided by Aquatherm.com

To compare the benefits in the cost of heat fusion over soldering, a simple estimation was done by connecting a 1” pipe diameter to a 1”x1”x1” tee fitting. (See chart below). The aquatherm option required fewer materials for the overall process.

Step by Step Process for Heat Fusion:

The following steps are taken from the 2013 Aquatherm Training Manual and have been simplified for the purposes of this report.

Photo provided by Aquatherm

1. The heating iron needs to be plugged into a working outlet or power source for the size plate that is being used. For the purposes of a 1” diameter pipe, the standard 120V outlet is appropriate for the fusion. For a 1” (25mm) diameter pipe, the heating time is approximately 11 minutes.
2. Once the iron is ready the fitting and the pipe, as shown in the figure above, are placed on either side of the iron and heated for 5 seconds.
3. After the pieces have been heated they are simply pushed together to form a bond. The cooling will take no longer 4 minutes. The piece will then be ready to install.

As shown in Figure 5.5, the weld that is created from the heat of fusion is a seamless fusion that makes the bond just as strong as the pipe itself.

Figure 5.5 Cross-section of finished pipe. Photo provided by Aquatherm


The welding tool is inserted into the pipe wall ...


...heating-up of the elements


Joining


Ready!

Advantages of Fusion Outlets

Many times when a plumbing line changes from 2” to 1”, a 2”x2”x1” tee will be used as a solution in order to make the transition. As shown in Appendix A, the costs of any size tee fitting can be costly and time consuming when the pipe has to be cut at a certain length in the line where the fitting will be placed. Aquatherm developed a means of eliminating the need for multiple size tees and reducers for their lines. Fusion outlets, also called weld-in saddles, allow for a fusion outlet to be fused into the main line pipe. The fusing process takes no additional time from the standard socket fusion process, however; depending on the size of the main line more time might be required in order to drill the hole for the fusion outlet. For example, the cost of a 3”x3”x ¾” tee is $85.00 for the Aquatherm fitting. The cost of the same copper tee is $61.72. If the installer were to use a fusion outlet that is ¾” on the 3” main line, then the cost would be reduced to $8.70. This allows for a savings of over $75.00 per fitting. Strategically placing these pieces on the main lines should be the responsibility of the mechanical designer in the design developmental phase.

PROCESS:

In order to show that Aquatherm will change the way that JSNN can manage its facilities and install piping that will last more than 50 years, it is recommended that they show the cost benefits, construction benefits, and safety aspects of the system. The domestic cold water line was used as the example to show the benefit of cost savings, because the domestic cold water line required no insulation due to its internal thermal resistance characteristics. This offers an added savings since they would not have to spend time and labor on insulating the domestic cold water line.

The biggest expenses for the contractors are the upfront costs of equipment and material, if not already purchased. A side-by-side comparison of the equipment cost will be given to show how Aquatherm must be budgeted.

From a mechanical standpoint, the Aquatherm system will outlast its competitors because it reduces the friction and head loss in a typical copper or steel. The reduction in head loss and friction loss allow for the possibility of reduced pump sizes as well as savings on the equipment operations. These calculations will fulfill the mechanical breadth requirements displaying its functionality.

RESULTS:

No insulation required

Aquatherm was uniquely designed to have a high internal thermal resistance value, meaning that it would not require insulation in certain applications. Referring to the chart below in Table 5.6, the domestic cold water line is one of the lines that will not require insulation in a commercial setting. By not having to insulate certain products, the cost of labor and material for the insulation process can be eliminated.

Condition	Thermal Insulation Required (Commercial)	Thermal Insulation Required (Residential)
Domestic Cold Water	No	No
Domestic Hot Water and Recirculated Hot Water	Yes	No
Heating Hot Water and Hot Water Return	Yes	Yes
Chilled Water, Above Grade	Yes	Yes
Chilled Water, Below Grade	No	No

Table 5.6 Insulation requirements provided by Aquatherm.com

The following calculations were made based on the total 1" diameter copper pipe size for all of the 1" DCW piping in JSNN. The total linear footage of type L copper piping costs $1,324.68, whereas Aquatherm's piping cost $0.00 (shown in table 5.7). If Gateway decides to not to use Aquatherm piping, then for every 300 linear feet of 1" copper piping in the building they can expect to spend a little over $1,400.00 on insulation. Assuming that there are 8 hour work days, the schedule would be reduced by 5 days per plumbing line where the "no insulation" clauses work for Aquatherm piping. Cost of labor was derived from the US Department of Labor Bureau of Labor Statistics and RS Means Construction Cost Data 2104.

Insulation Cost for 1" diam. Pipe on DCW							
Copper Line				Heat Fusion Aquatherm			
Type	Quantity (LF)	Cost/ LF	Subtotal	Type	Quantity (LF)	Cost/ LF	Subtotal
Type L Copper 1" Fiberglass Insulation	332	$3.99	$1,324.68	Climatherm Pipe: 1" Fiberglass Insulation	332	$0.00	$0.00
Insulator	Total Time (hours)	Base Labor Cost/ hour	Subtotal	Insulator	Total Time (hours)	Base Labor Cost/ hour	Subtotal
1" Fiberglass Insulation	5	$17.28	$86.40	1" Fiberglass Insulation	5	$0.00	$0.00
		Total Cost:	$1,411.08			Total Cost:	$0.00

Table 5.7 Insulation Cost for 1" Type L Copper

Material Cost Savings

Comparing the side-by-side material cost of copper versus Aquatherm, Aquatherm won the battle by a significant amount. According to Matthew Martin, a sales representative for Aquatherm, based in Bensalem, PA, the linear footage cost of Aquatherm can change depending on the current price of oil. It is the same reason copper prices rise and fall depending on the current market value of the material. Based on 2009 data, located in Appendix A from Aquatherm and Penstan Supply costs for copper piping, the base cost of the domestic cold water line of 2,797 linear feet is $55,390.63 for Copper and $50,613.11 for Aquatherm. These costs do not include any added contractor fees or taxes. Even though labor costs were not shown for the domestic cold water line, it is expected that costs will be relatively close. The process of adding fusion outlets can reduce the amount of times welding or fusing should take place. Another comparison is shown between the cost of the supplies and the cost of the equipment needed to put the system together. Soldering copper piping will cost up to $727.75 versus the iron equipment for Aquatherm, which would cost $683.16. The costs are close estimates, however; material for the copper line such as the gas tank, plumber's dope, and flux will need to be continuously purchased for copper pipping, whereas the Aquatherm system will not.

Mechanical Breadth Results

A current industry issue is the decrease in efficiency of any plumbing line over time. When a system is first installed it is considered to be operating at its prime because the pipes are free of scales and build up. The pumps will work at their lowest RPM since it does not have to increase its flow rate to push through the debris left in the pipe. The picture to the below shows the corrosion of a copper pipe over time. This occurs because the copper is weakened by the oxidization which causes debris to build up in the pipe.

Figure 5.8 Copper pipe corrosion provided by Amtec Consultants

Aquatherm claims in its brochure (shown in Figure 5.9) and on its homepage that its system will outlast the copper system due to the chemical makeup of the pipe. They also claim their system reduces head loss.

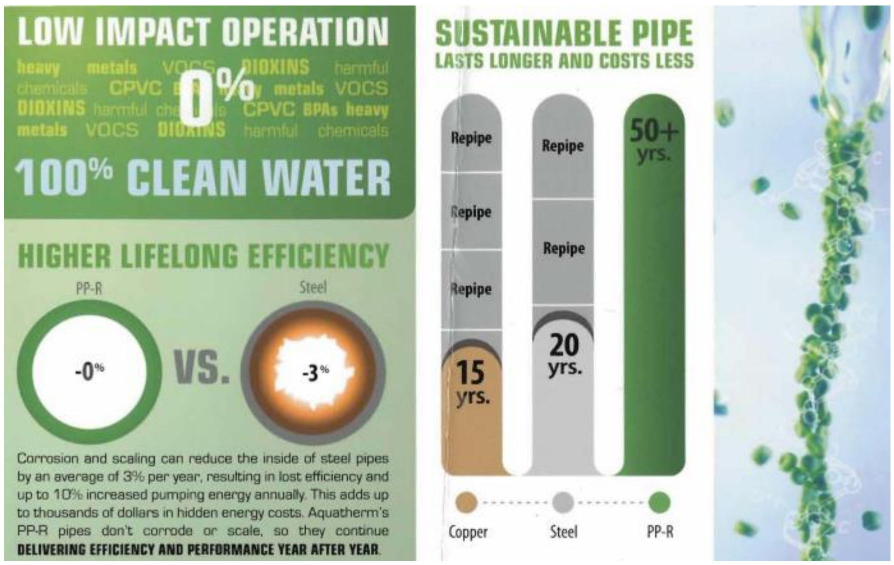


Figure 5.9 Life Expectancy Chart from Aquatherm Brochure

The mechanical breadth analyzed the amount of pressure loss each system had over a linear foot of pipe as well as the head loss per linear foot of pipe. The calculations, located in Appendix B, proved that the reduction in head loss was able to reduce the power consumption of the pump by 22%. Since the buildup scales in Aquatherm piping does not occur as rapidly as it does in copper or steel pipes, the pumps do not have to increase their flow rates or power output, as early on as standard piping systems.

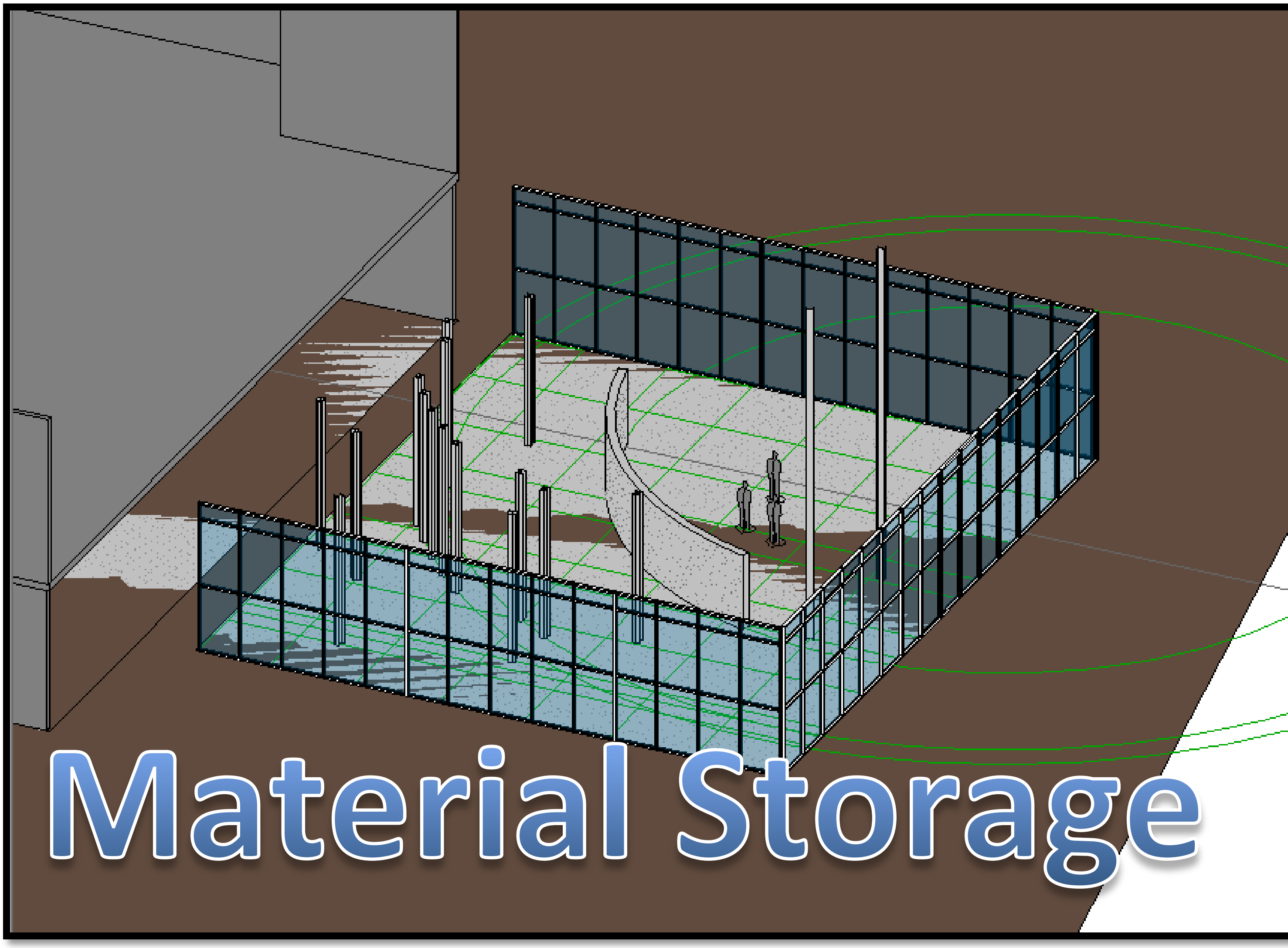
Case Study: Tri-State Laundry

A healthcare laundry facility in Covington, Kentucky, has a tremendous amount of piping circulating through it, which therefore speeds up the wear and tear on the piping in the building. In a month's time, the facility goes though over a million gallons of water. The company wanted to test the Aquatherm system by replacing a 21 foot section of process water piping to test how it would hold up in three years. After the three-year period was up, the facilities management took apart the 21-foot section of their piping and a rust and corrosion free pipe. Tri-State then had Aquatherm replace their 6" mains with the Aquatherm pipe (The full story can be located in Appendix C).

CONCLUSIONS/ RECOMMENDATIONS:

Aquatherm has proven that its installation costs are lower and that it will outlast steel and copper piping, in a building. This is seen in their case studies where they were able to prove its effectiveness in the industrial, commercial, and residential markets. It is recommended that Aquatherm is used to replace the domestic cold water and chilled water systems in order to learn and understand how the Aquatherm systems will perform in JSNN. Referring back to the problem statement in the beginning, JSNN could have avoided the issues of replacing the fan filters if Aquatherm piping had been used for the lines and p-traps. This way no insulation would have interfered with the construction sensitive area such as the clean rooms.

Aquatherm is a safer means of installation because combustion cannot occur in the space where the piping is fused together. The lightweight piping also makes overhead work and the moving of materials around the building easier and less strenuous for workers. The system is not recommended for steam pipes, deionized water or lines that are constantly at pressures of 100psi or greater. Aquatherm cannot take the place of all process piping because of the types of chemicals running through the building.



Material Storage

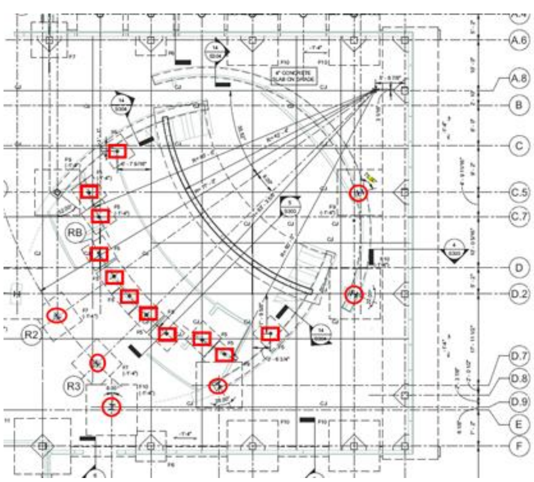
Warehouse

Analysis II: Material Storage Warehouse

PROBLEM/ TOPIC:

In the submittal process, there are instances where the approval process is slowed because of the time lapse on the project, installation of the product or the lead times needed for the product to be manufactured and shipped out to the jobsite. Typically jobsites are not equipped to house materials that need to be in a warehouse setting until they are shipped to the jobsite. This occurs because the jobsites are usually pinched for space. Building a miniature warehouse to store the products or equipment that needs the conditioned space prior to arriving on site alleviates this issue. The construction schedule for JSNN sequences its activities and milestones around the cleanrooms: some activities are on hold and some are accelerated to balance the schedule for completion. The clean rooms have sensitive construction and protocol that require continued focus throughout the project when deciding how to sequence activities and areas of JSNN. When the air handler for the penthouse level had to be set, there were issues where they could not place the air handler due to its massive size.

Construction Scheduling Affects



Since a 5500 square foot area of construction space is being converted into a warehouse space for temporary storage and prefabrication, the sequence of activities is affected. The space that the material storage warehouse will occupy is the lobby and auditorium area. Due to its structure there are space limitations for how much area the warehouse can occupy. Throughout different phases of construction, the space becomes more defined and new structures appear to make it difficult for the warehouse to continue serving its purpose.

PROCESS:

Housing a material storage facility can always be a cumbersome task, whether it is building a storage facility manually or placing a conex on a jobsite. The project team for JSNN had the advantage of having a spacious site to allow for an easy flow of work during construction. Because of this advantage, the proposed idea is to build a material storage warehouse that will serve two purposes: prefabrication and tool equipment storage. The warehouse will alleviate some of the concerns of the owner and the team on the quality control aspects of JSNN. The quality control for the clean rooms depends on whether or not protocol is being closely followed by the team. At different levels of protocol, it is advised that construction work is not completed in the rooms and that certain types of suits should be worn. In order to prevent the work from taking place in the rooms, there needs to be an accessible area where workers can prefabricate pipe, studs, cut drywall, etc. so that the workers are not hindered by the distance from the actual work space. The material storage warehouse will sit in the northeast corner of the auditorium area so that it does not conflict with the 9' structural wall and steel columns that extrude from the slab.

The warehouse will also be a holding area for tools and other laboratory equipment that arrives on the site. Since most of the jobsite is covered in soils preparing for landscaping, there is not a clean or prepped space for the equipment to rest on until it is ready for installation. The bid packages for the project were of high priority to the project team because the equipment that JSNN selected determined the voltage supply to different outlets and dimensioning for rooms where the equipment was going to be set. Also, the specialty contractors such as the process piping contractors needed to coordinate with the project team about the days and/or weeks that they were going to be on the project to hook up the piping to the equipment. As an example, JSNN purchase an MRI which requires extensive set up prior to start up. If an MRI is to be temporarily stored on site, then the slab on which it is resting must be able to support its 10 ton weight. The MRI must also be strategically located so that it can be set into place once its room is ready to house it. These aspects will require phasing plans to show that while the construction for the auditorium continues, the warehouse will be flexible and not delay the schedule.

The structural breadth for the analysis consists of resizing the auditorium slab in order to ensure that it can temporarily hold the MRI and other laboratory equipment in place. Within the phasing plan, some of the structural elements that are located within the warehouse space will be used as part of the structure. Structural analysis will prove that the elements are capable of being used to support the temporary facility.

RESULTS:

Benefits to Warehouse

Mahaffey Fabric Structures is located in Memphis, TN and proves the solution for material storage and prefabrication construction issues. In Figure 6.2, a dimensional layout of the structure is provided by project manager, Mark Huels.

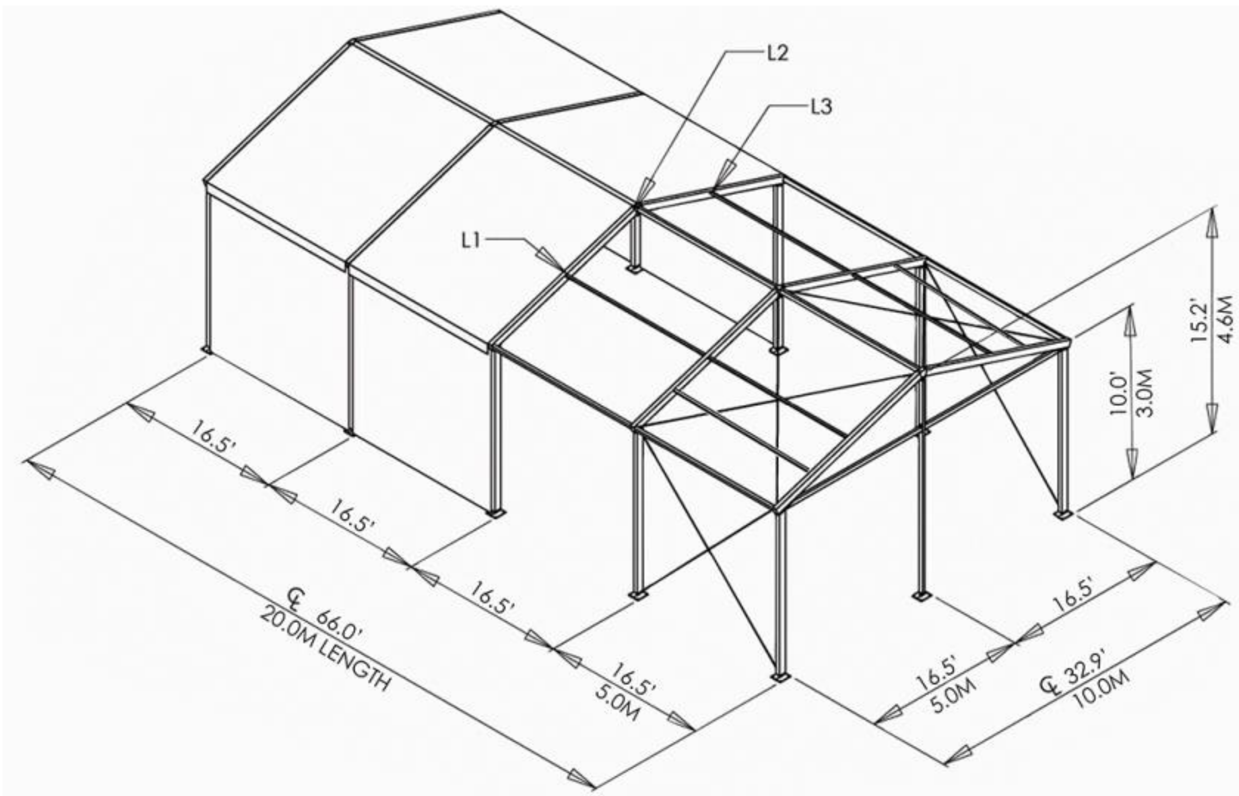
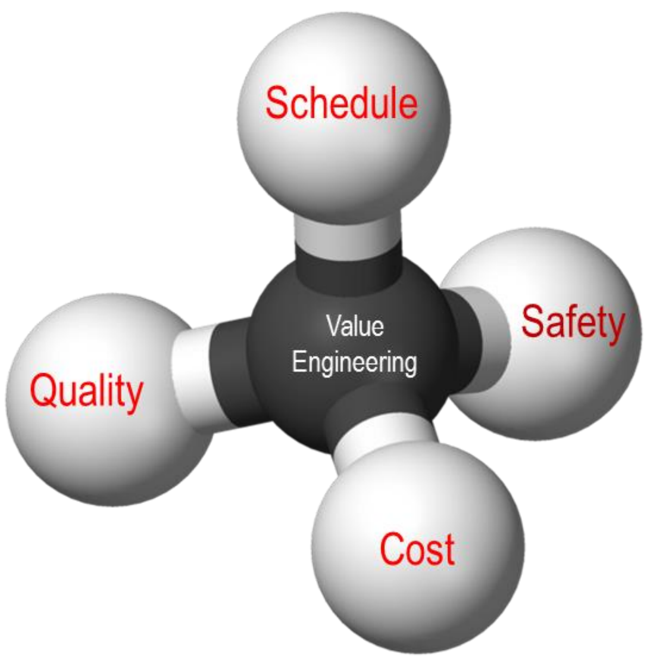


Figure 6.2 Isometric view of warehouse provided by Mark Huels

The laydown area for the warehouse sits snuggly in the northeast corner of the auditorium slab as shown in Figure 6.4. Mahaffey structures estimates warehouse for the activities and uses are described in terms of JSNN's situation. Appendix D delivers a full estimate of the two options for a six-month lease of a fabric structure. A fabric structure is ideal for JSNN because if the structure was going to be made out of lumber or sheet metal, then there would have to a way to dispose of it. Since JSNN is trying to achieve a LEED rating of Silver, it would be ideal to rent a structure that could be removed from the site and reused so that no extra construction waste is generated. Option 1 is a standard 33'x33'x10' with a 14' peak for $17,500.00. Option 2 includes added accessories such as lighting, exhaust fans, a metal personnel door, and panels to construct office spaces within the warehouse. This option costs $32,827.00. Since most of these additional items can be or already are covered in general condition cost, there is no need to purchase Option 2 unless fumes from certain gases will cause an issue for prefabricated parts in the warehouse.

Clean Room Benefits – Protocol

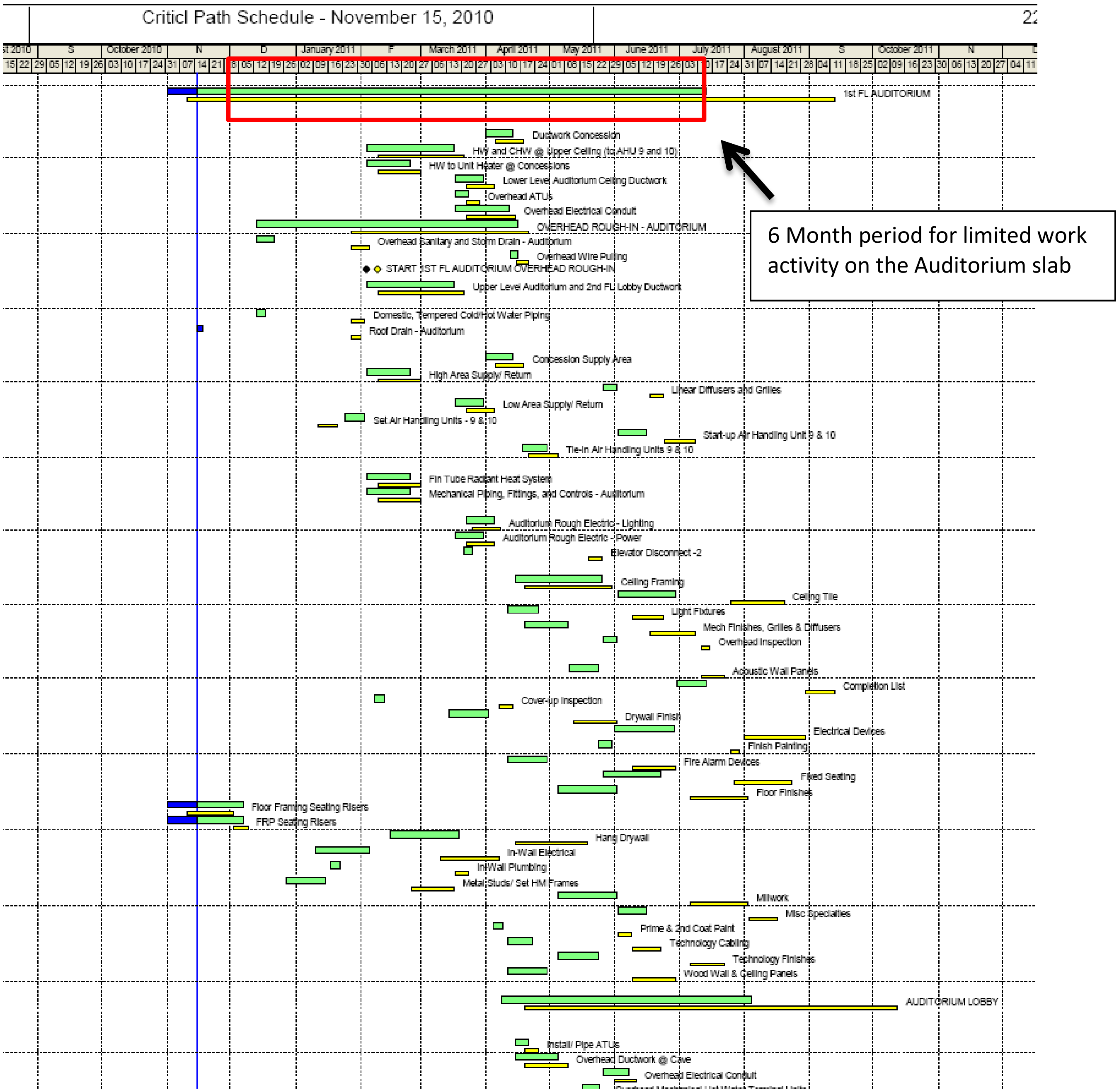
Specification section 13 60 16 lays out the protocol in which the clean rooms are supposed to be constructed by. Appendix E hosts a copy of the specification sheets for the clean rooms. At certain levels of protocol, there are sensitive rules that must be followed such as what products are allowed in the space and what particles are and are not. For instance, there is a point in the construction of the clean rooms where a normal pen and pencil cannot be used because of the particles they would put in the air when writing on a standard piece of paper.



The owner cares about the quality and output of the clean rooms so that research at this facility can be advertised as state of the art. If the facilities are not to the standard that they need to be, then the effort of the laboratory will be fruitless. The warehouse is a key player in ensuring the quality construction of the clean rooms. Since most of the cutting and building cannot happen in the space due to the particles and dust generated, the warehouse provides a means of prefabricating these items locally to the clean room. The clean rooms are conveniently located on the same level as the warehouse. All soldering, pipe cutting, drywall cutting, etc. will be eliminated from the clean room construction. Not all of the debris will be removed from the clean rooms construction area, but the majority of it will be. The warehouse will be the prefabrication site for the clean rooms and other laboratories that can benefit from having a cleaner construction phase.

Schedule changes from Warehouse

The location of the warehouse is placed on the auditorium slab where construction is to take place during the use of the warehouse. The construction of the warehouse, after the concrete and steel structures are in place, is to take place from November of 2010 to Mid-July 2011. The warehouse is to be placed on the slab from December 2010 to May 2011 as delineated in the schedule below in Figure 6.3. The auditorium did not have complicated or time altering features to its construction other than artistic features such as the conical plaster covering. Most of the auditorium's activities were placed at the end since the project team was working its way from the back of the building out to the lobby entrance area. The warehouse is located so that the northeast rim of the cone cannot finish its structural design until the warehouse is moved. Completion was originally scheduled for November 25th, 2011, however, due to the change in the schedule from the delay of the auditorium work, the new date for substantial completion is December 15th, 2011. Moving the auditorium back in the schedule of activities pushes the overall completion of the project back by 25 days, assuming that activities for the auditorium can happen concurrently to the auditorium lobby's activities.



In Appendix F, a new schedule shows how the delay of the work in the auditorium affects the close out of the building. The black star in Figure 6.5 shows that substantial completion is occurring 11 work days away from the completion of the auditorium space.

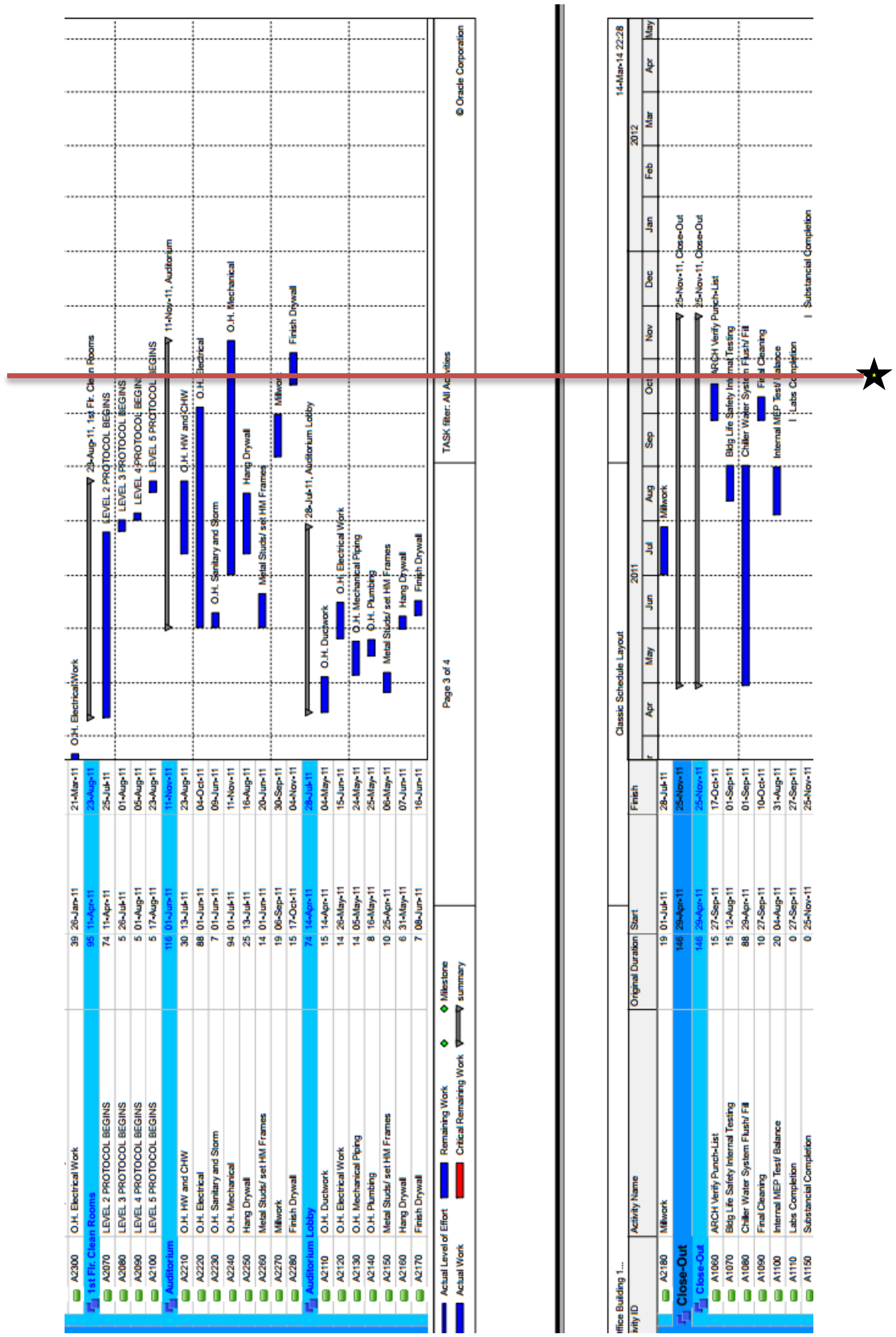


Figure 6.5 Revised PM schedule in Primavera

Structural Breadth Results

With the addition of the MRI resting on the slab for a period of time, the slab on grade for the auditorium needed to be redesigned to ensure that the slab could hold the weight without cracking or being damaged. Currently, the slab on grade for the auditorium is 4”. The slab has no rebar for reinforcing, but it does have welded wire fabric as the supplement. The auditorium slab is 80’-0” wide by 69’-0” in length. Figure 6.1 shows the structural plan for the auditorium and lobby entrance for JSNN. According to the American Concrete Institute (ACI), it is required that 0’-3” of concrete covers rebar on the face where the concrete is exposed to earth. The top of the concrete that is in the interior of the building needs to be covered by 0’-¾” of concrete according to ACI. With those two standards, it is easy to see how the slab needs to be at least 0’-4” of concrete total. The original loading of the auditorium is:

$$P_u = 1.2(Dead\ Load) + 1.6(\ Live\ Load) + 0.5\ (Snow\ Load)$$

$$D_L = 20PSF$$

$$L_L = 100\ PSF$$

$$S_L = 11PSF$$

The additional weight from the specified Siemens’ Magentom MRI would add 13 ton to the slab. The added dead load calculated to be 1083 PSF.

Since the purpose for the warehouse was to temporarily store the MRI and any other laboratory equipment, the location for the MRI is to be within the bounds of the warehouse. As shown in Figure 6.4, the MRI will be sitting in a corner of the slab instead of in the center.

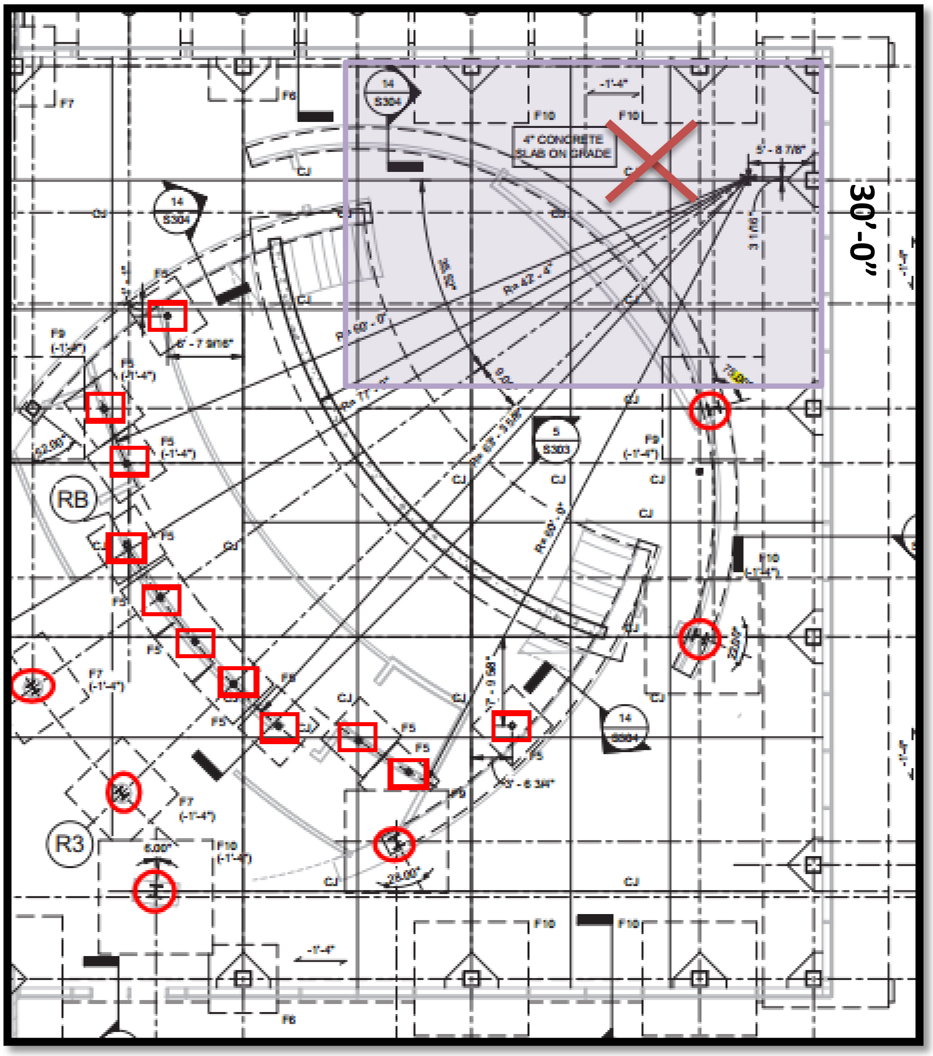
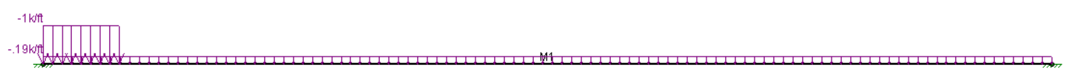


Figure 6.4 Location of MRI in warehouse

With the 13 ton load resting on the corner of the slab, the moment distribution was expected to change drastically. The new moments calculated were 51 ft-k in the positive direction and 117ft-k in the negative direction. The shear and moment diagrams below show the change in the loading on the slab with in turn changed the slab depth, see Chart 6.4. This additional weight is likely to damage the new slab in some manner that would require a rebuild. In order to determine the slab depth, a new maximum and minimum moment had to be calculated. Using RISA© -2D Educational Software the new moment was determine. Appendix G shows how the calculations were derived for the slab on grade. Below is the newly replicated moment diagram for the location of the MRI based on the location of the warehouse.

Loading Diagram



Shear Diagram

Moment Diagram

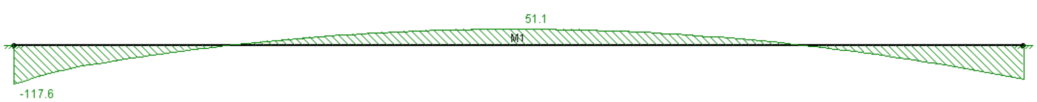


Chart 6.4 Loading Diagrams from RISA ©

In order to calculate the slab on grade, it had to be broken down into individual 1'-0" wide concrete beams with one side of the beam being susceptible to exposed earth. Two beams were considered since there was a negative and positive moment side of the beam. After the calculations were performed, the new slab on grade depth became 0'-8" using #5 and #4 rebar spaced in mat forms.

CONCLUSIONS/ RECOMMENDATIONS:

The material storage facility has many beneficial aspects to it in order to help the laboratory be a successful project. Having the facility as a prefabrication and storage area for the laboratory equipment allows for the quality of the project to increase significantly. JSNN has had the benefit from the start of having a generous amount of space to work the site around.

While the original intent was to place the warehouse on the auditorium slab to prevent the construction of the slab, having the warehouse located on the auditorium slab after the structure is built delays the overall construction schedule by 14 work days. Substantial completion is pushed back into Mid-December and while there is no fine for delayed work days, there are consequential damages for the project being delayed.

It is recommended that, if the project team and owner can agree upon the importance of the warehouse, the warehouse should be located outside of the jobsite on north side of E. Lee Street as show in Figure 6.6.

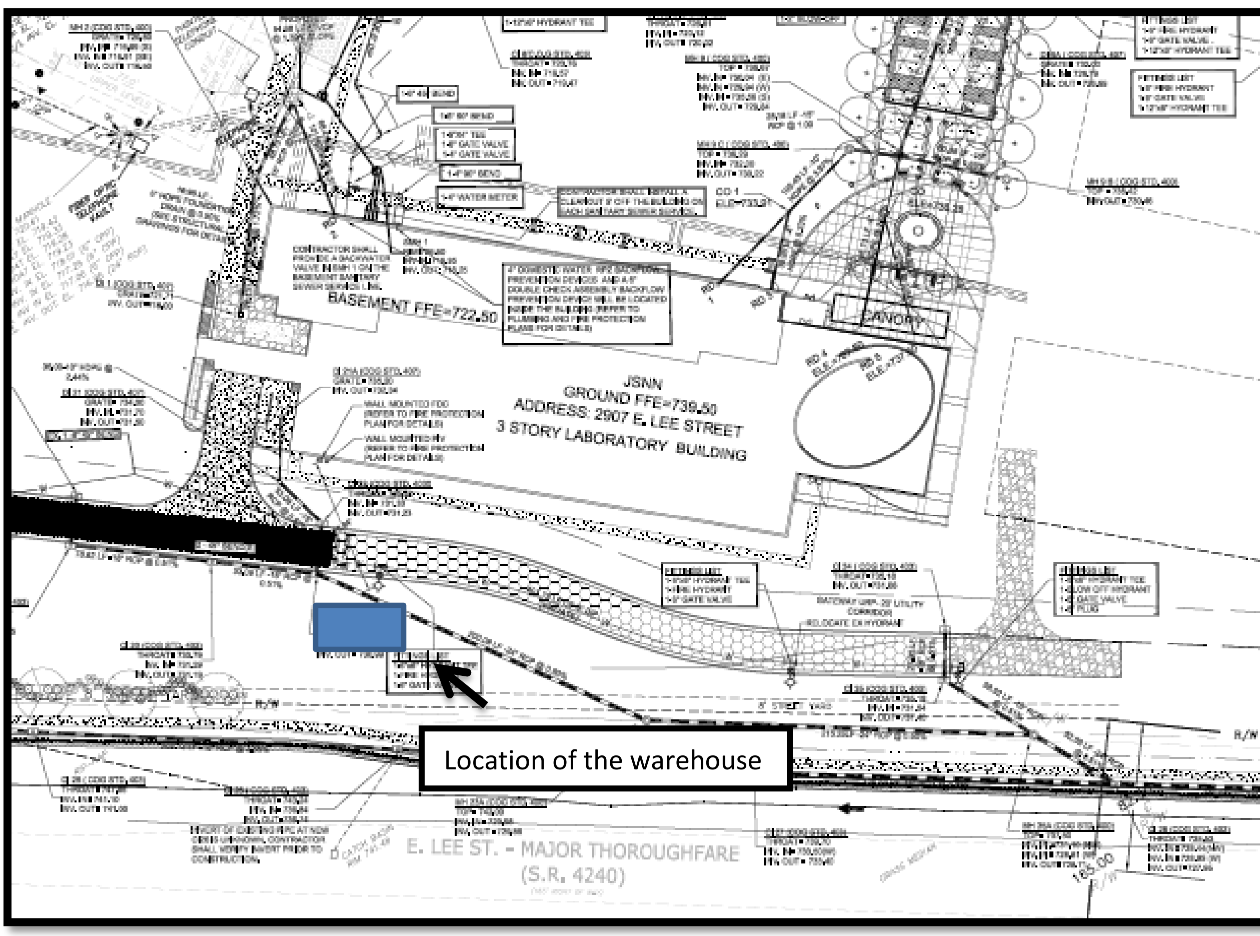


Figure 6.6 Location of warehouse on site

As discussed earlier, the total cost for a 6-month lease of the warehouse is $17,500.00. If the warehouse should be moved off the site onto a built up slab, then the added cost for a slab would have to be constructed. This slab is estimated at $5,147.63 from the data gathered below in Table 6.7. Between the cost of the slab and lease of the fabric tent, the total estimated cost to the owner would be $22,647.63.

Material	C.FT.	C.Y.	LF.	Lb/LF.	Ton	# of Boards	$/ C.Y.	$/ Ton	$/ Board	Subtotal
Concrete	800	30			-	-	$115			$3,450.00
#4 Rebar	-	-	1800	0.668	0.601	-		$1,000		$601.00
#5 Rebar	-	-	1800	1.043	0.9385	-		$1,000		$938.50
2x8x16 Lumber	-	-	-	-	-	9			$17.57	$158.13
									Total Mat.	$5,147.63

Table 6.7 Independent concrete slab estimate

Analysis

Wetland Preservation

Analysis III: Wetland Preservation

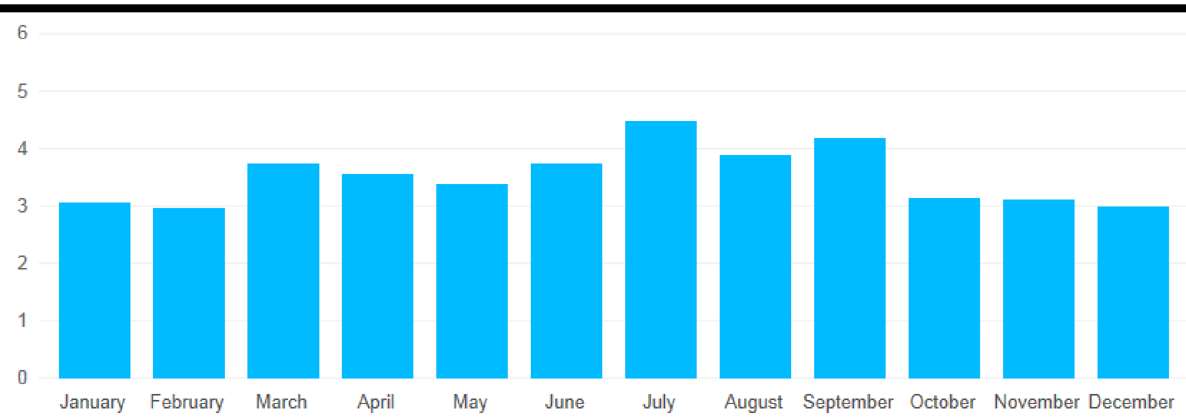
PROBLEM/ TOPIC:

Before the construction team for JSNN was to begin breaking ground, the team was confronted by the North Carolina Department of Environment and Natural NCDENR who told them that certain violations from the previous contractor needed to be resolved before they could start working. The site work plan or the civil drawings would not be approved and released until the erosion control issues were cleaned up. Clean up was put on Barton Malow and Samet to resolve, while Gateway was going to have to supplement the cost for cleaning this up out of their design contingency. The cost was approximately $13,000 to run a pipe extension to Lee Street and clean up the issue.

PROCESS:

The North Carolina Department of Environment and Natural Resources (NCDENR) regulate storm water management throughout the state. The NCDENR mandates construction projects and their run off issues. When it comes to managing the storm water that inhabits an area, the NCDENR has a manual, developed back in 2007, that lists and encourages different options to preserve and mange storm water in different areas. Excerpts from this manual are provided in Appendix H.

To determine which type of storm water management plan is best for JSNN, the amount of rainfall that is expected for the project needs to be calculated. Figure 7.1 is the average rainfall that Greensboro, NC receives on average each month provided by **weatherdb.com**. The summer months accumulate the most amount of rain for Greensboro, but the charts show that the rainfall is fairly consistent in terms of inches collected. Greensboro receives an average that is lower than the state average.



Month	Average Rainfall	2014 Rainfall
January	3.06 in	3.98 in
February	2.96 in	2.24 in
March	3.73 in	
April	3.57 in	
May	3.38 in	
June	3.73 in	
July	4.48 in	
August	3.88 in	
September	4.19 in	
October	3.13 in	
November	3.11 in	
December	2.98 in	

AVERAGE ANNUAL PRECIPITATION

Greensboro, North Carolina 42.20 inches

North Carolina 46.79 inches

All Average Rainfall 41.11 inches

Figure 7.1 Rainfall for Greensboro, NC provided by weatherdb.com

The site is mainly composed of silty sand soil. Soil of that type can cause issues when it rains because of the muck it creates. When silty sand collects water, it turns into a very muddy slop that slides around easily. If on a hillside, it is expected that the runoff will create huge muddy swamps at the base of a hill. The wetlands are located on the north side of the site and the site slopes down to the wetlands. Towards the northern most wetlands, the site slopes from 740'-0" to 710'-0". On the north western side of the side, where wetlands are located outside the adjacent office building, the site slopes down to these wetlands from 740'-0" to 720'-0" as shown on C-200 topography drawing in Figure 7.2.

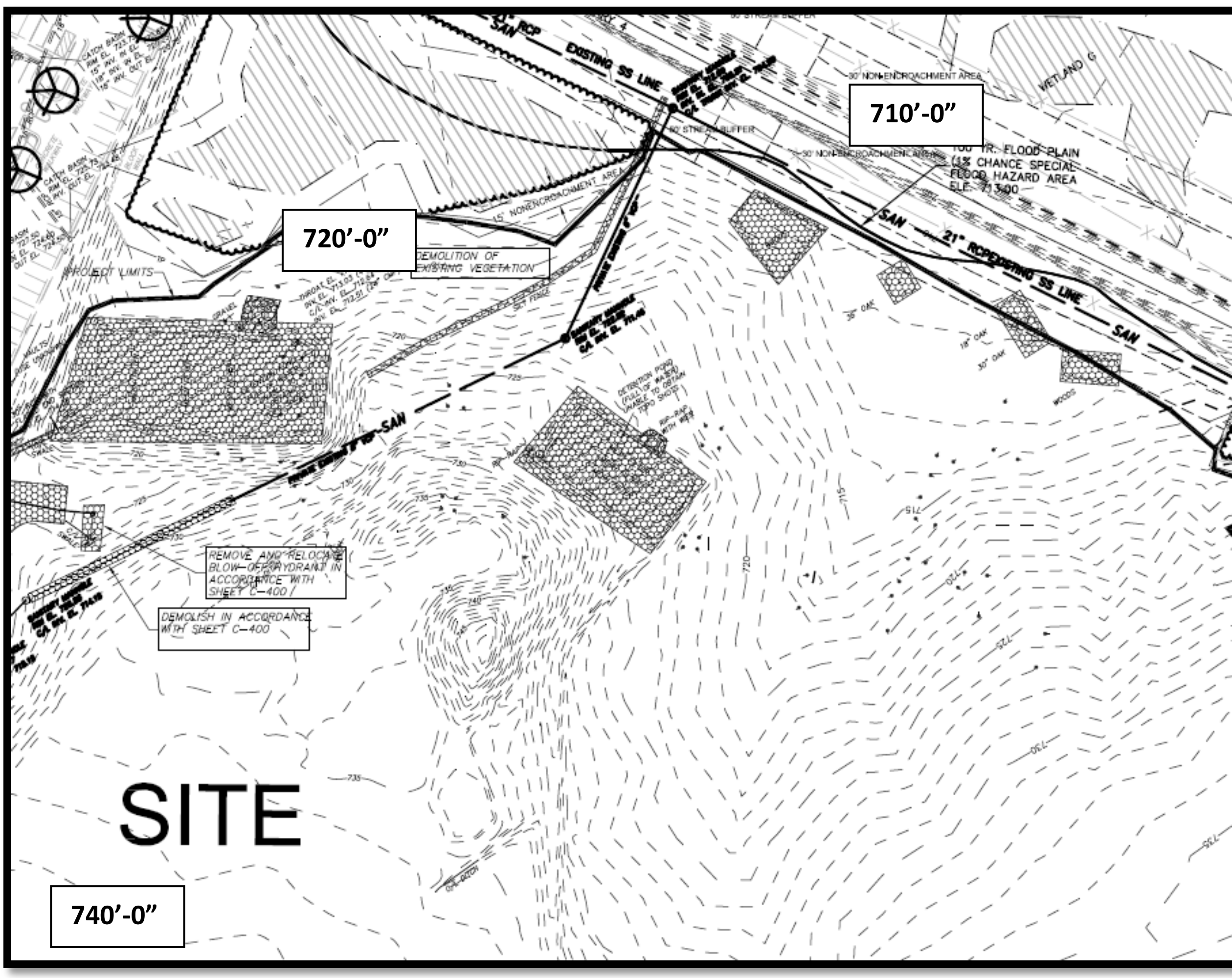


Figure 7.2 Topography of JSNN site, C-200

With this type of set up for wetlands, the best method, proposed by the NCDENR, for storm water management and site run off is a sand filter. A sand filter is two-chamber trench that allows for water to drain into the first chamber and then filter out the unwanted items into the sand. The water that filters though the sand is then able to escape through a pipe that can drain into the wetlands. Figure 7.3 shows a schematic of how the system is intended to work.

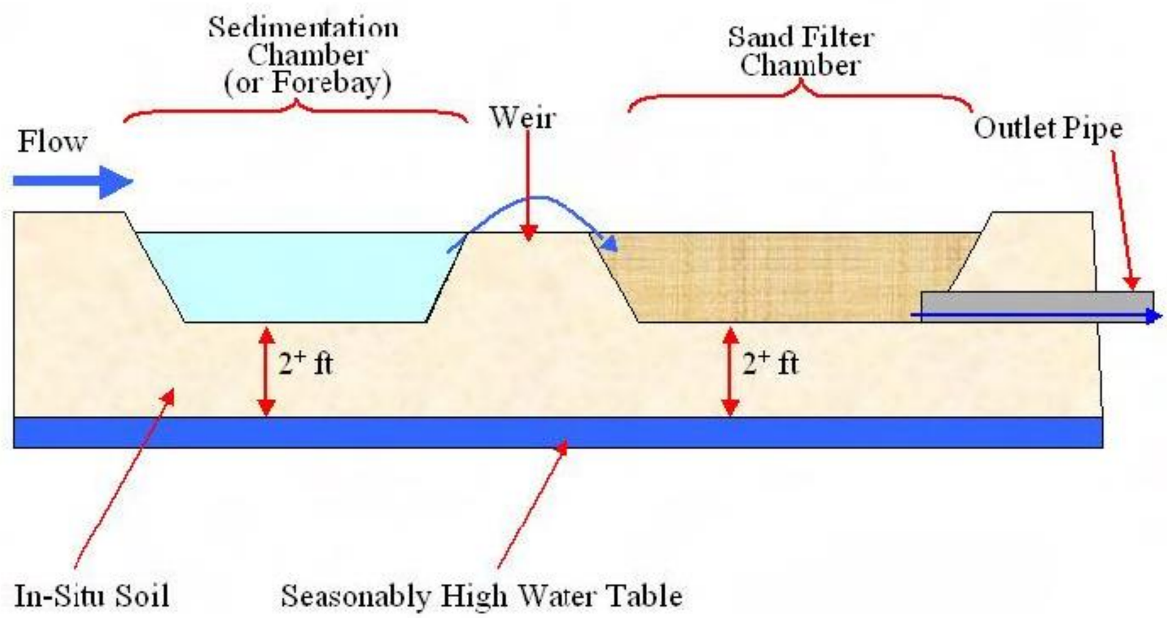


Figure 7.3 Schematic of Sand Filter provided by NCDENR Stormwater BMP Manual

In order to show how the system is beneficial, a plan and cost analysis will be drafted. The sand filter is intended to stay intact after construction of JSNN has been complete. If another building or structure is going to be built over the sand filter, then the current contractor will be repsonsible to contact the NCDENR to incur proper removal proccdures. The sand used for the filtering will be the commmerical grade sand (medium sand) that can be purchased at any local hardware store.

RESULTS:

Design of Sand Filter

The NCDENR compiled a Best Management Practices (BMP) manual in July of 2007 to encourage people to pursue different options that best suit the type of environment they are working in to preserve the land. Several applications would be suitable for the wetlands around JSNN. Originally, the project management team built a concrete dam to protect run off and storm water from flowing down into the wetlands and the dam was left in place for after JSNN was constructed. Placing this concrete dam cost the owner an extra $5,500.00. The civil drawings did not specify how the wetlands were to be protected after construction so the logical solution seemed to be building the dam in line with the 18" pipe that the project team put in place.

The storm water management manual proposed a few options that would add value to the wetlands by not putting in construction efforts that would alter or upset the wetlands. Grass swale, riprap, a bioretention plot, and sand filter were among the options. The one best suited for JSNN and its environment is the sand filter. The sand filter is a two-chambered system where water builds up in the first chamber and slowly rolls over into the second chamber where it seeps down into in the sand through an outlet pipe into the environment it is intended to. The construction of the sand filter, as depicted in Figure 7.3, shows the two chambers as well as what the typical design looks like. In the storm water BMP manual, there are several others ways to construct the sand filter depending on the location or how the sand filter is intended to drain the water (these options are displayed in Appendix H).

Within the BMP manual, there were step-by-step calculations to determine the size of the sand filter by depth and surface area to prevent an overflow of the two chambers. Figure 7.4 shows the acres of land that the filters will have to consume and filter before dumping into the wetlands. Since the actual acreage is a little over 6 acres, the calculations were done assuming that the sand filters were combating 7 acres of drainage. The acreage was determined using the topography lines to show where the slopes and run off were going to be affecting. The calculations, found in Appendix I, determined that the depth of the chambers needed to be 1'-6". The lengths of the chambers are consistent for both sides; 1120 ft. The sedimentation chamber needs to be 1'-6" in width and the sand filer needs to be 2'-0" in width. The chamber will be constructed out of concrete, shown in Appendix I. The sand filter when completed will encompass the area of wetlands between the 3-story office building and JSNN. The sand filter will have to sit behind the 15' non-encroachment area that is show on drawing C-200. Locations of wetlands cannot be tampered with or altered. This means that the contractors will have to build the sand filter 15' from the beginning of the outline of the wetlands. This also meant that the outlet pipe will have to extend a foot out over the non-encroachment line.

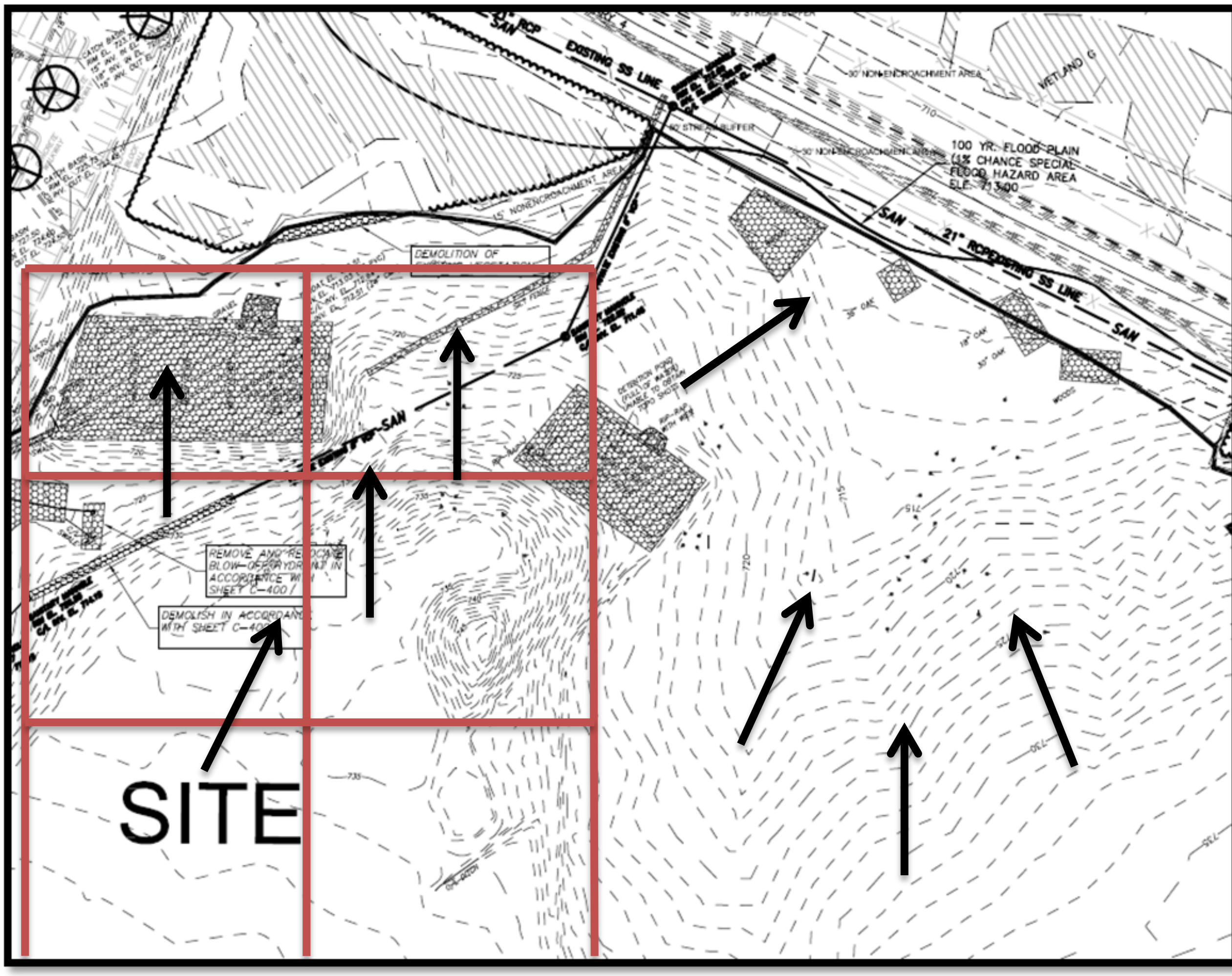


Figure 7.4 Acreage of Rainfall to NW Wetlands

Another consideration when selecting the right type of BMP for the site was the likelihood that the area would flood. From the Flood Risk Information System (F.R.I.S.), Greensboro, NC lays in a zone where there is minimal flooding as shown in Figure 7.5 from the website. Since the area is under minimal risk, the sand filter is considered an applicable BMP for the site.

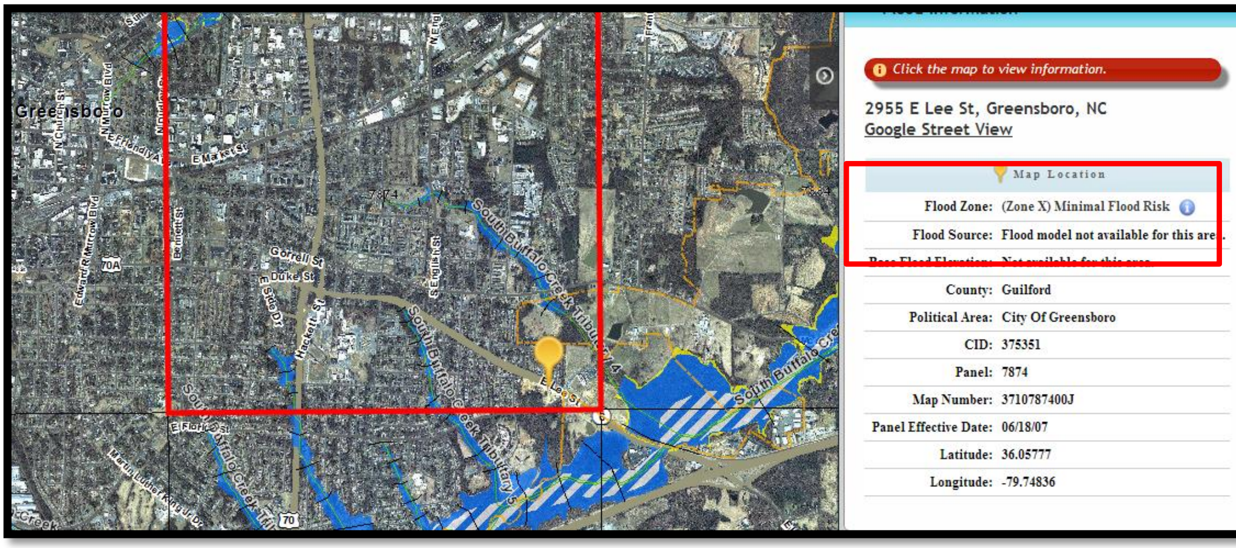


Table 7.5 Flood Zone Risks Provided by F.R.I.S website

Amount of RainFall

According to **weatherbd.com**, Greensboro, NC receives an annual average of 40" of rainfall per year and the relative humidity hangs around 68% throughout the year. These pieces of data affect the rate at which the water is evaporated or retained. Table 7.5 shows the net water retained after a monthly rainfall.

Net Rainfall for Greensboro, NC after Evaporation						
	January	**February**	**March**	**April**	**May**	**June**
Amount Evaporated	0.18	0.18	0.22	0.21	0.2	0.22
Amount Rainfall	3.06	2.96	3.73	3.57	3.38	3.73
Net Retainage	2.88	2.78	3.51	3.36	3.18	3.51
	July	**August**	**September**	**October**	**Novemeber**	**December**
Amount Evaporated	0.27	0.23	0.25	0.19	0.19	0.18
Amount Rainfall	4.48	3.88	4.19	3.13	3.11	2.98
Net Retainage	4.21	3.65	3.94	2.94	2.92	2.8

Table 7.5 Evaporation Rate by Month

The evaporation rates were calculated based on the amount, leaving a square footage of surface area.

$$g_h = (25 + 19v)A(x_s - x) \text{ where,}$$

g_h = amount of water evaporated per hour (kg/hr)

Θ = evaporation coefficient (kg/m^2 h) = (25+19v)

v = velocity of air above surface (m/s)

A = water surface area (m^2)

X_s = humidity ratio in saturated air (100%)

X = humidity ratio in air

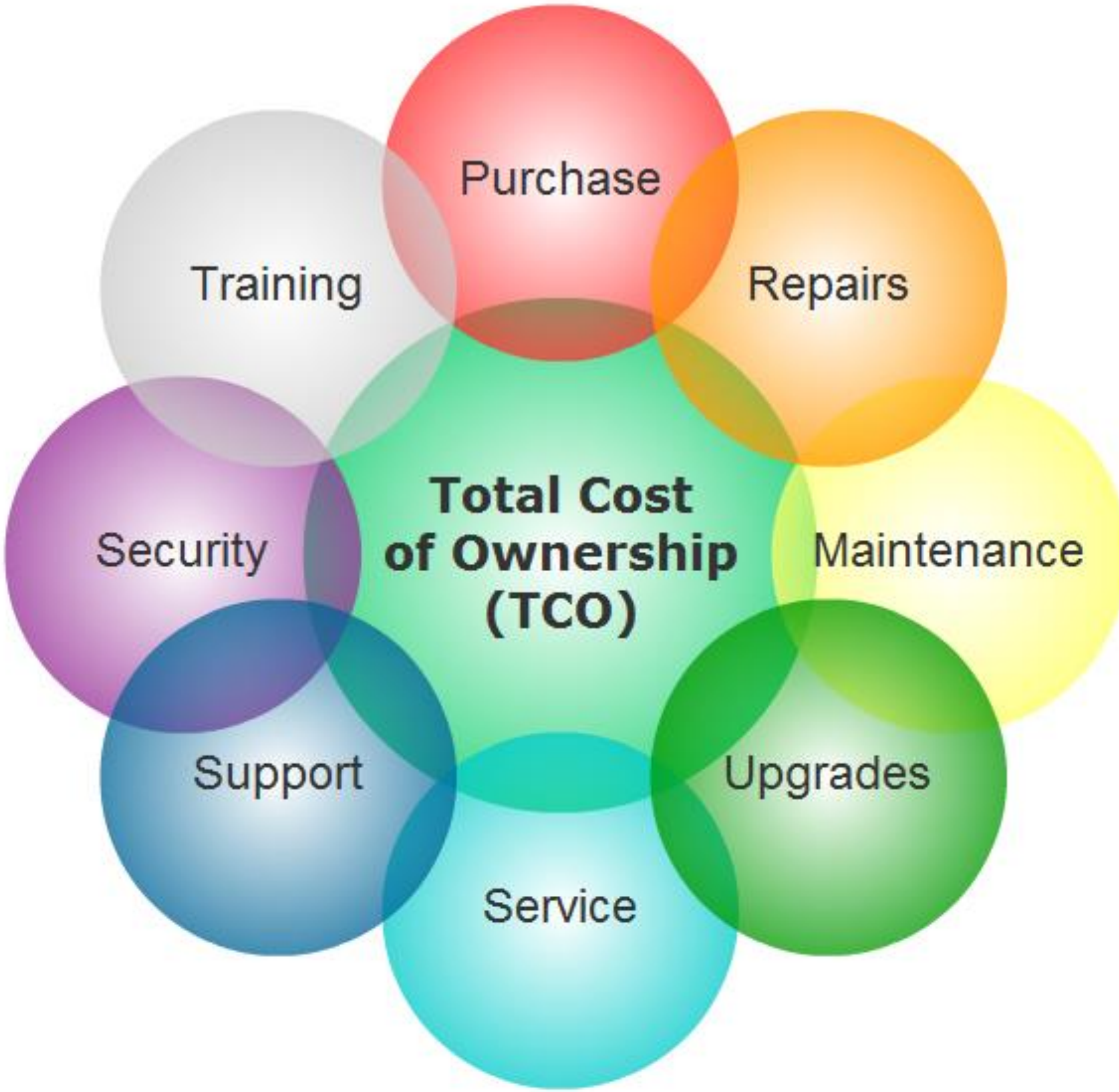
Determining the amount of kilograms of water that is evaporated per month required the consideration of the change of humidity and wind speeds over the different months of the year. The information of average humidity and average wind speeds were provided by the Southeast Regional Climate Center and **weatherdb.com**. The table and charts referring to the calculations that determine the amount of evaporated water per month can be found in Appendix J.

Cost of Sand Filter

The original solution that the project team proposed to do, costing $5,500.00 to JSNN, was to build a concrete dam post construction to prevent soil and future run off from dumping into the wetlands. While this idea was accepted by the NCDENR, it is not a system that works. The wetlands would not be able to allow nature to operate as it usually does because working facilities will surround it. The cost of the sand filter should be considered as a future investment on the projects since Gateway University hopes to plant on the grounds surrounding JSNN. When the NCDENR first approached the project team and Gateway about the issues left by the previous contractor, it cost Gateway and extra $13,000.00 to fix the erosion and then protect the wetlands during construction. Once the project team decided to put in the concrete dam, the added cost made the entire environmental issue a little over $18,500.00. The estimated cost for the base materials nee to construct the sand filter around the northwestern wetland is $34,500.00. Labor is not included in this estimate since it would be up to Gateway to decide if the issue should be handled separately from the construction of JSNN or with the construction. The cost of the medium sand commercial grade is $5.56/ bag of 50lb sand at any Lowes store. The amount needed to cover 2240 ft^3 of sand chamber is 1871 bags which come to $10,402.00. In order to construct the dam, it will require 197 cubic yards of concrete and excavation of 11,200 ft^3 of soil. The cost for excavation and concrete together, with costs supplied by RS Means 2014, would be $24,111.

CONCLUSIONS/ RECOMMMENDATIONS:

If allowed, the contractor can be crafty with the storm water management procedures and deciding what method would be the best for the project and future of the site. While the project team made an acceptable decision for the time and conflict they faced, Gateway will still have to plan and project how future projects will continue to affect the wetlands. The cost of the sand filter is significantly higher, but the remedial cost of repair that Gateway faced from the NCDENR from no erosion and storm water management control was a significant price too. It is recommended that Gateway considers the investment of the sand filter as a means of finalizing a plan that would mean a drop in construction cost for the project team to not have to budget for run-off and erosion. Wetlands are not only a primary target of state environmental protection entities but it also on the radar of the Environmental Protection Agency (EPA). If no measures are considered in protecting the wetlands from run off that happens year round, then Gateway can face the fines on each new project it plans to pursue. These fines can add up to be well over the cost of the construction of the sand filter. Not only is the storm water management an investment in future protection from construction projects, but it is an encouragement to other owners who build facilities on a campus frequently such as an higher education complex or medical campus.


Purchase
Training
Repairs
Total Cost
of Ownership
(TCO)
Security
Maintenance
Support
Upgrades
Service

Analysis IV: Total Cost of Ownership for Magnetron MRI

PROBLEM/ TOPIC:

When a university is looking to build, install, fabricate, invest, or embark on a new idea, there are costs associated that will hinder or advance the idea. In the case of JSNN, A&T and UNCG are looking to expand Gateway Research Park and the facilities it offers to researchers. The Nanosciences and Nanoengineering courses require costly pieces of equipment to run and operate the experiments the students want to conduct. From a construction standpoint, the purchasing of these types of equipment makes planning a difficult task. Most of the time the owner wants to hold off on making the decision until it's absolutely necessary to ensure that they are purchasing the latest and greatest equipment. Gateway University Research is a non-profit organization that is set up to manage the facilities. Gateway, A&T, UNCG are working together to attract new researchers who are interested in giving the funds to conduct certain experiments. Having the best and most up-to-date equipment available is a huge priority of JSNN. In the same way, having the best equipment can be costly if the funds do not support the overall cost of the building especially with maintenance of the different laboratory equipment.

PROCESS:

Owners and clients who house and operate expensive and ever changing equipment always have the issue of purchasing the best equipment when it is time to upgrade, or in the case of JSNN, building a new facility. Gateway is established as one entity that serves two universities interests; UNCG and NC A&T. Sciences and engineering are combining under one roof to operate together. This situation is very different from have a sole entity such as Penn State focusing on its personal goals. NC A&T and UNCG need to have each of their universities needs met as well as the other partner's. Trying to decide on specific equipment that will serve both universities' needs is twice as difficult as if it were just trying to be one university deciding on equipment for its students.

In order to show how looking at the total cost of ownership needs to be approached for selecting a piece of equipment, the Siemens Magnetom MRI will be the analyzed piece of equipment. If some of the equipment is shared, then the cost of ownership becomes complicated between deciding who is responsible for different maintenance elements once the equipment is in operation.

When it comes to the operation and maintenance of equipment, there are three different approaches that the facility manager and owner consider when looking at maintaining any piece of equipment it purchases. In a discussion with Craig Dubler, a virtual facilities engineer at the Office of the Physical Plant at Penn State University, he commented on three different was that the university looks at equipment and decides how to approach managing it. Those three different ways are, "Run it to Failure," "Preventative Maintenance," and "Predictive Maintenance." Table 8.1 lists examples and explains these ideas in depth.

	CATERGORY OF MAINTANATIVE CARE		
	Run it to Failure	**Preventative Maintenance**	**Predictive Maintenance**
Idea	Wear out particular piece of equipment to point of total replacement of system	Use precaution in preserving piece of equipment to outlast life expectancy	Determining the best solution, through trial and error, of operating the equipment
Level of Cost	High	Low	Moderate
Types of equipment associated	• Motors • Computers	• Laboratory Equipment • Chillers • Air Handlers	• Vehicles • Musical Instruments

Figure 8.1 Category of Maintainative Care

Having this type of break down readily available allows the owner of the equipment or facility to decide up front the level of attention and planning that will be involved in selecting the best piece of equipment for its purpose.

RESULTS:

Benefits to Gateway

Gateway was established between the two universities, NC A&T and UNCG, as the solution to bringing the nanosciences and nanoengineering under one roof. The non-profit management facility operates under one roof and title the Joint School of Nanoscience and Nanoengineering. In the beginning, when the decision was made to bring the strengths of both schools together, the funding for the construction of the facility came from the state and structured as shown in Figure 8.2.

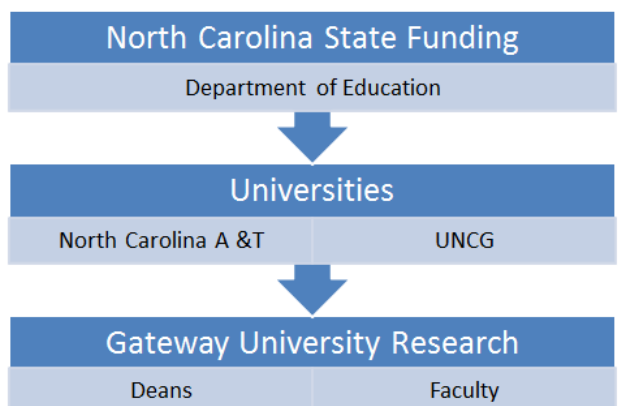


Figure 8.2 Funding Source Chart

Each entity had its own interests in mind for the facility, but the schools were able to work together cohesively to purchase equipment and fund the construction as JSNN was going through Design Development. In an interview with John Merrill, Director of Gateway Research, he explained how the structure of the contract made it easy for both universities to make their decisions concerning the laboratories and the equipment in them. Once the equipment was installed, by contract, it was turned over to Gateway for complete ownership and maintenance thereafter.

Figure 8.3 Partnership Chart

Since Gateway was established as a non-profit entity, it is always looking for corporate sponsor ship as this was the goal of the research facility. In his interview, John Merrill spoke about how now that JSNN is in full swing operation, many of the corporate sponsors have taken the lead to take care and update the equipment on a need by need basis to ensure the quality of the research done in the laboratories. John further stated that when the time comes to construct another research facility on the Gateway campus, the universities and Gateway are trying to build relationships with the corporate sponsors that would engage their interest in funding the new facilities and turn over ownership and maintenance to the Gateway team. So far several corporate sponsors have committed to the goals and missions of the Gateway Research Park and have considered the laboratories in JSNN as their own. This has provided security to the research done at JSNN and the continued maintenance on equipment such as the MRI.

Siemens MAGNETOM MRI

The largest purchase that UNCG made for JSNN was the purchase of the Siemens Magnetom MRI. The initial cost of the MRI was $1,330,000.00. The MRI was a refurbished unit and caused minor delays in getting replacement parts for it. The MRI was delivered by a truck and hauled into the facility by a crane as shown in Figure 8.4.

Figure 8.4 MRI unloading picture

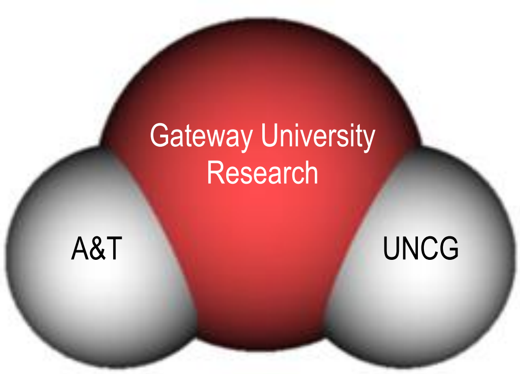
For the maintenance on a Siemens MRI, the company establishes a contract with the facility to make Siemens responsible for the maintenance. After speaking with Karen Ryan, Equipment Engineer for Gateway, the contact currently costs $135,181.00 per year for Siemens technicians to do preventative maintenance on the MRI. The MRI requires liquid helium tanks to be changed out about three or four times a year. Siemens has the ability to remotely monitor the MRI and will order the tanks for the facility when the MRI is ready for the equipment.

Equipment with this type of care and maintenance required is a decision that needs to have planning and reasoning behind putting the MRI in place. In addition to running process piping to the MRI, considerations about the loading the MRI places on the slab it rests on and the electrical loading that the MRI will put on the building. Karen mentioned that the MRI is not metered and track for its energy consumption. The MRI does add heat to the space which required that an additional AC unit be placed in the facility to cool the space.

Ideal Order of Operations

The overall goal for the cost of ownership for a campus such as Gateway Research is to build partnerships that supply JSNN and the universities with the resources it needs to proceed with the research it embarks on. In order for this to happen, a hierarchal order must be established to ensure that the success of the ideal happens. When UNCG and A&T decided to embrace a partnership to enhance the research capabilities of both universities, they decided to establish Gateway as a means of managing the operations of JSNN. Gateway is also a mean of mediating the interests of both universities.

In terms of managing the facilities, JSNN gains full ownership of the equipment after it is installed. By doing so it takes the responsibility of owning the equipment off of UNCG and A&T. When it comes to sharing the equipment that both universities contributed funds too, the students, from both universities, schedule time on the equipment through the use of BookItLab©. BookItLab allows for each university to sign up for use on the equipment at different times so that one student group's research conflicts with another



Maximo and Maintenance Connection

As Gateway looks to expand its facilities in the future by adding more buildings to its campus, managing and maintaining the campus will become more of a challenge. Several more pieces of equipment are likely to be added and will need someone or something to be watching over their operation. A plausible solution, which Gateway has already implemented, is the use of a web based server in which the assessment of the equipment, work order releases, and operation settings are controlled. Gateway has been making use of the Maintenance Connection server, which is enterprise web-based maintenance management software for owners such as Gateway. In comparison, Penn State uses similar type of software called Maximo. In an interview with Rick Philips, Quality Assurance Coordinator at the Office of the Physical Plant, he shared the upgrade Maximo just made on its new software, Maximo v.7.5.0.5, and the new software has covered the glitches in the old version, Maximo v.4.1.1. Both software pieces are a means of supporting and maintaining the equipment and facilities on campus. The software, since both are cloud based can be accessed from iPads, personal laptops and phones.

CONCLUSIONS/ RECOMMMENDATIONS:

Gateway is a unique partnership of two universities interests and goals. Contractually, the universities are one entity under Gateway University Research. Once the building was built and equipment was fired up, the responsibility for maintaining the facilities fell on Gateway, led by John Merrill. From the perspective of a university such as Penn State, the partnership and collaboration is a unique scenario, where conflict is minimal. UNCG and A&T were able to see the strengths of each other’s programs and the benefit of bringing them together strengthened the curriculum, research, and collaboration efforts of the universities especially in the areas of financing the operations. It is recommended that other universities look into partnerships that can reap benefits that JSNN has from corporate sponsors.

Gateway is a non-profit organization completely operating off of grants and funds from corporate partners whom are interested in the facilities the labs have. Maintaining state of the art equipment requires a management system that is just as innovate as the equipment in place. It is recommended that Gateway considers updating the maintenance management software alongside of maintaining the equipment. Most equipment can be operated remotely and the specific type of equipment may require an upgrade on the software side. Especially as the Gateway Research Campus increases in size and number of buildings, the flexibility in a system to be cloud based is a primary operation feature.

Final Recommendations and Conclusions

Once again, through the 2013/2014 school year, the Joint School of Nanoscience and Nanoengineering (JSNN) was analyzed to denote areas during the construction process, design, and facility management of the laboratory that would enhance their functions. Feedback from the project team, owners, and facility managers helped to pinpoint topics that are relevant to JSNN. The following represents the three analyses performed as part of the final senior thesis project for the undergraduate architectural engineering program at Penn State University. It is important to note that the purpose of this thesis is strictly educational and is not intended to critique the project team, owner, and facility managers in anyway.

Analysis 1: Aquatherm

After a comparsion between cost of copper versus Aquatherm and the reduced amount of power the system needs to operate over a period of time, it is recommended that Aquatherm is used on the domestic cold water line for JSNN. Further analysis is needed to determine the effectiveness on other lines such as chilled water, hot water, greywater, and processed piping.

Analysis 2: On-Site Material Storage Warehouse

While the use of the building footprint of JSNN is not a viable option, there is still value in placing the warehouse on a temporary slab outside of the building to continue to make use of the benefits from the material storage warehouse. The warehouse is the idea size for holding equipment that arrives to the site early such as the laboratory equipment and larger items such as the MRI and NMR.

Analysis 3: Wetland Preservation

The richness of a wetland and environmentally rich area such as the Gateway Research Park should be placed in a category of high importance. It is recommended to install a sand filter to make a permanent means of preservation and maintenance for the wetlands that can be affected by construction run-off. Since Gateway plans to expand their campus and plant more building on site, there is a means of considering in investing in the cost of sand filters around them to preservation and maintain them in the most natural way.

Analysis 4: Total Cost of Ownership Magentom MRI

JSNN is a unique development from two universities desires to want to come together for research and development with, what seems to be, low political issues involved. It is recommended that Gateway become a staple for how two universities interest become one effort to improve the strengths of the other. In another light, it is also recommended that universities make sure that Gateway is continuing to do the operations that the university originally expected to have happen. The maintenance software, as the university grows, should grow and improve as the facility should. The facilities are the main reason that the corporate sponsors are interested in putting funding towards the programs and research. If the facilities are not maintained to the best of the facility's ability, then the quality and funding can be expected to decrease.

Conclusion

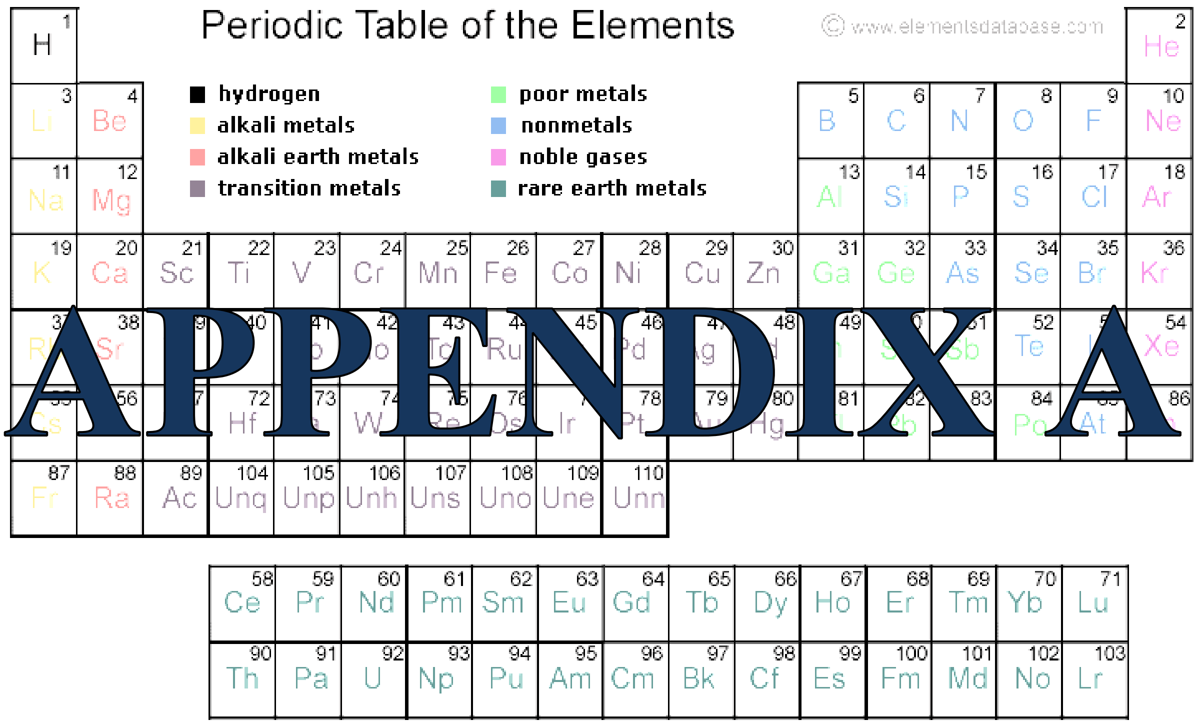
These analyses were chosen for JSNN to improve upon the current operations. Quality of research is an important feature to JSNN and quality of the facilities should be a primary concern of the Gateway University team. The suggestions and recommendations outlined in this report are meant to improve the quality and health of the facility. In instances where there were costs savings, there were also cases where a cost was added so that prevention and preservation were in place. The recommendations are merely areas where the Gateway should consider improving and/or implementing for the next facility that is to be built on the Gateway campus.

Sincerely,

Aubrey L Fulton

Aubrey L. Fulton

APPENDIX A



Periodic Table of the Elements
© www.elementsdatabase.com
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

PP-R PIPING SYSTEMS

MADE IN GERMANY
a
Pipe Systems

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801.805.6657

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Printed in USA

aquatherm green pipe aquatherm blue pipe aquatherm lilac pipe Aquatherm Piping Systems **aquatherm** - 2013 **NA Edition**

aquatherm
piping systems

aquatherm green pipe®
aquatherm blue pipe®
aquatherm lilac pipe®

40 years

40 Years of Innovation

TECHNICAL INFORMATION AND PRODUCT CATALOG FOR

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pressure pipe system for potable water,
food processing, and hygienically sensitive applications

aquatherm blue pipe®

pressure pipe system for hydronic, compressed air,
chemical and industrial applications

aquatherm lilac pipe®

pressure pipe system for
recycled and reclaimed water systems

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CHAPTER 1
FEATURES

Welcome to Aquatherm

We make the best polypropylene pressure piping systems in the world. Period.

Over the past forty years, we've used our hard work, technology, and industry-leading expertise to provide the highest quality pipe made anywhere. It's important to us, because pipes provide everyone with the most basic elements they need to live and thrive. As we've grown from one man working out of his garage to the world's largest and most advanced PP-R pressure pipe manufacturer, we've always strived to make our products better and better.

And we stand by the philosophy that a better product is better for everyone, including our planet. So while our pipes are built to highest standards of quality and engineering, they are also made following the strictest ecological criteria. Our pipes are designed to last for over 60 years without corroding, leaking, or failing, which reduces both costs to the owner and waste in the environment.

This catalog focuses on Aquatherm's **green pipe**, **blue pipe**, and **lilac pipe** systems. It provides detailed information regarding acceptable applications, code approvals, engineering parameters, installation instructions, and list of available parts. Following the directions here will deliver optimal results from our superior products. We've changed what's possible when it comes to pipes. Now it's your turn.

Aquatherm's team (from left): Chief Digital Officer **Parr Young**, President and CEO **Steve Clark**, Director of Advertising and Media Relations **Barry Campbell**, National Accounts Manager **Charles Clark**, CFO **Jordan Hardy**, COO **David Chen**, Chief Brand Officer **Adam Clark**, Marketing and Travel Coordinator **Camilla Shoemaker**, Managing Director **Dirk Rosenberg** (Germany), Manager of Financial Operations **Shawna Gobble**, Executive VP of US Sales **Ed Eldredge**, and NA Export Liaison **Philip Menke** (Germany).

Not pictured: Executive VP of Canada Sales **Don Schneider**, Eastern Regional Sales Manager **John Grabarits**, Senior Applications Engineer **Clifford Holmes**, Lead Technical Writer **Andrew Deaver**, Graphic Designer **Rebecca Moorhouse**, Financial Controller **Jaron McCloy**, Administrative and Training Assistant **Kim Schneider**, Chief Instructor **Buddy Finley**, Training Specialist **Dalton Clark**, and Special Applications Engineer **Brigham Arce**.

1973
Aquatherm founded by Gerhard Rosenberg

1978
Transfer to the first factory in Attendorn, Germany

1985
Factory 1 in Attendorn, Germany completed

1996
Founding of the metal processing company, Aquatherm Metal, in Attendorn

1999
Main campus in Attendorn completed as one complex (factories 1+2, storage, assembly, laboratory and training center)

2002
Logistics center in Attendorn completed

2005
Aquatherm launched in Canada

2007
Aquatherm launched in the United States

2012
Aquatherm North American logistics center established in Lindon, Utah

Aquatherm Founder Gerhard Rosenberg (center left), with Managing Directors Maik, Christof, and Dirk Rosenberg (shown left to right).

aquatherm green pipe®

THE ULTIMATE IN POTABLE WATER PIPING TECHNOLOGY

aquatherm green pipe is a pressure pipe system with a wide range of applications. Exceptional chemical purity and outstanding physical strength have made **aquatherm green pipe** successful in over 70 countries worldwide.

aquatherm green pipe can be used in almost every aspect of the piping industry, but is best suited for potable and food-grade applications where the combination of chemical safety and physical durability can truly perform. **aquatherm green pipe** can also be used for multipurpose residential sprinkler applications per NFPA 13D.

With over 400 fittings, transitions, and valves, **aquatherm green pipe** is an easy fit into any design or space. The dimensions range from ½" to 18" nominal diameter (ND). **aquatherm green pipe** is also available with UV protection for outdoor installations and faser-composite technology, which reduces linear expansion.

THE aquatherm green pipe ADVANTAGE

- Leak-free connections
- Resistant to hard water & aggressive chemicals
- Environmentally friendly material
- Reduced insulation requirements
- Increased flow rate
- Potable and food rated
- Fast and easy assembly
- Flame, smoke, and fume-free installation
- Reduced noise from water hammer and vibration

aquatherm blue pipe®

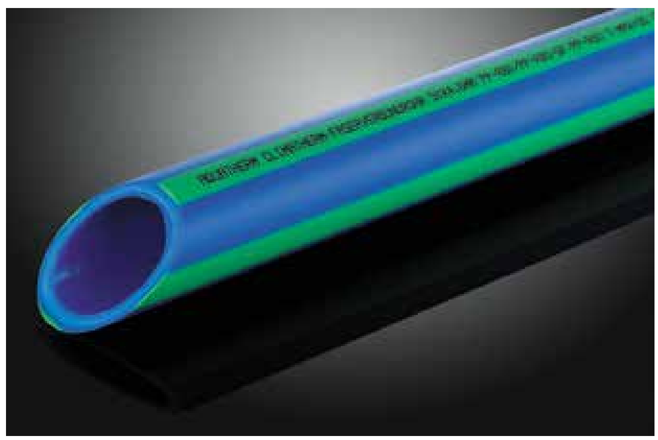
(FORMERLY CLIMATHERM)

A BETTER CHOICE FOR HYDRONICS, COMPRESSED AIR, AND INDUSTRIAL APPLICATIONS

aquatherm blue pipe is specifically engineered for applications beyond potable water installations. It offers a tougher, longer lasting, more environmentally responsible solution to comparable non-potable pressure systems.

In addition to the general advantages of the PP-R pipe system, **aquatherm blue pipe** offers higher volumetric flow values due to smaller wall thickness and is high-heat stabilized for short exposures to temperatures beyond the intended design. PP-R piping is extremely resistant to impact, corrosion, and seismic stresses.

aquatherm blue pipe uses the same socket fittings and tools as **aquatherm green pipe**, making installation simple and easy. The dimensions range from ½" to 24" ND. **aquatherm blue pipe** is also available with UV protection for outdoor installations and faser-composite technology, which reduces linear expansion.



THE aquatherm blue pipe ADVANTAGE

- Resistant to most chemicals
- Increased flow rate
- Fast, welded connections
- Light, impact-resistant material
- Corrosion-free pipe and fittings
- Natural sound and heat insulation
- Long lasting
- Fully recyclable
- High-heat stabilized

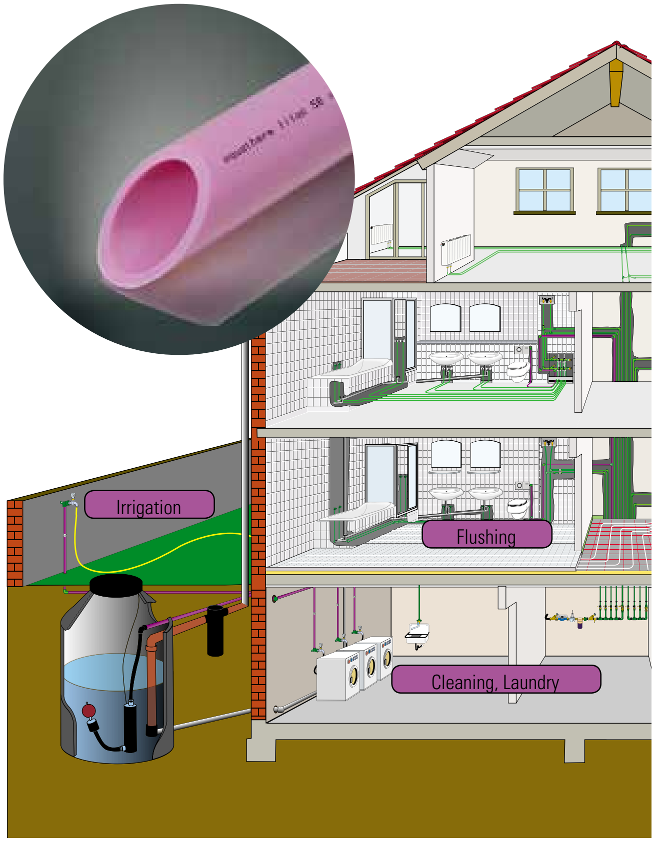
aquatherm lilac pipe®

THE PERFECT SOLUTION FOR RECYCLED, RECLAIMED, & RAINWATER APPLICATIONS

Water conservation systems are being specified and installed much more frequently as building and plumbing codes are updated to encourage more responsible water use. Most codes require that these systems be kept entirely separate from the potable water supply and that the piping be color coded and labeled to identify it as non-potable.

The water from reclaimed, recycled and rainwater sources can be used for flushing, irrigation, cleaning and other applications. **aquatherm lilac pipe** is available from ½" to 10" sizes and uses the same fittings as other Aquatherm systems.

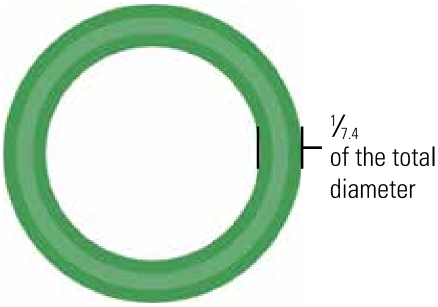
aquatherm lilac pipe is designed exclusively for these applications. The piping uses the same durable, corrosion-resistant PP-R material that has been successfully used for hot and cold water distribution for over 35 years. This, combined with design modifications, coloring, marking, and independent third-party certification by NSF International, make **aquatherm lilac pipe** the ideal choice for water conservation.



STANDARD DIMENSION RATIO

Aquatherm's pipes are manufactured using a standard dimension ratio (SDR), meaning that the wall thickness is a ratio of the total diameter. This is different from schedules, which are commonly used in North America, but is typical of fusible plastics.

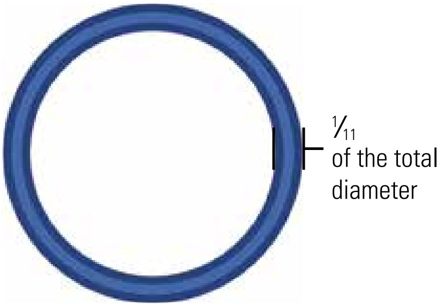
Each SDR provides its own advantages. The SDR is one of the major factors used in engineering an Aquatherm piping system for a specific application.



SDR 7.4

A heavy wall provides increased pressure and temperature ratings for high-stress applications such as hot water recirculation.

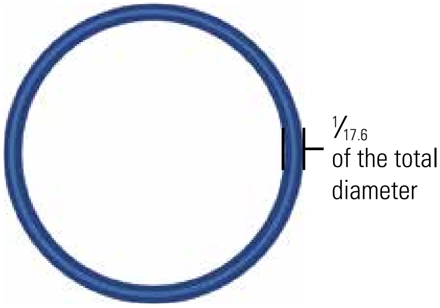
aquatherm green pipe faser-composite (all ½" and ¾"pipes are SDR 7.4 unless otherwise indicated)



SDR 11

A balanced wall thickness to provide higher flow rates while maintaining high pressures. Suitable for most applications.

aquatherm green pipe
aquatherm blue pipe faser-composite
aquatherm lilac pipe



SDR 17.6

A thinner wall provides maximum flow rate while minimizing material weight, cost, and fusion times. For chilled, cooling, and condenser applications.

aquatherm blue pipe faser-composite

FIELDS OF APPLICATION FOR AQUATHERM PIPING SYSTEMS:

System is ideal for this application: ●

System is suitable for this application, but not ideal: ❍

	aquatherm green pipe®	aquatherm blue pipe®	aquatherm lilac pipe®
Potable water and food-grade applications	●		
Swimming pools	❍	●	
Compressed air systems	●	●	
Heating distribution	❍	●	
Marine applications	●	●	●
Chilled water distribution	❍	●	
Direct-buried applications	●	●	●
Recycled, reclaimed, and rainwater applications			●
Irrigation	❍	❍	●
Industrial applications and chemical transport	❍	●	
In-floor heating systems	❍	●	
Multipurpose fire sprinkler applications	●		

FIELDS OF APPLICATION

Aquatherm piping systems are ideal for many pressurized applications due to their durability and versatility.

Potable water and food-grade applications
For use in residential buildings, hospitals, hotels, office and school buildings, shipbuilding, sports facilities, high-rise construction, distribution mains, and many other applications, **aquatherm green pipe** is safe for use in direct contact with food and potable water.

Swimming pools

For applications where aggressive chemicals are constantly present inside the pipe, **aquatherm blue pipe** is highly resistant and non-corroding. (For information regarding chemical compatibility refer to page <?>).

Compressed air systems
Both **aquatherm green pipe** and **aquatherm blue pipe** are ideal for use in light industry, heavy industry, automotive mechanic shops, etc. due to phenomenal pressure ratings and resistance to shattering. Aquatherm piping systems do not corrode, protecting the attached equipment from rust and debris.

Heating distribution
For residential, commercial, and industrial use, **aquatherm blue pipe** with faser-composite is an ideal choice due to its reduced linear expansion and resistance to corrosion, which increases service life. It can also be used for snow-melt applications in concrete or asphalt.

Marine applications
Aquatherm pipes and fittings are made from a hydrophobic, low-friction material that is safe from the dissolved minerals contained in seawater, freshwater, and brine.

Chilled water distribution

For residential, commercial, and industrial use, **aquatherm blue pipe** has a natural insulation value that helps reduce heat gain and often eliminates problems with condensation. Excellent for cooling towers and condenser water.

Direct-buried applications

In cases where the pipe needs to be buried in soil, sand, or concrete, **aquatherm blue** pipe, **aquatherm green** pipe, and **aquatherm lilac** pipe are all safe and non-leaching. Aquatherm pipe is also suitable for directional boring.

Recycled, reclaimed, and rainwater applications

aquatherm lilac pipe is ideally suited for non-potable service water due to its resistance to corrosion, scaling, and microbiological growth and distinct purple coloring.

Irrigation

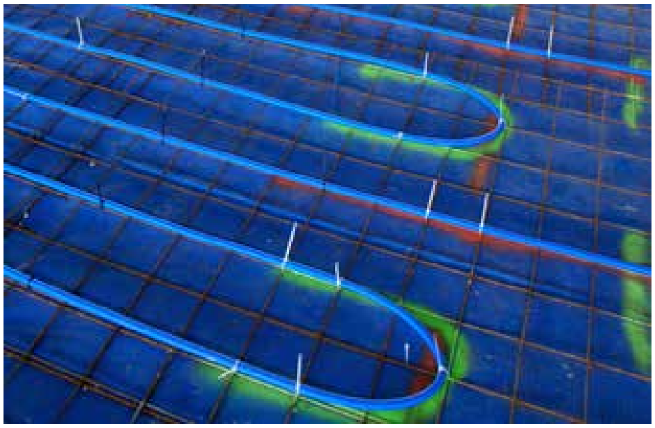
For greywater applications where the system is exposed to varying water quality and the potential of freezing, **aquatherm lilac** pipe is corrosion resistant and can withstand isolated instances of freezing.

Industrial applications

For the processing and transport of aggressive mediums and materials, **aquatherm green** pipe and **aquatherm blue** pipe resist most types of chemicals.

In-floor heating systems

For use in radiant heating applications. Aquatherm's fused connections, low pressure drops, and 8 to 1 bending radius (non-faser only) make for a safe and efficient installation. Aquatherm's fusion outlets allow for an extended manifold layout, reducing costs, and improving performance.



Multipurpose fire sprinkler applications

For light hazard occupancies, **aquatherm green** pipe can be integrated with the potable water system to provide fire protection. The high flow rates allow for mains and branches to be run through the building rather than many individual pipes, keeping the system simple and efficient. External fittings do not restrict flow throughout the system.

fusiolen® PP-R

All Aquatherm pipes and fittings are made of **fusiolen** PP-R. The **fusiolen** PP-R material is both physically and chemically resistant to the abuse that can damage other materials. It is also a low friction material, protecting it from abrasion and reducing pressure loss. The superior fusion properties of **fusiolen** PP-R result in a permanent, homogeneous connection that is chemically indistinguishable from the rest of the material. This and countless other benefits have made the Aquatherm pipe systems and the raw material **fusiolen** PP-R successful and respected worldwide.

Non-leaching composition

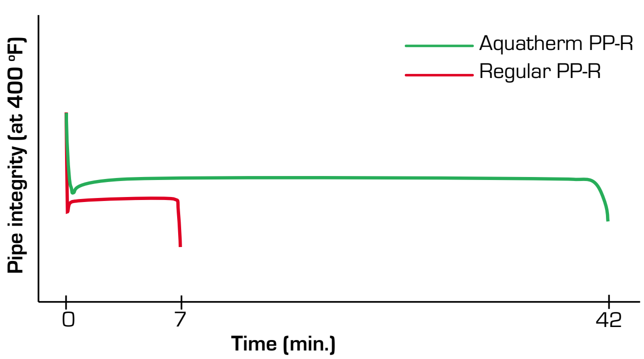
PP-R is a hydrophobic material, meaning it repels polarized molecules like H_2O. By using a material that does not interact with water or most other fluids, Aquatherm ensures that chemicals from the pipe walls and fittings will never leach into drinking water or the underground water table. This makes the pipe healthier for the people using it and safer for the environment they live in.

Superior fusion properties

fusiolen PP-R is engineered to have an ideal melt index for socket fusion and butt welding, resulting in connections that are strong and homogeneous. The material does not burn or change during fusion, so the actual point of fusion is chemically indistinguishable from the rest. This prevents weaknesses and cracking in the joints.

High-temperature stabilization

fusiolen PP-R is heat stabilized, giving it a much higher safety factor than traditional polypropylene. Under extreme temperatures, **fusiolen** PP-R will last six times longer without material degradation. **fusiolen**® PP-R C, the material used in **aquatherm blue pipe**®, is high-heat stabilized to last even longer. This means that occasional exposure to high temperatures due to mechanical failure won't damage the Aquatherm pipe systems.



Raw **fusiolen** PP-R granules.

High-opacity pigmentation

To prevent biofilm formation, **fusiolen** PP-R is intentionally pigmented to be opaque, preventing light from entering the pipe. This helps protect the pipe from microbiological build-up and increases the service life of the system.

Low-impact lifecycle

fusiolen PP-R is fully recyclable and can be ground, melted, and re-used in car parts, home products, food packaging, medical equipment, and other applications. There are no harmful waste products created by the processing or disposal of **fusiolen** PP-R. The pipe and fittings made with **fusiolen** PP-R have an estimated service life of over 60 years. As a result, Aquatherm's pipe systems require no maintenance or costly repairs.

Proven worldwide

The exceptional performance of Aquatherm piping systems has been proven worldwide for nearly 40 years. Aquatherm piping systems have been tested, listed, and certified by numerous national and international organizations, including:

- NSF, ICC, IAPMO, ASTM, FM (USA)
- CSA, BNQ, CFIA (Canada)
- DVGW, SKZ (Germany)
- WRAS (UK)
- SVGW (Switzerland)
- SAI-Global (Australia)
- SITAC (Sweden) … and many more!

The quality of Aquatherm's **fusiolen** PP-R is recognized around the world.

ECOLOGICAL ADVANTAGES

Since its founding in 1973, Aquatherm has worked hard to ensure that its products and manufacturing processes do not pollute the earth's sensitive ecosystems. Long before environmental protection was recognized as a global issue, Aquatherm piping systems fulfilled the high ecological standards demanded today. Being green isn't just a fad with Aquatherm; it's our way of doing business.

Aquatherm believes that ecological and economic interests should go hand-in-hand, both in the production and installation of our products. Aquatherm's PP-R pipes and fittings are even fully recyclable, minimizing their impact from start to finish.

To ensure its environmental compatibility, the base PP-R material and additives (color pigments and stabilizers) are extensively tested by Aquatherm's own laboratory as well as independent researchers to ensure that nothing harmful is ever put into our pipes.

aquatherm and LEED credits

Aquatherm pipe has been used on many LEED certified projects. Although there are no direct LEED credits for using a particular piping material, there are several points which the right piping system can address.

Please refer to the Aquatherm LEED Planning Guide on our website at www.aquatherm.com/technical-documents for further details. Information regarding LEED projects that have used Aquatherm pipes can be found in the Case Studies section.

Reduced pumping energy

One of the most overlooked issues in energy efficient buildings is the energy used by the piping system. While some energy is lost from heat transfer, a great deal more is lost from the pumping energy used to move water around. Aquatherm's pipes have a low friction factor, reducing the energy lost during transit. Even more importantly, Aquatherm pipes do not corrode, meaning that the energy savings increase over time when compared to a system made from ferrous metals.

Extended service life

Aquatherm pipes will last for over 60 years within the design parameters given in this catalog. This eliminates the environmental impact of repairs, mold, leaks, and other problems that can be caused by piping failure. By using components that last longer, buildings can be made safer and more sustainable.

No BPAs, dioxins, or VOCs

Unlike many other plastics, Aquatherm's PP-R material is completely non-toxic. It does not contain any BPA or dioxins that could leach into drinking water and there are no VOCs released during the joining process. This helps improve the on-site air quality during installation and the water quality throughout the life of the system.

Greywater-safe material

To help reduce waste, many buildings are integrating water conservation systems. These systems use non-potable water for irrigation, flushing, and other suitable applications. Greywater can be highly oxygenated and aggressive toward most piping materials, but PP-R is resistant to all qualities of greywater, making it an ideal choice for water conservation systems. aquatherm lilac pipe® is colored purple to help distinguish it from potable and hydronic lines.

Fully recyclable pipe and fittings

Aquatherm's pipe and fittings are made from over 97% PP-R, a material that is easily processed and recycled into a variety of other goods. The heat-fused connections don't damage or alter the PP-R, so there are no problems with recycling an entire system.

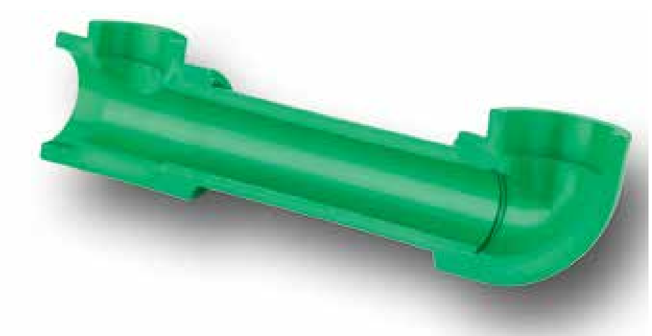
SYSTEM FEATURES

Polypropylene-random

Aquatherm piping systems are made from the same type of material used in high-purity systems, making them ideal for potable water and food-grade applications. Aquatherm piping systems do not support the formation of mineral deposits and are opaque so as to not promote microbiological growth. PP-R does not contain any chemicals that can leach from the pipe wall into the water. The water delivered to the tap is always the same quality as when it entered the system.

Heat fusion connections

The connections in an Aquatherm piping system are made using heat fusion, a simple process which actually turns the pipe and fitting into a single piece of PP-R. There are never any solders, solvents, or glues added to the connection, eliminating traditional weak points and harmful chemicals from the system.



Application-specific engineering

Aquatherm's pipe systems are engineered for optimal performance based on the application type. **aquatherm green pipe®** is rated for potability, and comes with faser-composite and non-faser variations to optimize efficiency and economics. **aquatherm blue pipe®** is high-heat stabilized to have a higher safety factor while maintaining superior flow rates. **aquatherm lilac pipe®** is designed without faser-composite, providing the highest value for a greywater installation. Each of these systems has distinct colors and stripes for easy identification.

Corrosion and scale resistance

While other piping materials lose performance over time to scaling and corrosion, Aquatherm's PP-R material resists any form of change to the material wall. Even after decades of use, the Aquatherm pipe will retain its original flow characteristics. This prevents the loss of efficiency that occurs when using a pipe that can scale or corrode and will save energy over the life of the system.

Incidental freezing tolerance

Due to their natural insulation value, Aquatherm pipes are resistant to freezing if left exposed. And because of the strong but flexible nature of the PP-R and heat fusion connections, Aquatherm pipes can freeze solid with water in them without breaking.

Note: Aquatherm pipes can withstand isolated instances of freezing. They are not designed to be repeatedly frozen and thawed.

Nominal imperial sizing

All Aquatherm piping systems are manufactured based on metric units of measurement. In order to make the systems more intuitive to the North American market, Aquatherm has converted each of its standard pipe sizes into an imperial nominal diameter based on comparable size and flow rate. The following table gives a standard nominal diameter for each metric size of pipe. Use the flow rate tables given in chapter 3 to verify proper selection for an application based on SDR and flow rate.

Socket fusion

Manufac-tured metric OD	Nominal diameter
20 mm	½"
25 mm	¾"
32 mm	1"
40 mm	1 ¼"
50 mm	1 ½"
63 mm	2"
75 mm	2 ½"
90 mm	3"
110 mm	3 ½"
125 mm	4"

Butt welding

Manufac-tured metric OD	Nominal diameter
160 mm	6"
200 mm	8"
250 mm	10"
315 mm	12"
355 mm	14"
400 mm	16"
450 mm	18"
500 mm	20"
560 mm	22"
630 mm	24"

Full system range

Aquatherm piping systems can be used in nearly any pressure application and range in size from ½" to 24". This allows installers to use one type of pipe for an entire system rather than mixing multiple materials and joining methods. An entire project can be done using Aquatherm pipes, eliminating the need for multiple toolsets and maintenance programs. Transitions to ANSI flanges, NPT threads, PEX piping, and copper tube make combining Aquatherm pipe with other systems and components simple and easy.

Note: All Aquatherm products are manufactured using metric sizing. This table shows matching nominal diameters in imperial units. Metric OD is printed on the pipe and fittings. The nominal imperial OD is printed on the pipe and on the fitting bags.

60+ year lifespan

Aquatherm piping systems resist the scaling and corrosion that reduce the performance of other piping systems. The walls of the PP-R piping systems generate less friction than other systems, eliminating the abrasion that can cause pinhole leaks and shorten the life cycle of the pipe. The heat fusion joints maintain the same properties as the pipe itself, so physical stresses will not damage their integrity. Overall, the Aquatherm piping systems last longer with less maintenance than other systems, adding greater value to each installation. With proper design, Aquatherm piping systems can last for over 60 years.

Shatterproof material

Unlike other rigid plastics that often shatter under impact, Aquatherm's piping systems remain flexible and resilient at normal operating temperatures. When hit by a high-speed impact or crushed by a heavy object, systems made from **fusiolen**® PP-R tend to flatten and split rather than throwing dangerous shrapnel. Often, no structural damage will occur at all. This makes the pipe safer to use, even in high-risk applications. (Note: Damaged pipe may break apart during pressure testing. If there is any risk that the pipe was damaged before or during installation, it is best to stand clear during air testing).

Potable water rating

Aquatherm piping systems meet the requirements of NSF Standard 14 and **aquatherm green pipe** meets NSF Standard 61, showing that it is safe for direct contact with drinking water. In addition, **aquatherm green pipe** has been tested to NSF 51 and is acceptable for direct food contact and food processing applications up to 212 °F. Aquatherm piping systems meet the stringent requirements for strength, material quality, dimension, damage resistance, marking, and quality control of ASTM F2389 and CSA B137.11.

Natural sound insulation

Aquatherm's PP-R material absorbs the force from pressure surges and also dampens the noise created by water flow and hydraulic shock. The sound generated and carried by the pipe is much less than that of other piping systems, adding to the comfort of the building's occupants.

Consistent quality

Aquatherm creates its **fusiolen** PP-R from the highest quality PP-R granules and tests it for consistency, purity, and performance at every step. This ensures the quality of every pipe and fitting that Aquatherm makes.

Faser-composite technology

To increase maximum operating temperatures and overall performance, Aquatherm has developed the revolutionary faser-composite layer. The faser-composite material is a mixture of glass fibers and **fusiolen** PP-R or **fusiolen**® PP-R C. This material is extruded as the middle layer of the pipe and allows the pipe to remain rigid at high temperatures without sacrificing any of the other benefits of the pipe. The low concentration of glass fibers does not interfere with the fusion process or the recycling process, so all other aspects of installation and use remain the same.

An unmatched guarantee

As proof of Aquatherm's demanding quality standards, all properly installed Aquatherm pipe systems carry a 10-year warranty for property damage liability coverage of up to €15 million per damage event. This warranty covers the pipes, the fittings, and any incidental damage caused by material failure from manufacturer defect. The policy also provides coverage for personal injury and for financial loss.

Note: The Aquatherm warranty only applies to material failures from manufacturer's defect. Systems must be properly installed by an Aquatherm-trained installer. Improper installation or fusing to non-**fusiolen** parts will void the warranty for those connections. Following all the procedures in the Aquatherm Installer manual will minimize the risk of material failure and help ensure coverage in the event of a problem. Pressure testing is required to verify proper installation.

The Aquatherm warranty does not cover the following issues*:

- Improperly assembled transitions (threads, flanges, copper stub outs, etc) unless the fitting was originally defective.
- Time lost due to poor planning, supplier issues, or failure to order the proper parts/tools.
- Connections that have not been properly fused.
- Failures in systems that were not pressure tested before operation (evaluated on a case-by-case basis).
- Damage to pipe or fittings from mishandling after they have left Aquatherm's possession.
- Use of defective tools and equipment to make welded joints or fittings connections.

*Not a comprehensive list

INSTALLATION ADVANTAGES

Lightweight pipe and fittings

Aquatherm pipes weigh up to 80% less than similarly sized metal piping, making it easier to ship, unpack, position, hang, and put together. It's an added bonus that lets the installer carry more, work faster, and feel less tired at the end of the day.

Suitable for air testing

Aquatherm's unique properties allow the pipes to be tested using air pressure, which can be a huge time saver to the installer. It also helps prevent water spray in the event that there is a leak during the pressure test. The system can also be tested using water or an air/water mix.

Durable material

Damaged pipe means lost time and money, which are things that no installer can afford. PP-R is chemically and physically tough and can withstand most forms of incidental damage without cracking or breaking. Installers should still follow the care and handling procedures given in chapter 2 to prevent system failure.

Full system compatibility

Almost every job will require the installer to switch to and from other piping systems and integrate various pieces of mechanical equipment. With a wide range of flange connections and the world's most advanced PP-R to metal transitions, connecting to equipment and other pipes is quick, easy, and secure. Transitions include flanges, brass and stainless steel threads, brass PEX connections, and PP-R to copper stubs for fixture transitions.

Fast connection times

Aquatherm pipes and fittings are assembled with heat fusion, a fast and simple process that involves heating the materials and sliding them together for a perfect connection every time. Heat fusion can save over 50% on labor time compared to traditional welding and soldering and is comparable to the quickest labor-saving connections.

Fusion outlets

This innovation allows for branch lines to be added after the mains are already in place, reducing labor times and giving the installer unparalleled flexibility. Fusion outlets replace standard reducing tees and offer many advantages such as replacing two connections with one, having a lower pressure drop, and using less material. Fusion outlets are fused through the pipe wall for maximum reliability.

Rigid hanging pipe

Aquatherm's pipes are designed to remain rigid on hangers, giving the pipe a clean, conventional layout with elbows and tees. This allows installers to create a craftsman's appearance in the final product while being able to prefabricate more pipe due to its lighter weight.

Flexible lengths and connections

Heat fusion connections have the exact same properties as the pipes and fittings, so there is a certain level of flexibility in the assembled pipe that makes it easy to prefabricate and move on-site without the risk of the joints cracking and leaking. This flexibility also allows for a wider range of applications and protects the pipe from seismic stresses.

USA-based fabrication

As part of ongoing efforts to provide superior service to match its superior products, Aquatherm offers prefabrication options for manifolds and other complicated or large assemblies. For a quote and lead time, submit a spec to fabrication@aquatherm.com. Aquatherm's Utah-based fabrication team also builds all the segmented fittings for increased accuracy and reduced leads times.

Consistent results

One of the major advantages of using PP-R and heat fusion is that the results are both reliable and consistent. The double bead of plastic allows for accurate visual inspection. Imagine turning on an entire system and not having a single leak anywhere.

Simple expansion control

The faser-composite layer reduces linear expansion, reducing or eliminating the need for additional expansion control. The pipe can absorb its own stresses when anchored or buried, and expansion loops can be used for longer runs.

OPERATION ADVANTAGES

Reduced maintenance costs

Aquatherm's PP-R pipes and fittings require virtually no maintenance. They don't require chemical treatments to prevent corrosion and they are not prone to leaking, even from impact or accidental chemical exposure. Fused connections are one material throughout, so there's no issue of gaskets leaking or connections weeping as time goes on. This eliminates costly repairs for everything from small leaks to catastrophic failures.

Occupant-safe installation

Heat fusion is a safe and unobtrusive process that can be done while a building is fully occupied. It does not produce any smoke, fumes, or off-gassing, so there's no need to provide additional ventilation. And with no open flames, there are no requirements for burn permits or a fire watch. Heat-fused connections are also ready for full pressure within minutes, allowing minimum downtime during repairs and expansions.

Superior water quality

PP-R is a non-leaching plastic, meaning that it does not transfer chemicals or ions into water. And because Aquatherm's pipes and fittings are both made from PP-R, water arrives at the tap with the same quality it had when it left the pump. This eliminates metallic and plastic tastes in the water and allows building owners to install a filtered drinking water line throughout the building.

Improved energy efficiency

One of the most cost-effective ways of making a building more environmentally responsible is to reduce its energy costs, as these improvements can pay for themselves over time. Aquatherm's non-corrosive PP-R material can save thousands of dollars in energy costs over the life of the building. And the natural insulation value of the material helps reduce heat loss and heat gain on uninsulated sections of the pipe.

Extended service life

There is increasing pressure on building owners to "go green" and make their buildings more sustainable. Aquatherm piping systems give owners a longer lifecycle, improved performance, and peace of mind while having one of the smallest carbon footprints in the industry. Put simply, Aquatherm pipes improve the quality of the building while reducing its impact on the environment.

CHAPTER 2
QUALITY ASSURANCE

Standards, regulations, and listings

Aquatherm quality control

Labeling, shipping, and handling

Test certificates


200
200
150
100

Standards, regulations, and listings

The following national and international standards, regulations, and listings are applicable to Aquatherm piping systems.

- NSF Standard 61 (C.HOT 180 °F/82 °C)
  Suitable for potable water

- NSF Standard 14
  Meets piping performance requirements

- NSF Standard 51
  Suitable for food processing up to 212 °F (100 °C)

- CFIA #A508
  Canadian Food Inspection Agency approval #A508

- ICC ESR-1613 / PMG Listing 1014
  Polypropylene pipe and fittings meet or exceed North American standards

- DIN EN ISO 9001
  Quality management systems: requirements

- IPC 2009 Sec. 605
  Water distribution & Water service

- IMC 2009 Chapter 12
  Hydronic piping

- IRC 2009 Chapter 21 & 26
- Hydronic piping & Plumbing

- UMC 2009 Chapter 12
  Hydronic piping

- UPC 2012 Chapter 6
  Water distribution & Building supply

- IAPMO File M-6022
  Mechanical

- IAPMO File 5053
  Plumbing

- ASTM F2389
  Standard specification for pressure rated polypropylene (PP) piping systems

- CSA B137.11
  Polypropylene (PP-R) pipe and fittings for pressure applications

- CSA B214
  Polypropylene (PP-R) pipe and fittings for hydronic applications

- BNQ 3660-950
  Safety of products and materials in contact with drinking water

- ISO 15874
  Plastic pipe system for hot and cold water installation: polypropylene

- ASTM F2023
  Standard test method for evaluating the oxidative resistance of plastic piping to hot chlorinated water

- ASTM D 635
  Standard test method for rate of burning and/or extent and time of burning of plastics in a horizontal position

- FM 1635
  For wet pipe automatic sprinkler systems in light-hazard occupancies

- NFPA 13D
  Standard for the installation of sprinkler systems in one/two-family dwellings & manufactured homes

- DIN EN ISO 14001
  Standard for environmental management

Aquatherm quality control

The production of a quality-controlled pipe system demands supervision, regulation, and control in every step of the process. All results and processes are carefully documented.

In its manufacturing process, Aquatherm requires:

- testing and acceptance of incoming goods
- in-process inspection and testing
- process control at all stages
- final inspection and testing

Aquathem complies with all relevant regulations and standards for the quality control of potable water pipe systems established by:

- NSF
- CSA
- CFIA
- ASTM
- ICC
- IAPMO
- ISO
- DIN

These standards and guidelines detail the minimum requirements for internal control. Conformance to these standards is verified by independent institutions in the form of unannounced factory audits, random product sampling, and laboratory testing.

Quality from experience

Decades of experience in the extrusion and injection molding industries have made Aquatherm the market leader and pioneer in manufacturing polypropylene piping systems. This experience is reflected in Aquatherm's demanding quality control standards and carefully established procedures. The value of this experience can be seen in the consistent and superior quality of Aquatherm's products.

External control

External supervision consists of tests with a defined scope in set intervals. The respective supervising institutions appoint authorized test organizations to carry out these tests.

The external supervision includes:

- external tests of the products
- internal audit of Aquatherm's quality assurance system and test procedures
- calibration of the test equipment
- hygiene and toxicity tests

The results of the supervisory visits as well as external tests made on pipe and fitting samples are confirmed to Aquatherm with test certificates.

In addition to the extensive quality assurance testing conducted by Aquatherm at its production facilities, independent third-party auditing is carried out by several North American certification agencies including NSF International, IAPMO, and ICC. NSF conducts four unannounced plant inspections each year, verifying that the materials, processes, quality control, and piping system performance are in accordance with national and international consensus standards.

NSF is an independent, non-profit, third-party organization that certifies piping products in accordance with national and international quality standards related to public health and safety.

Internal control

Trained, qualified employees and a modern, well-equipped laboratory ensure that all tests are carried out and regulations are complied with in accordance to Aquatherm's quality control policy.

All internal quality controls are documented and recorded in accordance with the quality control policy.

To ensure consistent performance, Aquatherm produces all of the fusiolen® PP-R material used in the production of its piping systems, accepting only the highest quality of raw polypropylene. By manufacturing its own resin for the extrusion process, Aquatherm minimizes the possibility of material failure.

All metal inserts used in Aquatherm's transition fittings are machined in the Aquatherm Metal facility, where each piece is designed and engineered to meet the exacting quality standards that Aquatherm demands.

Test and acceptance of incoming goods

All incoming materials are subject to testing. This ensures that incoming products conform to specified requirements. Materials that have not been tested are not released for production. Materials which fail the testing in any way are rejected and returned to the supplier.

In-process inspection and testing

The quality control standards require that tests and inspections be carried out before and during production. At the start of production all quality-relevant data is checked by the quality assurance department. Preproduction samples are tested by the laboratory technicians for proper surface finish and dimensional accuracy.

The data from the extrusion and injection molding machines are cross-checked with the actual pipe dimensions and the materials are released for production only if optimal test results are achieved. These tests are carried out at the start of each production series to ensure perfect quality.

Process control

Ultrasonic measurement and process data recording in the field of extrusion are only two examples of Aquatherm's extensive quality control process. This equipment allows for constant observation and control of production.

Ultrasonic waves automatically measure and report any deviations in tolerance to the cutting device on the extrusion machine so that the sizing controls can automatically isolate a substandard product. This ensures that only perfect quality products are packed and stored. All data received during production is analyzed in detail.

Final inspection and testing

The quality control standards require that inspections be carried out on all finished products and tests performed on samples from every production run. The results are documented in test reports. Finished products are only released to stock when all tests and inspections conform to the prescribed procedures and specifications.

The final inspection and testing includes time-lapse test procedures. This allows Aquatherm to accurately predict the performance of the products in various fields of application.

These tests are used for quality assurance during production and product development. They allow Aquatherm to discover and remove any potential weaknesses.

The results document the system quality and optimize the manufacturing process. The final inspection and tests cover the following procedures:

- dimensional control
- surface finish
- measurement of the melt flow index
- impact bending test
- heat reversion test
- homogeneity of the material
- internal pressure test

In addition to the tests mentioned above, daily hygiene tests in accordance with international guidelines are carried out in the company's own sensory analysis laboratory.

Labeling, shipping, and handling

Labeling and packaging

All Aquatherm pipes are labeled every three feet to identify the size and type of pipe and the test standards which they meet. Fittings are sorted according to the designated packing units and are packaged in bags with coded labels to make storage and identification easier. Fittings also have their size and production run stamped onto them so they can be identified after being removed from their packaging.

Storage, packing, and shipping

After passing all tests and inspections, the products are released for storage and shipping. The pipe and fittings are processed through the Aquatherm warehouse in Attendorn and shipped around the world for use in over 70 countries.

In North America, pipe is stored at Aquatherm's Logistics Center in Lindon, UT, and distributed through many local and regional wholesalers. Containers of pipe can also be shipped directly on-site for larger projects.

Upon receipt of piping shipments, the customer should inspect the pipe to ensure that it has not been damaged during shipping. Damaged pipe should be cataloged and returned for replacement, following all of the distributor's procedures for returns.

Note: Aquatherm only accepts responsibility for damage caused to the pipe and fittings while they are still in Aquatherm's possession. Once another party takes possession of the product (i.e., receiving a shipment), Aquatherm can no longer accept responsibility for incidental damages that happen to the pipe and fittings. Parts that were not reported damaged upon receipt will be assumed to have been damaged after leaving Aquatherm's possession.

Care and handling of Aquatherm pipes and fittings

1. Always store the pipe on a flat surface. When storing the pipe on racks, always have at least three supports under 13 ft lengths and four supports under 19 ft lengths. It is best to place plywood or something similar on top of the supports to avoid any warping or flattening. PP-R has a memory and will bow if stored improperly.

2. Always handle the ends of the pipe carefully. Dropping the pipe, banging it into things, or stepping on it can cause fractures in the end of the pipe. If the pipe is exposed to impact or stress, inspect it for damage. Damaged ends or sections should be marked and removed before installation. Surface scratches deeper than 10% of the wall thickness are considered damage.

3. When storing the pipe outdoors, leave it in the factory-issued protective bag as much as possible. This bag will protect the pipe from dust, scratches, and UV damage. If the pipe is removed from its bag, do not store it uncovered for more than six months. Pipe that is exposed to direct sunlight longer than six months is no longer covered under the warranty. The black-coated UV pipe may be stored outdoors indefinitely.

4. Never place the forks of a forklift into the ends of the pipe. This will damage the pipe and can cause it to crack. Handlers may use a padded rug ram inside the pipe. Otherwise, it is recommended to use a crane or lift to handle larger pipes.

5. In cold weather, take extra care when handling the pipe. Cold temperatures reduce the pipe's flexibility, making it more susceptible to impact damage.

6. Keep the fittings in their original bags. Many of the fittings do not have detailed labels printed on them and can get mixed up if they are not stored with their bags. When storing loose fittings in boxes or bins, attach a label from the packing bag to identify the fittings.

7. When shipping the pipe, always load it onto a flat surface or one which is evenly supported. Only strap the pipe at a place where it is supported to prevent bowing.

8. When covering the pipe, always use a light colored tarp such as blue or white. Do not use a black tarp, as this may cause heat damage to the pipe. Pipe may also be covered with a structure that provides shade.

9. Additional care and handling instructions can be found in the Aquatherm Installer Manual.

NSF International

RECOGNIZES

AQUATHERM GMBH
GERMANY

AS COMPLYING WITH NSF/ANSI 14.
PRODUCTS APPEARING IN THE NSF OFFICIAL LISTING ARE
AUTHORIZED TO BEAR THE NSF MARK.

Certification Program
Accredited by the
American National
Standards Institute

Certification Program
Accredited by the
Standards Council
of Canada

This certificate is the property of NSF International and must be returned upon request. To verify Certification, call 800 NSF-MARK or 734 769-8010.

April 25, 2003
Certificate# 03850 - 01

Mark L. Jost, Senior V.P., Water Systems
Water Distribution Systems

NSF International

RECOGNIZES

AQUATHERM KUNSTSTOFF EXTRUSIONS- UND SPRITZGIEßTECHNIK
GERMANY

AS COMPLYING WITH NSF/ANSI 51.
PRODUCTS APPEARING IN THE NSF OFFICIAL LISTING ARE
AUTHORIZED TO BEAR THE NSF MARK.

Certification Program
Accredited by the
American National
Standards Institute

Certification Program
Accredited by the
Standards Council
of Canada

This certificate is the property of NSF International and must be returned upon request. For the most current and complete information, please access NSF's website (www.nsf.org).

NSF International

RECOGNIZES

AQUATHERM GMBH
GERMANY

AS COMPLYING WITH ANSI/NSF 61.
PRODUCTS APPEARING IN THE NSF OFFICIAL LISTING ARE
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Certification Program Accredited by the American National Standards Institute

Certification Program Accredited by the Standards Council of Canada

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May 25, 2001
Certificate# 03850 - 01

Ronald M. Coiner, General Manager
Water Distribution Systems

FM APPROVED

Certificate of Compliance

This certificate is issued for the following:

GREENPIPE F
FUSIOLEN® PP-R PIPE AND FITTINGS
FOR WET PIPE AUTOMATIC SPRINKLER SYSTEMS
IN LIGHT HAZARD OCCUPANCIES

SIZES 3/4 THROUGH 4 INCH NPS

Prepared for:

Aquatherm GmbH
Biggen 5
57439 Attendorn
Germany

FM Approvals Class: 1635

Approval Identification: 3036285 Approval Granted: April 13, 2010

Said Approval is subject to satisfactory field performance, continuing follow-up Facilities and Procedures Audits, and strict conformity to the constructions as shown in the Approval Guide, an online resource of FM Approvals.

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April 13, 2010

IAPMO RESEARCH AND TESTING, INC.
5001 East Philadelphia Street, Ontario, California 91761-2816 • (909) 472-4100 Fax (909) 472-4244 • www.iapmo.org

ANSI Accredited Program PRODUCT CERTIFICATION #0202

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CERTIFICATE OF LISTING

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Effective Date:	April 2012	Void After: April 2013
Product:	Pressure Rated Polypropylene Piping Systems	File No. M-6022
Issued To:	Aquatherm Gmbh Biggen 5 D-57439 Attendorn, Germany	

IDENTIFICATION: Pipe shall be marked at intervals of not more than 5 ft. with the manufacturer's name or trademark, nominal size, for metric series pipe - the term "metric" and the dimension ratio or both the outside diameter and wall thickness, IPS series pipe shall include "Schedule 80" or "SCH 80", type of material (PP-R) and classification number (80 or 100), pressure rating and temperature for which pressure rating is valid, the designation "F2389", manufacturer's production code, and pipe intended for the transport of potable water shall bear the mark of the lab making such evaluation. Fittings shall be marked with the manufacturer's name or trademark, nominal size, dimension ratio or schedule for corresponding pipe and type of material (PP-R). The fitting or packaging shall be marked with "Metric" or "NPT" for threaded fittings, and the designation "F2389". All products shall bear the UMC certification mark.

Chairman, Product Certification Committee

CEO, The IAPMO Group

For the most accurate and updated information please visit http://pld.iapmo.org/M-6022

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Effective Date: June 2012 Void After: June 2013

Product: Pressure Rated Polypropylene Piping Systems File No. 5053

Issued To: AQUATHERM GMBH
Biggen 5
D-57439 Attendorn,
Germany

IDENTIFICATION: Pipe shall be marked at intervals of not more than 5 ft. with the manufacturer's name or trademark, nominal size, for metric series pipe - the term "metric" and the dimension ratio or both the outside diameter and wall thickness, IPS series pipe shall include "Schedule 80" or "SCH 80", type of material (PP-R) and classification number (80 or 100), pressure rating and temperature for which pressure rating is valid, the designation "F2389", manufacturer's production code, and pipe intended for the transport of potable water shall bear the mark of the lab making such evaluation. Fittings shall be marked with the manufacturer's name or trademark, nominal size, dimension ratio or schedule for corresponding pipe and type of material (PP-R). The fitting or packaging shall be marked with "Metric" or "NPT" for threaded fittings, and the designation "F2389". All products shall bear the UPC® certification mark.

Chairman, Product Certification Committee

CEO, The IAPMO Group

For the most accurate and updated information please visit http://pld.iapmo.org/5053

This listing period is based upon the last date of the month indicated on the Effective Date and Void After Date shown above. Any change in material, manufacturing process, marking or design without having first obtained the approval of the Product Certification Committee, or any evidence of non-compliance with applicable codes and standards or of inferior workmanship, may be deemed sufficient cause for revocation of this listing. Production of or reference to this form for advertising purposes may be made only by specific written permission of IAPMO Research and Testing, Inc. Any alteration of this certificate could be grounds for revocation of the listing.

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CHAPTER 3
PLANNING

Planning and engineering with Aquatherm

With unique advantages over both metal and other plastic systems, Aquatherm piping systems offer new possibilities for design and application. By combining revolutionary strength and longevity with industry-leading purity and neutrality, Aquatherm manufactures piping systems that can truly address all possible concerns for potable, food-grade, hydronic, chemical, and industrial applications.

When designing with Aquatherm piping systems, it is important to be aware of its unique features such as the faser-composite for expansion control, the fusion connections, the impact and chemical resistance, and the sound insulation.

The natural R-value and reduced friction factors are particularly important because they reduce the amount of energy needed for the system to perform. With careful planning and engineering, it is possible to exceed existing performance standards and maximize a system's efficiency.

Be sure to verify all calculations before installing an Aquatherm piping system. The sizing and insulation recommendations given in this catalog are intended for easy reference and are not a substitute for actual engineering.

Determining compatibility

The first step to designing with Aquatherm is to verify that PP-R is an acceptable material choice for a particular application. Aquatherm pipes are suited to a wide variety of applications and generally perform without the problems that plague other systems. However, PP-R still has some chemical, pressure, and temperature considerations that need to be addressed in order to eliminate the risk of failure.

Operating outside of the safety parameters provided by Aquatherm can shorten the life of the pipe. By bringing a system's intended load in line with the safety parameters given in this chapter, a designer can ensure that the pipes will last for their entire 60-year lifespan or longer.

This chapter contains information to help determine the suitability of PP-R for a given application. Steam systems, water systems with both high temperature and pressure, or systems with high levels of certain aggressive chemicals will likely not be suitable for use with PP-R. If you are uncertain about a specific application, contact Aquatherm to determine the suitability of Aquatherm piping systems to the application.

Choosing your system

Aquatherm offers piping systems that are engineered for use in certain applications. Choosing the correct system for the application will maximize performance and minimize material costs.

As a general rule, **aquatherm green pipe**® should be used for potable and food-grade applications while **aquatherm blue pipe**® is used for heating and cooling, compressed air, and a variety of industrial applications. **aquatherm lilac pipe**® is intended for use in greywater systems. A more detailed list of suitable applications can be found in chapter 1.

Addressing additional needs

Aquatherm offers two major variations on its piping systems: the Aquatherm UV and the Aquatherm Advanced. Both are modifications to help the pipe perform in adverse conditions. The Aquatherm UV is a black polyethylene coating added to the exterior of the standard pipe and is used in outdoor installations where the pipe is regularly exposed to sunlight. The Aquatherm Advanced is a layer of fire-rated insulation that provides fire protection and can provide code-accepted insulation for the Aquatherm pipes. The designer or engineer will need to determine if and where these variations are needed.

Determining efficiency

Aquatherm's PP-R pipes offer a number of energy benefits including improved flow rates, reduced pressure loss, and reduced heat loss and heat gain. Designers can help reduce both installation and operation costs by taking advantage of these benefits. Reducing these costs not only helps the building's owner and occupants but also the environment.

Working pressure

The working pressure tables illustrate the permissible working pressures of the Aquatherm piping systems. The balance between working pressure and operating temperature varies based on the wall thickness of the pipe as well as the presence of a faser-composite layer. Aquatherm's heat-stabilized PP-R negates the effects of occasional, short-term increases in temperature, so these do not need to be taken into account. The burst pressure for the pipes is much higher.

The tables with "constant operating parameters" assume a steady, year-round load. Their expected minimums are based on negligible material degradation during that time. The "seasonal peaks" table assumes that the system will only operate at full capacity during winter months and will operate at a lower, more efficient capacity during the rest of the year. The "compressed air" table assumes an air temperature under 100 °F. For applications outside the parameters shown here, please submit a compatibility report (sample on page 3.6). Aquatherm pipe may be used for vacuum applications up to 29.92 inHg.

These tables are based on the piping system using water or water mixed with propylene or ethylene glycol. For applications using different fluids or operating conditions outside those given below please contact your local Aquatherm representative. Aquatherm pipes are not intended for operational temperatures colder than -5 °F, as the pipes begin to lose their resistance to impact.

Systems with constant operating parameters (60 year expected minimum)

Temperature	aquatherm green pipe® SDR 11 (non-faser)	aquatherm green pipe® SDR 7.4 (faser)	aquatherm blue pipe® SDR 11 (faser)	aquatherm blue pipe® SDR 17.6 (faser)
	Permissible working pressure (psi)			
50 °F	220	415	350	160
80 °F	180	340	275	125
100 °F	135	255	212	95
120 °F	112	213	180	80
140 °F	93	180	150	70
160 °F	-	120	100	45
180 °F	-	100	62	30
200 °F	-	45	30	15

Systems with constant operating parameters (25 year expected minimum)

Temperature	aquatherm green pipe® SDR 11 (non-faser)	aquatherm green pipe® SDR 7.4 (faser)	aquatherm blue pipe® SDR 11 (faser)	aquatherm blue pipe® SDR 17.6 (faser)
	Permissible working pressure (psi)			
50 °F	225	420	360	165
80 °F	185	360	280	130
100 °F	140	260	220	100
120 °F	116	220	185	85
140 °F	97	185	155	72
160 °F	-	140	115	55
180 °F	-	110	75	35
200 °F	-	55	45	20

Systems with seasonal peaks (60 year expected minimum)

Temperature		60 days		90 days	
		aquatherm blue pipe® SDR 11 (faser)	aquatherm blue pipe® SDR 17.6 (faser)	aquatherm blue pipe® SDR 11 (faser)	aquatherm blue pipe® SDR 17.6 (faser)
Regular load	Seasonal load	Permissible working pressure (psi)			
160 °F	175 °F	90	55	85	50
160 °F	185 °F	80	50	75	45
160 °F	195 °F	70	40	65	35

Compressed air

aquatherm green pipe® SDR 11 (non-faser)	aquatherm green pipe® SDR 7.4 (faser)	aquatherm blue pipe® SDR 11 (faser)	aquatherm blue pipe® SDR 17.6 (faser)
Permissible working pressure (psi)			
125	200	125	50

Integration with other systems

When integrating Aquatherm piping systems with other systems, make sure that the operating parameters for PP-R won't damage the other materials or vice versa. Be aware that even if the Aquatherm pipe is compatible with the chemical being transported, other materials in the system may not be. Make sure that all parts of the system are compatible with the medium being carried before installing them. And, while Aquatherm pipe does not require treatment to protect it from corrosion, ferrous metals in the system will. Do not mix Aquatherm pipe with other piping systems in conditions that will cause the other system to fail.

When there is extensive use of copper piping in conjunction with PP-R, care should be taken to ensure the operating conditions will not cause dissolution or corrosion of the copper. Aquatherm recommends following the Copper Development Agency's guidelines for sizing, temperature and flow speed in copper pipe. This will also help ensure that the copper levels in the water do not approach the regulatory action levels. Sustained high levels of copper ions in a water system can damage wetted surfaces within the system, even PP-R. Damage caused by unregulated copper ions may void the warranty.

Alternatively, you can avoid using large amounts of new copper upstream of the PP-R in hot water recirculation lines. If the copper fails, it may degrade the PP-R as well, shortening its service life. Small amounts of copper from valves and other equipment will generally not cause an issue. For maximum longevity, recirculation lines for domestic hot water should not exceed a flowspeed of 4 ft/s unless the piping is all PP-R.

If you are adding PP-R to an existing copper system, the level of copper in the water should be tested. These levels should not exceed 0.5 P.P.M., and are considered actionable by the EPA at 1.3 P.P.M. High levels of free copper indicate that the copper pipe is eroding due to system and/or water conditions..

Flame spread / Smoke developed

Aquatherm piping systems do not produce toxic by-products during combustion. In a fully developed fire, fusiolen® PP-R will only produce CO_2 and H_2O_{gas}. In an under-developed fire trace amounts of CO can be produced, but this is common in all combustible materials including wood and paper.

Many building codes do not consider the toxicity of the smoke produced but focus only on the volume and opacity of the smoke. Therefore, it is important to install only pipe that meets local code requirements. These codes generally reference ASTM E84 in the United States and CAN/ULC S-102.2 in Canada and require that the installed pipe have a Flame Spread Index of 25 or less and Smoke Developed Index of 50 or less.

According to the IMC and UMC building codes, materials that are completely enclosed in a fire rated material, such as pipe insulation, are considered fire rated as well, as they are not technically exposed in the plenum.

Flame and smoke rated options

For applications where the code requires the pipe to meet an FSI of 25 and SDI of 50, Aquatherm recommends one of the following solutions:

1. Aquatherm Advanced is a listed solution for meeting the E84 and S-102.2 ratings. Aquatherm Advanced is a combination of Aquatherm pipe and a fire-rated insulation (see next column). Aquatherm Advanced may also provide sufficient insulation value for hot and cold applications, but the thermal values are dependant on the manufacturer of the insulation.

2. Encasing the pipe inside of any insulation that meets the 25/50 flame spread and smoke development requirements (see page 3.5). This solution requires that the fittings be insulated as well and is subject to adoption of the relevant IMC and UMC codes, as well as the local authority having jurisdiction. Alternatively, the pipe can be enclosed in a fire-rated chase.

3. Avoid using a ceiling return air plenum. Using ducted or dedicated outdoor air eliminates the health and safety risks introduced by a return air plenum. It also eliminates the need for a large number of fire-retardant chemicals within the building. Pipe that is not inside a return air plenum generally does not need to meet flame spread and smoke development requirements.

With these options, the engineer should be able to comply with all local codes involving flame spread and smoke development. However, it is important to confirm with local officials that the measures being taken are acceptable before beginning the installation.

Aquatherm Advanced

In order to meet flamespread and smoke development ratings, Aquatherm has tested and listed a system in which the pipe is encased in a fire resistant material. Originally, this system required a double-foil bubblewrap insulation.

In Canada, improvements to building codes and additional testing from Aquatherm has allowed the Aquatherm Advanced system to be expanded from the original double-foil bubble wrap to include any insulation that meets the S-102.2 rating. However, while the wrap-based Aquatherm Advanced is tested and listed with the fitting exposed, other insulations require that the Aquatherm pipe be enclosed completely in the insulation. In the United States, only Aquatherm Advanced using the double-foil bubble wrap is considered a listed system to meet the E-84 requirements.

The wrapped pipe meets a Flame Spread Index of 25 and a Smoke Developed Index of 50, making the system safe for use in:

- return air plenums
- exposed installation in high-rise buildings
- non-combustible construction

As of December 1st, 2012, Aquatherm has stopped providing Reflectix-brand double foil bubble wrap directly to customers. Instead, Aquatherm encourages installers to use whatever variety of acceptable insulation they are most comfortable with. This is due to the improvements in the code requirements, the changes in the Aquatherm Advanced listing, and the frequent customer requests over the years for Aquatherm to allow a broader solution for fire rating. Visit **www.aquatherm.com/plenum-rating** for current plenum-rating information.

Fire-rated insulations should be installed using the manufacturer's specifications. Obtain information regarding thermal performance directly from the manufacturer.

Using the I-Codes

Under the IMC, materials exposed within plenums are required to meet the ASTM E 84 test for flame spread and smoke development. As given in the 2006 edition:

> **602.2.1 Materials exposed within plenums**
> Except as required by Sections 602.2.1.1 through 602.2.1.5, materials within plenums shall be noncombustible or shall have a flame spread index of not more than 25 and a smoke-developed index of not more than 50 when tested in accordance with ASTM E 84.
>
> **Exceptions:**
>
> 5. Combustible materials enclosed in noncombustible raceways or enclosures, approved gypsum board assemblies or enclosed in materials listed and labeled for such application.

Exception 5 excluded materials that were enclosed within noncombustible (or otherwise approved) materials, as the enclosed materials are technically concealed, rather than exposed. This exception was further detailed in the 2012 edition, making the intent of the previous editions clear:

> **602.2.1 Materials exposed within plenums**
> Except as required by Sections 602.2.1.1 through 602.2.1.5, materials within plenums shall be noncombustible or shall have a flame spread index of not more than 25 and a smoke-developed index of not more than 50 when tested in accordance with ASTM E 84 or UL 723
>
> **Exceptions:**
>
> 5. Combustible materials fully enclosed within one of the following:
> 5.1 Continuous noncombustible raceways or enclosures
> 5.2 Approved gypsym board assemblies
> 5.3 Materials listed and labeled for installation within a plenum.

Under the IMC, Aquatherm pipe may be safely installed in a plenum if the pipe and fittings are contained within an insulation that meets the ASTM E 84 test requirements. This is due to the fact that pipes enclosed within the insulation are no longer considered exposed inside the plenum. Where insulation is not needed, a plenum-rated wrap will also suffice.

Using the IAPMO codes

The UMC contains similar requirements to the IMC in regards to plenums. In turn, the exceptions are similar, although the UMC does not offer as detailed of an exception. In the 2009 edition, it reads:

> **602.2 Combustibles within Ducts or Plenums**
> Materials exposed within ducts or plenums shall be noncombustible or shall have a flame spread index not greater than twenty five (25) and a smoke developed index not greater than fifty (50), when tested as a composite product in accordance with one of the following test methods: NFPA 255, *Method of Test of Surface Burning Characteristics of Building Materials,* ASTM E 84, *Surface Burning Characteristics of Building Materials,* or UL 723, *Test for Surface Burning Characteristics of Building Materials* except as indicated below.

In this case, materials that are exposed are required to be non-combustible or meet flame spread and smoke developed requirements. Materials that are not exposed within the plenum are therefore excluded. This follows the logic and intent of the IMC.

More recent versions maintain this language, but simplify the associated test methods. In the 2012 edition:

> **602.2 Combustibles within Ducts or Plenums**
> Materials exposed within ducts or plenums shall be noncombustible or shall have a flame spread index not greater than twenty five (25) and a smoke developed index not greater than fifty (50), when tested as a composite product in accordance with ASTM E 84 or UL 723, except as indicated below.

In short, under the UMC, Aquatherm pipe may be safely installed in a plenum as long as the pipe is not exposed to the plenum space. This is easily solved by encasing the pipe and fittings in a plenum-rated insulation. Where insulation is not required, a plenum-rated wrap may be used instead.

Other solutions

If none of the plenum-rating options discussed here will suffice for a particular installation, please contact Aquatherm's Engineering Support department in Lindon, Utah via email (**engineering@aquatherm.com**) or phone (**801-805-6657**).

Special applications

Due to their special material properties, Aquatherm pipes and fittings are generally chemical resistant. However, there are certain application where PP-R may not be acceptable.

To find out if the pipe is suitable for a specific application, fill out the inquiry form below and submit it to an Aquatherm representative. This form can be used for chemical, high-heat, high-pressure, or other non-standard applications.

Transition elements with brass inserts are not suitable for all media. For corrosive applications, use connections and valves that are strictly polypropylene or stainless steel.

The special applications inquiry form can be found at **www.aquatherm.com/compatibility** and may be printed and sent in by fax. A digital version of this form is also available and may be submitted electronically.

Special application inquiry for Aquatherm pipe systems

Send to:

Aquatherm Technical Department
500 S 500 W Lindon, UT 84042
Phone: (801) 805-6657
Fax: (801) 847-6554

Inquirer:

Position:

Company ______________________

Contact ______________________

Street ______________________

City/State/Zip ______________________

Phone ______________________

Fax ______________________

E-mail ______________________

Building Project:

Street ______________________

City ______________________

State/Province ______________________

Date / Signature

E-mail: technical@aquatherm.com
Web site: www.aquatherm.com

Field of application:

Fluid transported:

Operating temperature [°C and/or °F]*: __________

Working pressure [mbar and/or psi]: __________

Service life [h/d]: __________

Concentration [%]: __________

____

Ambient medium:

____

____

Ambient temperature [°C and/or °F] __________

Ambient pressure [mbar and/or psi] __________

MSDS	attached	not attached
Fluid transported	☐	☐
Ambient medium	☐	☐

* If operating temperature and/or pressure vary over the year, please indicate typical monthly conditions below.

Fire stopping

Polypropylene is a combustible material and must be treated as such. Generally, when penetrating a fire-rated assembly, fire stopping must be used to give the penetration a fire rating that matches the rating of the assembly. However, building code requirements vary greatly between areas.

It is critical that fire stopping issues be addressed early in the design and construction of a project. Please contact your fire stopping manufacturer for current listing and installation requirements. Visit **www.aquatherm.com/firestopping** for a current list of manufacturers who have tested and listed their products for use with Aquatherm piping systems.

System protection

Allowing a pump to operate for an extended period of time with zero flow passing through it can result in the pump and adjoining piping system reaching temperatures and pressures far above those recommended by Aquatherm (see pages 3.2 - 3.3). While Aquatherm's heat stabilization will protect the pipe from brief exposure to these conditions, prolonged exposure can weaken the pipe and fittings considerably, potentially causing them and other components to fail.

It is recommended that the designer provide a sensor system that will warn of temperatures over 180 °F, an automatic temperature and pressure relief valve at the pump discharge, or a similar preventative measure.

To protect the pipe from exposure to unacceptably high temperatures and pressures that could occur due to prolonged "dead heading" (pump operating at full speed with flow completely restricted), Aquatherm recommends temperature and pressure relief valves at the discharge of 3 horsepower and larger pumps.

Thrust blocking

Due to the inherent strength and integrity of fused connections, thrust blocking is not required.

UV resistance

Pipes made from fusiolen® **PP-R** and fusiolen® **PP-R C** are normally not installed where they will be subject to UV radiation. UV radiation can damage and weaken the polypropylene chains over time. UV-rated solutions can be found on page <?>.

Isolating pump-to-pipe connectors

PP-R can absorb small vibrations, so isolators are not required if the pipe has some limited mobility on either side of the pump.

Pipe sizing by flow rate

PP-R is a low friction material, making Aquatherm piping systems highly resistant to abrasion and pinhole leaks. As a result, most Aquatherm piping systems are designed to run at 8 ft/s. At this speed, the flow rate (gpm) is determined by the pipe diameter and wall thickness. The following tables give the approximate flow rates based 8 ft/s.

Nominal diameter	GPM SDR 7.4	GPM SDR 11	GPM SDR 17.6
½″	6.3	8.0	-
¾″	9.8	12.6	-
1″	16.3	20.8	-
1 ¼″	25.5	32.3	-
1 ½″	39.8	50.5	-
2″	63.7	80.2	-
2 ½″	90	114	-
3″	129	164	-
3 ½″	193	246	-
4″	250	317	-
6″	409	519	611
8″	639	812	954
10″	1001	1270	1491
12″	1604	2020	2367
14″	2038	2600	3006
16″	-	3252	3817
18″	-	4116	4831
20″	-	-	5964
22″	-	-	7481
24″	-	-	9468

Noise and water hammer

To avoid noise generation and water hammer, the calculated flow rate should not exceed 8 ft/s. Noise generation at this speed is slightly less than copper tube at 4 ft/s. Buried pipe may run up to 12 ft/s, as noise generation is not an issue.

The surge pressure created in systems operating at 8 ft/s or lower velocity will be less than 50% of the maximum shock pressure the Aquatherm piping can withstand (725 psi). At higher flow velocity, the design engineer must still account for surge pressures and design accordingly.

Flow velocity and head (friction) losses in piping

The head loss (friction pressure loss) due to the flow of water through the Aquatherm PP-R piping is given in the following tables. The water velocity is also provided. These values are calculated from the equations below. The Hazen-Williams formula is widely used in water piping applications, but it does not account for differences in fluid viscosity (different fluids) and fluid temperature. Consult your Aquatherm representative for data using other fluids such as chemical process piping or compressed gases.

Hazen-Williams formula for pressure loss (psi/100 ft of pipe):

$$P_L = \frac{452}{d_i^{4.87}}\left(\frac{Q}{C}\right)^{1.85}$$

Where:

PL = pressure loss, psi /100 ft of pipe
Q = flow rate, gpm
d_i = inside diameter of pipe, inches
C = flow coefficient = 150 for PP-R piping

Conversion to head loss (ft of head loss per 100 ft of pipe):

HL = 2.31(PL)

Where: HL = head loss, ft / 100 ft of pipe

Calculation of flow velocity:

Where:

$$v = 0.4084\left(\frac{Q}{d_i^2}\right)$$

Pipe sizing by head loss

This section includes charts on the head loss of SDR 7.4, SDR 11, and SDR 17.6 systems as well as the estimated flow rate based on a flow speed of 8 ft/s. It is important to note the differences between the standard dimensional ratios as the actual IDs for each vary slightly.

Having a flow speed of 8 ft/s can allow for downsizing of the pipe when compared against other piping systems. For example, in an application where a six-inch copper pipe would have been used, a four-inch Aquatherm PP-R pipe may be sufficient. However, this is more common when using SDR 11 and 17.6 pipe because those pipes have a higher water content per foot.

The coefficients of loss for the fittings are also included on pages 3.27 - 3.31.

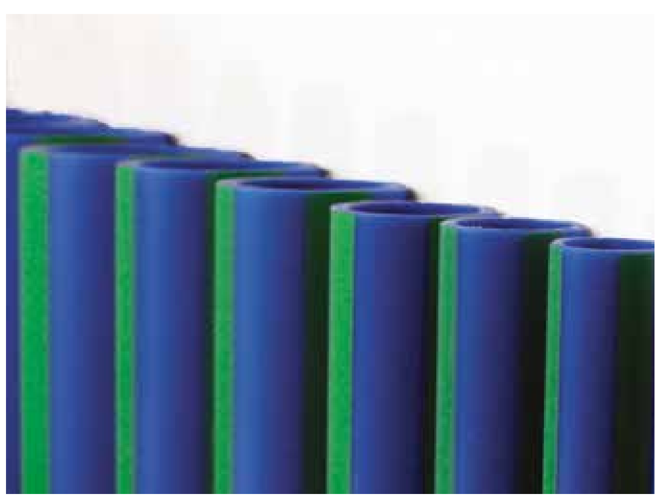
Recommended sizing

The following tables give the head loss and flow rates of the pipe based on the pipe size and the desired GPM. Reducing head loss on the critical leg of the system can allow for downsizing on other sections of pipe.

Blue indicates the recommended sizing based on flow rate (approx. 8 ft/s).

Yellow indicates the recommended size of the critical leg of the system based on head loss (avg. 3 ft /100 ft or less). This sizing is used for more energy-efficient operation.

Green indicates that the recommended size of pipe for the critical leg and other sections of the system are the same.



Pipe friction factor (R) in feet of head per 100 ft and calculated velocity (v) in feet per second based on the flow rate (Q)

SDR 11 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm
0.1 US gpm	R	0.0																
	v	0.1																
0.2 US gpm	R	0.0	0.0															
	v	0.2	0.1															
0.3 US gpm	R	0.1	0.0	0.0														
	v	0.3	0.2	0.1														
0.4 US gpm	R	0.2	0.1	0.0	0.0													
	v	0.4	0.3	0.2	0.1													
0.5 US gpm	R	0.2	0.1	0.0	0.0													
	v	0.5	0.3	0.2	0.1													
0.6 US gpm	R	0.3	0.1	0.0	0.0													
	v	0.6	0.4	0.2	0.2													
0.7 US gpm	R	0.5	0.2	0.0	0.0	0.0												
	v	0.7	0.4	0.3	0.2	0.1												
0.8 US gpm	R	0.6	0.2	0.1	0.0	0.0												
	v	0.8	0.5	0.3	0.2	0.1												
0.9 US gpm	R	0.7	0.2	0.1	0.0	0.0												
	v	0.9	0.6	0.4	0.2	0.1												
1 US gpm	R	0.9	0.3	0.1	0.0	0.0												
	v	1.0	0.6	0.4	0.3	0.2												
2 US gpm	R	3.2	1.0	0.3	0.1	0.0	0.0											
	v	2.0	1.3	0.8	0.5	0.3	0.2											
3 US gpm	R	6.7	2.2	0.6	0.2	0.1	0.0	0.0										
	v	3.0	1.9	1.2	0.7	0.5	0.3	0.2										
4 US gpm	R	11.4	3.7	1.1	0.4	0.1	0.0	0.0	0.0									
	v	4.0	2.5	1.5	1.0	0.6	0.4	0.3	0.2									
5 US gpm	R	17.2	5.6	1.7	0.6	0.2	0.1	0.0	0.0									
	v	5.0	3.2	1.9	1.2	0.8	0.5	0.4	0.2									
6 US gpm	R	24.1	7.8	2.3	0.8	0.3	0.1	0.0	0.0	0.0								
	v	6.0	3.8	2.3	1.5	1.0	0.6	0.4	0.3	0.2								
7 US gpm	R	32.0	10.4	3.1	1.1	0.4	0.1	0.1	0.0	0.0								
	v	7.0	4.4	2.7	1.7	1.1	0.7	0.5	0.3	0.2								
8 US gpm	R	41.0	13.4	4.0	1.4	0.5	0.2	0.1	0.0	0.0	0.0							
	v	8.0	5.1	3.1	2.0	1.3	0.8	0.6	0.4	0.3	0.2							
9 US gpm	R	50.9	16.6	4.9	1.7	0.6	0.2	0.1	0.0	0.0	0.0							
	v	9.0	5.7	3.5	2.2	1.4	0.9	0.6	0.4	0.3	0.2							
10 US gpm	R	61.9	20.2	6.0	2.1	0.7	0.2	0.1	0.0	0.0	0.0							
	v	10.0	6.3	3.8	2.5	1.6	1.0	0.7	0.5	0.3	0.3							
11 US gpm	R	73.8	24.1	7.1	2.5	0.8	0.3	0.1	0.1	0.0	0.0							
	v	11.0	7.0	4.2	2.7	1.7	1.1	0.8	0.5	0.4	0.3							
12 US gpm	R	86.7	28.3	8.4	2.9	1.0	0.3	0.1	0.1	0.0	0.0							
	v	12.0	7.6	4.6	3.0	1.9	1.2	0.8	0.6	0.4	0.3							

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

SDR 11 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm
13 US gpm	R		32.8	9.7	3.3	1.1	0.4	0.2	0.1	0.0	0.0							
	v		8.2	5.0	3.2	2.1	1.3	0.9	0.6	0.4	0.3							
14 US gpm	R		37.6	11.1	3.8	1.3	0.4	0.2	0.1	0.0	0.0							
	v		8.9	5.4	3.5	2.2	1.4	1.0	0.7	0.5	0.4							
15 US gpm	R		42.7	12.6	4.4	1.5	0.5	0.2	0.1	0.0	0.0	0.0						
	v		9.5	5.8	3.7	2.4	1.5	1.1	0.7	0.5	0.4	0.2						
16 US gpm	R		48.1	14.2	4.9	1.7	0.5	0.2	0.1	0.0	0.0	0.0						
	v		10.1	6.1	4.0	2.5	1.6	1.1	0.8	0.5	0.4	0.3						
17 US gpm	R		53.8	15.9	5.5	1.8	0.6	0.3	0.1	0.0	0.0	0.0						
	v		10.8	6.5	4.2	2.7	1.7	1.2	0.8	0.6	0.4	0.3						
18 US gpm	R		59.8	17.7	6.1	2.1	0.7	0.3	0.1	0.0	0.0	0.0						
	v		11.4	6.9	4.5	2.9	1.8	1.3	0.9	0.6	0.5	0.3						
19 US gpm	R		66.1	19.6	6.7	2.3	0.7	0.3	0.1	0.1	0.0	0.0						
	v		12.0	7.3	4.7	3.0	1.9	1.3	0.9	0.6	0.5	0.3						
20 US gpm	R		72.7	21.5	7.4	2.5	0.8	0.3	0.1	0.1	0.0	0.0						
	v		12.7	7.7	5.0	3.2	2.0	1.4	1.0	0.7	0.5	0.3						
22 US gpm	R		86.7	25.6	8.9	3.0	1.0	0.4	0.2	0.1	0.0	0.0						
	v		13.9	8.4	5.5	3.5	2.2	1.5	1.1	0.7	0.6	0.3						
24 US gpm	R			30.1	10.4	3.5	1.1	0.5	0.2	0.1	0.0	0.0						
	v			9.2	6.0	3.8	2.4	1.7	1.2	0.8	0.6	0.4						
26 US gpm	R			34.9	12.1	4.0	1.3	0.6	0.2	0.1	0.1	0.0						
	v			10.0	6.5	4.1	2.6	1.8	1.3	0.9	0.7	0.4						
28 US gpm	R			40.1	13.8	4.6	1.5	0.6	0.3	0.1	0.1	0.0	0.0					
	v			10.8	6.9	4.4	2.8	2.0	1.4	0.9	0.7	0.4	0.3					
30 US gpm	R			45.5	15.7	5.3	1.7	0.7	0.3	0.1	0.1	0.0	0.0					
	v			11.5	7.4	4.8	3.0	2.1	1.5	1.0	0.8	0.5	0.3					
32 US gpm	R			51.3	17.7	5.9	1.9	0.8	0.3	0.1	0.1	0.0	0.0					
	v			12.3	7.9	5.1	3.2	2.2	1.6	1.0	0.8	0.5	0.3					
34 US gpm	R			57.4	19.8	6.6	2.2	0.9	0.4	0.1	0.1	0.0	0.0					
	v			13.1	8.4	5.4	3.4	2.4	1.7	1.1	0.9	0.5	0.3					
36 US gpm	R			63.8	22.0	7.4	2.4	1.0	0.4	0.2	0.1	0.0	0.0					
	v			13.8	8.9	5.7	3.6	2.5	1.8	1.2	0.9	0.6	0.4					
38 US gpm	R			70.5	24.3	8.2	2.7	1.1	0.5	0.2	0.1	0.0	0.0					
	v			14.6	9.4	6.0	3.8	2.7	1.9	1.2	1.0	0.6	0.4					
40 US gpm	R			77.5	26.7	9.0	2.9	1.2	0.5	0.2	0.1	0.0	0.0					
	v			15.4	9.9	6.3	4.0	2.8	2.0	1.3	1.0	0.6	0.4					
45 US gpm	R				33.2	11.2	3.6	1.5	0.6	0.2	0.1	0.0	0.0					
	v				11.2	7.1	4.5	3.2	2.2	1.5	1.1	0.7	0.4					
50 US gpm	R				40.4	13.6	4.4	1.9	0.8	0.3	0.2	0.1	0.0	0.0				
	v				12.4	7.9	5.0	3.5	2.4	1.6	1.3	0.8	0.5	0.3				
55 US gpm	R				48.2	16.2	5.3	2.2	0.9	0.3	0.2	0.1	0.0	0.0				
	v				13.6	8.7	5.5	3.8	2.7	1.8	1.4	0.9	0.5	0.4				
60 US gpm	R				56.6	19.0	6.2	2.6	1.1	0.4	0.2	0.1	0.0	0.0				
	v				14.9	9.5	6.0	4.2	2.9	2.0	1.5	0.9	0.6	0.4				

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

SDR 11 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm
65 US gpm	R					22.0	7.2	3.0	1.2	0.5	0.3	0.1	0.0	0.0				
	v					10.3	6.5	4.5	3.2	2.1	1.6	1.0	0.6	0.4				
70 US gpm	R					25.2	8.2	3.5	1.4	0.5	0.3	0.1	0.0	0.0				
	v					11.1	7.0	4.9	3.4	2.3	1.8	1.1	0.7	0.4				
75 US gpm	R					28.7	9.3	3.9	1.6	0.6	0.3	0.1	0.0	0.0				
	v					11.9	7.5	5.2	3.7	2.4	1.9	1.2	0.7	0.5				
80 US gpm	R					32.3	10.5	4.4	1.8	0.7	0.4	0.1	0.0	0.0				
	v					12.7	8.0	5.6	3.9	2.6	2.0	1.2	0.8	0.5				
85 US gpm	R					36.2	11.7	4.9	2.0	0.8	0.4	0.1	0.0	0.0				
	v					13.5	8.5	5.9	4.1	2.8	2.1	1.3	0.8	0.5				
90 US gpm	R					40.2	13.1	5.5	2.3	0.9	0.5	0.1	0.1	0.0	0.0			
	v					14.3	9.0	6.3	4.4	2.9	2.3	1.4	0.9	0.6	0.4			
95 US gpm	R					44.4	14.4	6.1	2.5	0.9	0.5	0.2	0.1	0.0	0.0			
	v					15.0	9.5	6.6	4.6	3.1	2.4	1.5	0.9	0.6	0.4			
100 US gpm	R					48.8	15.9	6.7	2.8	1.0	0.6	0.2	0.1	0.0	0.0			
	v					15.8	10.0	7.0	4.9	3.3	2.5	1.5	1.0	0.6	0.4			
110 US gpm	R						18.9	8.0	3.3	1.2	0.7	0.2	0.1	0.0	0.0			
	v						11.0	7.7	5.4	3.6	2.8	1.7	1.1	0.7	0.4			
120 US gpm	R						22.2	9.4	3.9	1.5	0.8	0.2	0.1	0.0	0.0			
	v						12.0	8.4	5.8	3.9	3.0	1.9	1.2	0.8	0.5			
130 US gpm	R						25.8	10.8	4.5	1.7	0.9	0.3	0.1	0.0	0.0			
	v						13.0	9.1	6.3	4.2	3.3	2.0	1.3	0.8	0.5			
140 US gpm	R						29.6	12.4	5.1	1.9	1.0	0.3	0.1	0.0	0.0			
	v						14.0	9.8	6.8	4.6	3.5	2.2	1.4	0.9	0.6			
150 US gpm	R						33.6	14.1	5.8	2.2	1.2	0.4	0.1	0.0	0.0			
	v						15.0	10.5	7.3	4.9	3.8	2.3	1.5	0.9	0.6			
160 US gpm	R						37.8	15.9	6.6	2.5	1.3	0.4	0.1	0.1	0.0			
	v						16.0	11.2	7.8	5.2	4.0	2.5	1.6	1.0	0.6			
170 US gpm	R							17.8	7.4	2.8	1.5	0.5	0.2	0.1	0.0			
	v							11.9	8.3	5.5	4.3	2.6	1.7	1.1	0.7			
180 US gpm	R							19.8	8.2	3.1	1.7	0.5	0.2	0.1	0.0			
	v							12.6	8.8	5.9	4.5	2.8	1.8	1.1	0.7			
190 US gpm	R							21.9	9.1	3.4	1.8	0.6	0.2	0.1	0.0			
	v							13.3	9.2	6.2	4.8	2.9	1.9	1.2	0.8			
200 US gpm	R							24.1	10.0	3.7	2.0	0.6	0.2	0.1	0.0			
	v							14.0	9.7	6.5	5.1	3.1	2.0	1.3	0.8			
220 US gpm	R							28.7	11.9	4.5	2.4	0.7	0.2	0.1	0.0			
	v							15.4	10.7	7.2	5.6	3.4	2.2	1.4	0.9			
240 US gpm	R								13.9	5.2	2.8	0.9	0.3	0.1	0.0			
	v								11.7	7.8	6.1	3.7	2.4	1.5	1.0			
260 US gpm	R								16.2	6.1	3.3	1.0	0.3	0.1	0.0			
	v								12.7	8.5	6.6	4.0	2.6	1.6	1.0			
280 US gpm	R								18.5	7.0	3.8	1.1	0.4	0.1	0.0			
	v								13.6	9.1	7.1	4.3	2.8	1.8	1.1			

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

SDR 11 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm
300 US gpm	R								21.1	7.9	4.3	1.3	0.4	0.1	0.1			
	v								14.6	9.8	7.6	4.6	3.0	1.9	1.2			
320 US gpm	R								23.7	8.9	4.8	1.4	0.5	0.2	0.1			
	v								15.6	10.4	8.1	4.9	3.2	2.0	1.3			
340 US gpm	R									10.0	5.4	1.6	0.5	0.2	0.1			
	v									11.1	8.6	5.2	3.4	2.1	1.4			
360 US gpm	R									11.1	6.0	1.8	0.6	0.2	0.1			
	v									11.7	9.1	5.5	3.5	2.3	1.4			
380 US gpm	R									12.3	6.6	2.0	0.7	0.2	0.1			
	v									12.4	9.6	5.9	3.7	2.4	1.5			
400 US gpm	R									13.5	7.3	2.2	0.7	0.3	0.1	0.0		
	v									13.0	10.1	6.2	3.9	2.5	1.6	1.2		
450 US gpm	R									16.8	9.0	2.7	0.9	0.3	0.1	0.1		
	v									14.6	11.4	6.9	4.4	2.8	1.8	1.4		
500 US gpm	R										11.0	3.3	1.1	0.4	0.1	0.1		
	v										12.6	7.7	4.9	3.2	2.0	1.6		
550 US gpm	R										13.1	3.9	1.3	0.4	0.1	0.1		
	v										13.9	8.5	5.4	3.5	2.2	1.7		
600 US gpm	R										15.4	4.6	1.6	0.5	0.2	0.1		
	v										15.1	9.2	5.9	3.8	2.4	1.9		
650 US gpm	R											5.4	1.8	0.6	0.2	0.1		
	v											10.0	6.4	4.1	2.6	2.0		
700 US gpm	R											6.1	2.1	0.7	0.2	0.1		
	v											10.8	6.9	4.4	2.8	2.2		
750 US gpm	R											7.0	2.4	0.8	0.3	0.1		
	v											11.6	7.4	4.7	3.0	2.3		
800 US gpm	R											7.9	2.6	0.9	0.3	0.2		
	v											12.3	7.9	5.0	3.2	2.5		
850 US gpm	R											8.8	3.0	1.0	0.3	0.2		
	v											13.1	8.4	5.4	3.4	2.7		
900 US gpm	R											9.8	3.3	1.1	0.4	0.2		
	v											13.9	8.9	5.7	3.6	2.8		
950 US gpm	R											10.8	3.6	1.2	0.4	0.2		
	v											14.6	9.4	6.0	3.8	3.0		
1000 US gpm	R											11.9	4.0	1.3	0.4	0.2	0.1	0.1
	v											15.4	9.8	6.3	4.0	3.1	2.5	1.9
1100 US gpm	R												4.8	1.6	0.5	0.3	0.2	0.1
	v												10.8	6.9	4.4	3.4	2.7	2.1
1200 US gpm	R												5.6	1.9	0.6	0.3	0.2	0.1
	v												11.8	7.6	4.8	3.7	2.9	2.3
1300 US gpm	R												6.5	2.2	0.7	0.4	0.2	0.1
	v												12.8	8.2	5.2	4.1	3.2	2.5
1400 US gpm	R												7.4	2.5	0.8	0.5	0.3	0.1
	v												13.8	8.8	5.6	4.4	3.4	2.7

Q = flow rate (US gpm)   R = feet of head per 100 ft   v = velocity (ft/sec)

SDR 11 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm
1500 US gpm	R												8.5	2.9	0.9	0.5	0.3	0.2
	v												14.8	9.4	6.0	4.7	3.7	2.9
1600 US gpm	R												9.5	3.2	1.0	0.6	0.3	0.2
	v												15.8	10.1	6.3	5.0	3.9	3.1
1700 US gpm	R													3.6	1.2	0.7	0.4	0.2
	v													10.7	6.7	5.3	4.2	3.3
1800 US gpm	R													4.0	1.3	0.7	0.4	0.2
	v													11.3	7.1	5.6	4.4	3.5
1900 US gpm	R													4.4	1.4	0.8	0.4	0.3
	v													12.0	7.5	5.9	4.7	3.7
2000 US gpm	R													4.9	1.6	0.9	0.5	0.3
	v													12.6	7.9	6.2	4.9	3.9
2200 US gpm	R													5.8	1.9	1.1	0.6	0.3
	v													13.9	8.7	6.9	5.4	4.3
2400 US gpm	R													6.8	2.2	1.2	0.7	0.4
	v													15.1	9.5	7.5	5.9	4.7
2600 US gpm	R														2.6	1.4	0.8	0.5
	v														10.3	8.1	6.4	5.1
2800 US gpm	R														2.9	1.6	0.9	0.5
	v														11.1	8.7	6.9	5.4
3000 US gpm	R														3.3	1.9	1.0	0.6
	v														11.9	9.4	7.4	5.8
3200 US gpm	R															2.1	1.2	0.7
	v															10.0	7.9	6.2
3400 US gpm	R															2.4	1.3	0.7
	v															10.6	8.3	6.6
3600 US gpm	R															2.6	1.5	0.8
	v															11.2	8.8	7.0
3800 US gpm	R															2.9	1.6	0.9
	v															11.9	9.3	7.4
4000 US gpm	R															3.2	1.8	1.0
	v															12.5	9.8	7.8
4500 US gpm	R																2.2	1.2
	v																11.1	8.8
5000 US gpm	R																2.7	1.5
	v																12.3	9.7
5500 US gpm	R																	1.8
	v																	10.7
6000 US gpm	R																	2.1
	v																	11.7
6500 US gpm	R																	2.5
	v																	12.6

Q = flow rate (US gpm)   R = feet of head per 100 ft   v = velocity (ft/sec)

Pipe friction factor (R) in feet of head per 100 ft and calculated velocity (v) in feet per second based on the flow rate (Q)

SDR 7.4 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm
0.1 US gpm	R	0.0	0.0													
	v	0.1	0.1													
0.2 US gpm	R	0.1	0.0	0.0												
	v	0.3	0.2	0.1												
0.3 US gpm	R	0.2	0.1	0.0	0.0											
	v	0.4	0.2	0.2	0.1											
0.4 US gpm	R	0.3	0.1	0.0	0.0											
	v	0.5	0.3	0.2	0.1											
0.5 US gpm	R	0.4	0.2	0.0	0.0											
	v	0.6	0.4	0.2	0.2											
0.6 US gpm	R	0.6	0.2	0.1	0.0	0.0										
	v	0.8	0.5	0.3	0.2	0.1										
0.7 US gpm	R	0.8	0.3	0.1	0.0	0.0										
	v	0.9	0.6	0.3	0.2	0.1										
0.8 US gpm	R	1.0	0.4	0.1	0.0	0.0										
	v	1.0	0.7	0.4	0.3	0.2										
0.9 US gpm	R	1.3	0.4	0.1	0.0	0.0										
	v	1.1	0.7	0.4	0.3	0.2										
1 US gpm	R	1.6	0.5	0.2	0.1	0.0	0.0									
	v	1.3	0.8	0.5	0.3	0.2	0.1									
2 US gpm	R	5.6	1.9	0.6	0.2	0.1	0.0	0.0								
	v	2.5	1.6	1.0	0.6	0.4	0.3	0.2								
3 US gpm	R	11.9	4.0	1.2	0.4	0.1	0.0	0.0	0.0							
	v	3.8	2.4	1.5	0.9	0.6	0.4	0.3	0.2							
4 US gpm	R	20.2	6.8	2.0	0.7	0.2	0.1	0.0	0.0							
	v	5.1	3.3	2.0	1.3	0.8	0.5	0.4	0.3							
5 US gpm	R	30.5	10.3	3.0	1.0	0.3	0.1	0.1	0.0	0.0						
	v	6.4	4.1	2.5	1.6	1.0	0.6	0.5	0.3	0.2						
6 US gpm	R	42.8	14.4	4.2	1.4	0.5	0.2	0.1	0.0	0.0	0.0					
	v	7.6	4.9	2.9	1.9	1.2	0.8	0.5	0.4	0.3	0.2					
7 US gpm	R	56.9	19.2	5.6	1.9	0.6	0.2	0.1	0.0	0.0	0.0					
	v	8.9	5.7	3.4	2.2	1.4	0.9	0.6	0.4	0.3	0.2					
8 US gpm	R	72.8	24.6	7.1	2.4	0.8	0.3	0.1	0.1	0.0	0.0					
	v	10.2	6.5	3.9	2.5	1.6	1.0	0.7	0.5	0.3	0.3					
9 US gpm	R	90.5	30.5	8.9	3.0	1.0	0.3	0.1	0.1	0.0	0.0					
	v	11.4	7.3	4.4	2.8	1.8	1.1	0.8	0.6	0.4	0.3					
10 US gpm	R		37.1	10.8	3.6	1.2	0.4	0.2	0.1	0.0	0.0					
	v		8.1	4.9	3.1	2.0	1.3	0.9	0.6	0.4	0.3					
11 US gpm	R		44.3	12.9	4.3	1.5	0.5	0.2	0.1	0.0	0.0	0.0				
	v		9.0	5.4	3.5	2.2	1.4	1.0	0.7	0.5	0.4	0.2				

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

SDR 7.4 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm
12 US gpm	R		52.0	15.1	5.1	1.7	0.6	0.2	0.1	0.0	0.0	0.0				
	v		9.8	5.9	3.8	2.4	1.5	1.1	0.7	0.5	0.4	0.2				
13 US gpm	R		60.3	17.5	5.9	2.0	0.6	0.3	0.1	0.0	0.0	0.0				
	v		10.6	6.4	4.1	2.6	1.6	1.2	0.8	0.5	0.4	0.3				
14 US gpm	R		69.2	20.1	6.8	2.3	0.7	0.3	0.1	0.1	0.0	0.0				
	v		11.4	6.9	4.4	2.8	1.8	1.3	0.9	0.6	0.5	0.3				
15 US gpm	R		78.6	22.8	7.7	2.6	0.8	0.4	0.2	0.1	0.0	0.0				
	v		12.2	7.3	4.7	3.0	1.9	1.3	0.9	0.6	0.5	0.3				
16 US gpm	R		88.5	25.7	8.7	3.0	0.9	0.4	0.2	0.1	0.0	0.0				
	v		13.0	7.8	5.0	3.2	2.0	1.4	1.0	0.7	0.5	0.3				
17 US gpm	R		99.0	28.8	9.7	3.3	1.1	0.5	0.2	0.1	0.0	0.0				
	v		13.8	8.3	5.3	3.4	2.1	1.5	1.1	0.7	0.5	0.3				
18 US gpm	R			32.0	10.8	3.7	1.2	0.5	0.2	0.1	0.0	0.0				
	v			8.8	5.6	3.6	2.3	1.6	1.1	0.7	0.6	0.4				
19 US gpm	R			35.4	11.9	4.1	1.3	0.6	0.2	0.1	0.1	0.0				
	v			9.3	6.0	3.8	2.4	1.7	1.2	0.8	0.6	0.4				
20 US gpm	R			38.9	13.1	4.5	1.4	0.6	0.3	0.1	0.1	0.0	0.0			
	v			9.8	6.3	4.0	2.5	1.8	1.2	0.8	0.6	0.4	0.3			
22 US gpm	R			46.4	15.6	5.3	1.7	0.7	0.3	0.1	0.1	0.0	0.0			
	v			10.8	6.9	4.4	2.8	2.0	1.4	0.9	0.7	0.4	0.3			
24 US gpm	R			54.5	18.4	6.2	2.0	0.9	0.4	0.1	0.1	0.0	0.0			
	v			11.8	7.5	4.8	3.0	2.1	1.5	1.0	0.8	0.5	0.3			
26 US gpm	R			63.2	21.3	7.2	2.3	1.0	0.4	0.2	0.1	0.0	0.0			
	v			12.7	8.2	5.2	3.3	2.3	1.6	1.1	0.8	0.5	0.3			
28 US gpm	R			72.4	24.4	8.3	2.6	1.1	0.5	0.2	0.1	0.0	0.0			
	v			13.7	8.8	5.6	3.5	2.5	1.7	1.2	0.9	0.6	0.4			
30 US gpm	R			82.3	27.8	9.4	3.0	1.3	0.5	0.2	0.1	0.0	0.0			
	v			14.7	9.4	6.0	3.8	2.7	1.9	1.2	1.0	0.6	0.4			
32 US gpm	R			92.7	31.3	10.6	3.4	1.5	0.6	0.2	0.1	0.0	0.0			
	v			15.7	10.0	6.4	4.0	2.9	2.0	1.3	1.0	0.6	0.4			
34 US gpm	R				35.0	11.9	3.8	1.6	0.7	0.3	0.1	0.0	0.0			
	v				10.7	6.8	4.3	3.0	2.1	1.4	1.1	0.7	0.4			
36 US gpm	R				38.9	13.2	4.2	1.8	0.7	0.3	0.2	0.1	0.0	0.0		
	v				11.3	7.2	4.5	3.2	2.2	1.5	1.2	0.7	0.5	0.3		
38 US gpm	R				43.0	14.6	4.6	2.0	0.8	0.3	0.2	0.1	0.0	0.0		
	v				11.9	7.6	4.8	3.4	2.3	1.6	1.2	0.7	0.5	0.3		
40 US gpm	R				47.3	16.1	5.1	2.2	0.9	0.3	0.2	0.1	0.0	0.0		
	v				12.5	8.0	5.0	3.6	2.5	1.7	1.3	0.8	0.5	0.3		
45 US gpm	R				58.8	20.0	6.4	2.8	1.1	0.4	0.2	0.1	0.0	0.0		
	v				14.1	9.1	5.7	4.0	2.8	1.9	1.4	0.9	0.6	0.4		
50 US gpm	R				71.4	24.3	7.7	3.3	1.4	0.5	0.3	0.1	0.0	0.0		
	v				15.7	10.1	6.3	4.5	3.1	2.1	1.6	1.0	0.6	0.4		

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

SDR 7.4 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm
55 US gpm	R					28.9	9.2	4.0	1.6	0.6	0.3	0.1	0.0	0.0		
	v					11.1	6.9	4.9	3.4	2.3	1.8	1.1	0.7	0.4		
60 US gpm	R					34.0	10.8	4.7	1.9	0.7	0.4	0.1	0.0	0.0		
	v					12.1	7.5	5.3	3.7	2.5	1.9	1.2	0.8	0.5		
65 US gpm	R					39.4	12.5	5.4	2.2	0.8	0.5	0.1	0.1	0.0		
	v					13.1	8.2	5.8	4.0	2.7	2.1	1.3	0.8	0.5		
70 US gpm	R					45.2	14.4	6.2	2.5	1.0	0.5	0.2	0.1	0.0		
	v					14.1	8.8	6.2	4.3	2.9	2.2	1.4	0.9	0.6		
75 US gpm	R					51.4	16.3	7.1	2.9	1.1	0.6	0.2	0.1	0.0		
	v					15.1	9.4	6.7	4.6	3.1	2.4	1.5	0.9	0.6		
80 US gpm	R						18.4	8.0	3.3	1.2	0.7	0.2	0.1	0.0		
	v						10.1	7.1	4.9	3.3	2.6	1.6	1.0	0.6		
85 US gpm	R						20.6	8.9	3.6	1.4	0.7	0.2	0.1	0.0		
	v						10.7	7.6	5.2	3.5	2.7	1.7	1.1	0.7		
90 US gpm	R						22.9	9.9	4.0	1.5	0.8	0.3	0.1	0.0		
	v						11.3	8.0	5.5	3.7	2.9	1.8	1.1	0.7		
95 US gpm	R						25.3	10.9	4.5	1.7	0.9	0.3	0.1	0.0		
	v						11.9	8.5	5.9	3.9	3.0	1.9	1.2	0.8		
100 US gpm	R						27.8	12.0	4.9	1.9	1.0	0.3	0.1	0.0		
	v						12.6	8.9	6.2	4.1	3.2	2.0	1.3	0.8		
110 US gpm	R						33.2	14.4	5.9	2.2	1.2	0.4	0.1	0.0		
	v						13.8	9.8	6.8	4.6	3.5	2.2	1.4	0.9		
120 US gpm	R						39.0	16.9	6.9	2.6	1.4	0.4	0.1	0.1		
	v						15.1	10.7	7.4	5.0	3.8	2.3	1.5	1.0		
130 US gpm	R							19.6	8.0	3.0	1.6	0.5	0.2	0.1		
	v							11.6	8.0	5.4	4.2	2.5	1.6	1.0		
140 US gpm	R							22.4	9.1	3.5	1.9	0.6	0.2	0.1		
	v							12.5	8.6	5.8	4.5	2.7	1.8	1.1		
150 US gpm	R							25.5	10.4	3.9	2.1	0.6	0.2	0.1		
	v							13.4	9.2	6.2	4.8	2.9	1.9	1.2		
160 US gpm	R							28.7	11.7	4.4	2.4	0.7	0.2	0.1		
	v							14.3	9.9	6.6	5.1	3.1	2.0	1.3		
170 US gpm	R							32.1	13.1	5.0	2.7	0.8	0.3	0.1		
	v							15.1	10.5	7.0	5.4	3.3	2.1	1.4		
180 US gpm	R								14.6	5.5	2.9	0.9	0.3	0.1		
	v								11.1	7.5	5.8	3.5	2.3	1.4		
190 US gpm	R								16.1	6.1	3.3	1.0	0.3	0.1		
	v								11.7	7.9	6.1	3.7	2.4	1.5		
200 US gpm	R								17.7	6.7	3.6	1.1	0.4	0.1		
	v								12.3	8.3	6.4	3.9	2.5	1.6		
220 US gpm	R								21.1	8.0	4.3	1.3	0.4	0.2		
	v								13.6	9.1	7.0	4.3	2.8	1.8		

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

SDR 7.4 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm
240 US gpm	R								24.8	9.4	5.0	1.5	0.5	0.2		
	v								14.8	9.9	7.7	4.7	3.0	1.9		
260 US gpm	R									10.9	5.8	1.8	0.6	0.2		
	v									10.8	8.3	5.1	3.3	2.1		
280 US gpm	R									12.5	6.7	2.0	0.7	0.2		
	v									11.6	9.0	5.5	3.5	2.2		
300 US gpm	R									14.2	7.6	2.3	0.8	0.3	0.1	
	v									12.4	9.6	5.9	3.8	2.4	1.5	
320 US gpm	R									16.0	8.5	2.6	0.9	0.3	0.1	
	v									13.2	10.2	6.2	4.0	2.6	1.6	
340 US gpm	R									17.9	9.6	2.9	1.0	0.3	0.1	
	v									14.1	10.9	6.6	4.3	2.7	1.7	
360 US gpm	R									19.9	10.6	3.2	1.1	0.4	0.1	
	v									14.9	11.5	7.0	4.5	2.9	1.8	
380 US gpm	R									22.0	11.7	3.5	1.2	0.4	0.1	
	v									15.7	12.1	7.4	4.8	3.0	1.9	
400 US gpm	R										12.9	3.9	1.3	0.4	0.1	
	v										12.8	7.8	5.0	3.2	2.0	
450 US gpm	R										16.0	4.8	1.6	0.6	0.2	
	v										14.4	8.8	5.6	3.6	2.3	
500 US gpm	R										19.5	5.9	2.0	0.7	0.2	0.1
	v										16.0	9.8	6.3	4.0	2.5	2.0
550 US gpm	R											7.0	2.4	0.8	0.3	0.1
	v											10.7	6.9	4.4	2.7	2.7
600 US gpm	R											8.2	2.8	0.9	0.3	0.2
	v											11.7	7.5	4.8	3.0	2.4
650 US gpm	R											9.5	3.2	1.1	0.3	0.2
	v											12.7	8.1	5.2	3.2	2.6
700 US gpm	R											10.9	3.7	1.2	0.4	0.2
	v											13.7	8.8	5.6	3.5	2.8
750 US gpm	R											12.4	4.2	1.4	0.5	0.3
	v											14.6	9.4	6.0	3.7	2.9
800 US gpm	R											14.0	4.7	1.6	0.5	0.3
	v											15.6	10.0	6.4	4.0	3.1
850 US gpm	R												5.3	1.8	0.6	0.3
	v												10.6	6.8	4.2	3.3
900 US gpm	R												5.9	2.0	0.6	0.4
	v												11.3	7.2	4.5	3.5
950 US gpm	R												6.5	2.2	0.7	0.4
	v												11.9	7.6	4.7	3.7
1000 US gpm	R												7.1	2.4	0.8	0.4
	v												12.5	8.0	5.0	3.9

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

SDR 7.4 pipe

Q	Dimension	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm
1100 US gpm	R												8.5	2.9	0.9	0.5
	v												13.8	8.8	5.5	4.3
1200 US gpm	R												10.0	3.4	1.1	0.6
	v												15.0	9.6	6.0	4.7
1300 US gpm	R													3.9	1.2	0.7
	v													10.4	6.5	5.1
1400 US gpm	R													4.5	1.4	0.8
	v													11.2	7.0	5.5
1500 US gpm	R													5.0	1.6	0.9
	v													11.9	7.5	5.9
1600 US gpm	R													5.6	1.8	1.0
	v													12.7	8.0	6.3
1700 US gpm	R														2.0	1.1
	v														8.5	6.7
1800 US gpm	R														2.3	1.3
	v														9.0	7.0
1900 US gpm	R														2.5	1.4
	v														9.5	7.5
2000 US gpm	R														2.8	1.5
	v														10.0	7.9
2200 US gpm	R														3.3	1.8
	v														11.0	8.6
2400 US gpm	R														3.8	2.1
	v														12.0	9.4
2600 US gpm	R															2.5
	v															10.2
2800 US gpm	R															2.9
	v															11.0
3000 US gpm	R															3.3
	v															11.8

Q = flow rate (US gpm) R = feet of head per 100 ft v = velocity (ft/sec)

Pipe friction factor (R) in feet of head per 100 ft and calculated velocity (v) in feet per second based on the flow rate (Q)

SDR 17.6 pipe

Q	Dimension	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
200 US gpm	R	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	v	2.6	1.7	1.1	0.7	0.5	0.4	0.3	0.3	0.2	0.2
220 US gpm	R	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	v	2.9	1.8	1.2	0.7	0.6	0.5	0.4	0.3	0.2	0.2
240 US gpm	R	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	v	3.1	2.0	1.3	0.8	0.6	0.5	0.4	0.3	0.3	0.2
260 US gpm	R	0.7	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	v	3.4	2.2	1.4	0.9	0.7	0.5	0.4	0.3	0.3	0.2
280 US gpm	R	0.8	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	v	3.7	2.3	1.5	0.9	0.7	0.6	0.5	0.4	0.3	0.2
300 US gpm	R	0.9	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	v	3.9	2.5	1.6	1.0	0.8	0.6	0.5	0.4	0.3	0.3
350 US gpm	R	1.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	v	4.6	2.9	1.9	1.2	0.9	0.7	0.6	0.5	0.4	0.3
400 US gpm	R	1.5	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	v	5.2	3.4	2.1	1.4	1.1	0.8	0.7	0.5	0.4	0.3
450 US gpm	R	1.8	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	v	5.9	3.8	2.4	1.5	1.2	0.9	0.7	0.6	0.5	0.4
500 US gpm	R	2.2	0.8	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	v	6.6	4.2	2.7	1.7	1.3	1.0	0.8	0.7	0.5	0.4
550 US gpm	R	2.7	0.9	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0
	v	7.2	4.6	3.0	1.9	1.5	1.2	0.9	0.7	0.6	0.5
600 US gpm	R	3.1	1.1	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0
	v	7.9	5.0	3.2	2.0	1.6	1.3	1.0	0.8	0.6	0.5
650 US gpm	R	3.6	1.2	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0
	v	8.5	5.4	3.5	2.2	1.7	1.4	1.1	0.9	0.7	0.5
700 US gpm	R	4.2	1.4	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0
	v	9.2	5.9	3.8	2.4	1.9	1.5	1.2	0.9	0.7	0.6
750 US gpm	R	4.7	1.6	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0
	v	9.8	6.3	4.0	2.5	2.0	1.6	1.2	1.0	0.8	0.6
800 US gpm	R	5.3	1.8	0.6	0.2	0.1	0.1	0.0	0.0	0.0	0.0
	v	10.5	6.7	4.3	2.7	2.1	1.7	1.3	1.1	0.9	0.7
900 US gpm	R		2.2	0.8	0.2	0.1	0.1	0.0	0.0	0.0	0.0
	v		7.5	4.8	3.0	2.4	1.9	1.5	1.2	1.0	0.8
1000 US gpm	R		2.7	0.9	0.3	0.2	0.1	0.1	0.0	0.0	0.0
	v		8.4	5.4	3.4	2.7	2.1	1.7	1.3	1.1	0.8
1100 US gpm	R		3.2	1.1	0.4	0.2	0.1	0.1	0.0	0.0	0.0
	v		9.2	5.9	3.7	2.9	2.3	1.8	1.5	1.2	0.9
1200 US gpm	R		3.8	1.3	0.4	0.2	0.1	0.1	0.0	0.0	0.0
	v		10.1	6.4	4.1	3.2	2.5	2.0	1.6	1.3	1.0
Q = flow rate (US gpm)				R= feet of head per 100 ft.				v = velocity (ft./ sec}			

SDR 17.6 pipe

Q	Dimension	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
1300 US gpm	R		4.4	1.5	0.5	0.3	0.2	0.1	0.1	0.0	0.0
	v		10.9	7.0	4.4	3.5	2.7	2.2	1.7	1.4	1.1
1400 US gpm	R		5.1	1.7	0.6	0.3	0.2	0.1	0.1	0.0	0.0
	v		11.7	7.5	4.7	3.7	2.9	2.3	1.9	1.5	1.2
1500 US gpm	R		5.7	1.9	0.6	0.4	0.2	0.1	0.1	0.0	0.0
	v		12.6	8.1	5.1	4.0	3.1	2.5	2.0	1.6	1.3
1600 US gpm	R		6.5	2.2	0.7	0.4	0.2	0.1	0.1	0.0	0.0
	v		13.4	8.6	5.4	4.3	3.3	2.6	2.1	1.7	1.4
1700 US gpm	R		7.2	2.4	0.8	0.4	0.2	0.1	0.1	0.0	0.0
	v		14.3	9.1	5.7	4.5	3.6	2.8	2.3	1.8	1.4
1800 US gpm	R		8.0	2.7	0.9	0.5	0.3	0.2	0.1	0.1	0.0
	v		15.1	9.7	6.1	4.8	3.8	3.0	2.4	1.9	1.5
1900 US gpm	R		8.9	3.0	1.0	0.5	0.3	0.2	0.1	0.1	0.0
	v		15.9	10.2	6.4	5.1	4.0	3.1	2.5	2.0	1.6
2000 US gpm	R		9.8	3.3	1.1	0.6	0.3	0.2	0.1	0.1	0.0
	v		16.8	10.7	6.8	5.3	4.2	3.3	2.7	2.1	1.7
2200 US gpm	R			3.9	1.3	0.7	0.4	0.2	0.1	0.1	0.0
	v			11.8	7.4	5.9	4.6	3.6	3.0	2.4	1.9
2400 US gpm	R			4.6	1.5	0.8	0.5	0.3	0.2	0.1	0.1
	v			12.9	8.1	6.4	5.0	4.0	3.2	2.6	2.0
2600 US gpm	R			5.4	1.7	1.0	0.5	0.3	0.2	0.1	0.1
	v			14.0	8.8	6.9	5.4	4.3	3.5	2.8	2.2
2800 US gpm	R			6.2	2.0	1.1	0.6	0.3	0.2	0.1	0.1
	v			15.0	9.5	7.4	5.9	4.6	3.8	3.0	2.4
3000 US gpm	R			7.0	2.3	1.3	0.7	0.4	0.2	0.1	0.1
	v			16.1	10.1	8.0	6.3	5.0	4.0	3.2	2.5
3200 US gpm	R				2.6	1.4	0.8	0.4	0.3	0.2	0.1
	v				10.8	8.5	6.7	5.3	4.3	3.4	2.7
3400 US gpm	R				2.9	1.6	0.9	0.5	0.3	0.2	0.1
	v				11.5	9.0	7.1	5.6	4.6	3.6	2.9
3600 US gpm	R				3.2	1.8	1.0	0.6	0.3	0.2	0.1
	v				12.2	9.6	7.5	6.0	4.8	3.8	3.0
3800 US gpm	R				3.5	2.0	1.1	0.6	0.4	0.2	0.1
	v				12.8	10.1	8.0	6.3	5.1	4.1	3.2
4000 US gpm	R				3.9	2.2	1.2	0.7	0.4	0.2	0.1
	v				13.5	10.6	8.4	6.6	5.4	4.3	3.4
4250 US gpm	R				4.3	2.4	1.3	0.8	0.5	0.3	0.1
	v				14.4	11.3	8.9	7.0	5.7	4.5	3.6
4500 US gpm	R				4.8	2.7	1.5	0.8	0.5	0.3	0.2
	v				15.2	12.0	9.4	7.4	6.0	4.8	3.8
4750 US gpm	R				5.3	3.0	1.7	0.9	0.6	0.3	0.2
	v				16.1	12.6	9.9	7.9	6.4	5.1	4.0
5000 US gpm	R				5.8	3.3	1.8	1.0	0.6	0.4	0.2
	v				16.9	13.3	10.5	8.3	6.7	5.3	4.2
5250 US gpm	R					3.6	2.0	1.1	0.7	0.4	0.2
	v					14.0	11.0	8.7	7.0	5.6	4.4
5500 US gpm	R					3.9	2.2	1.2	0.7	0.4	0.2
	v					14.6	11.5	9.1	7.4	5.9	4.6
5750 US gpm	R					4.2	2.4	1.3	0.8	0.5	0.3
	v					15.3	12.0	9.5	7.7	6.1	4.9

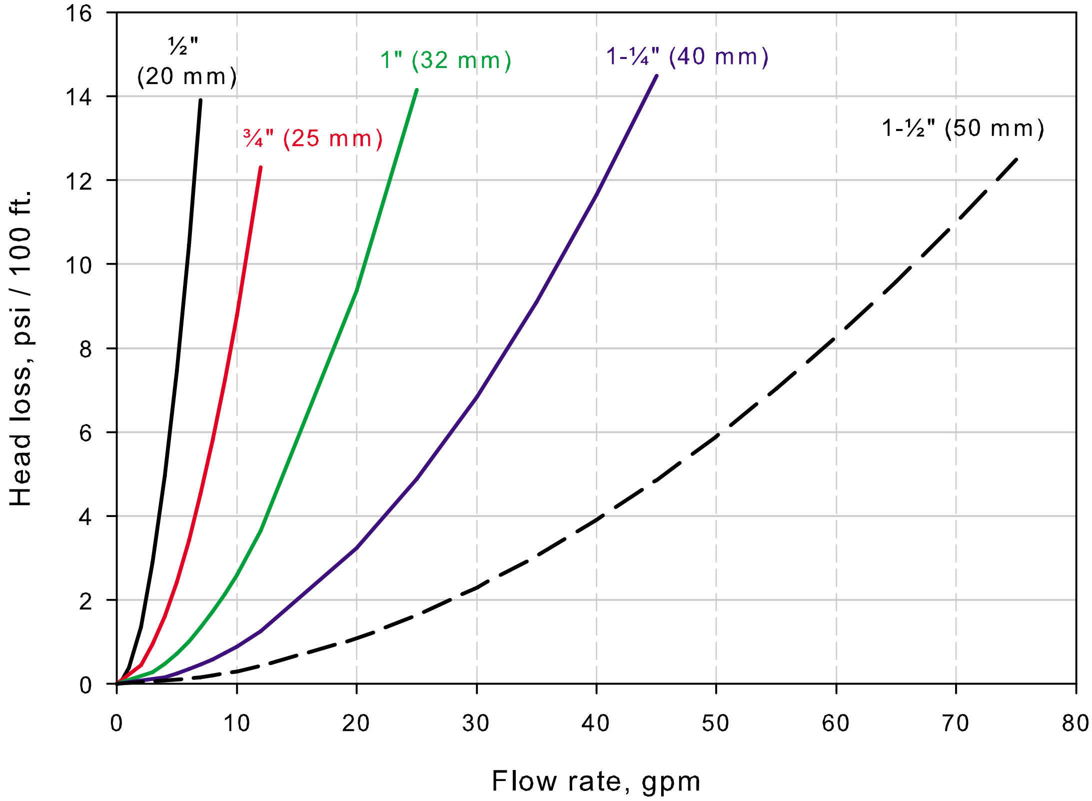
Q = flow rate (US gpm) R = feet of head per 100 ft. v = velocity (ft./sec)

SDR 17.6 pipe

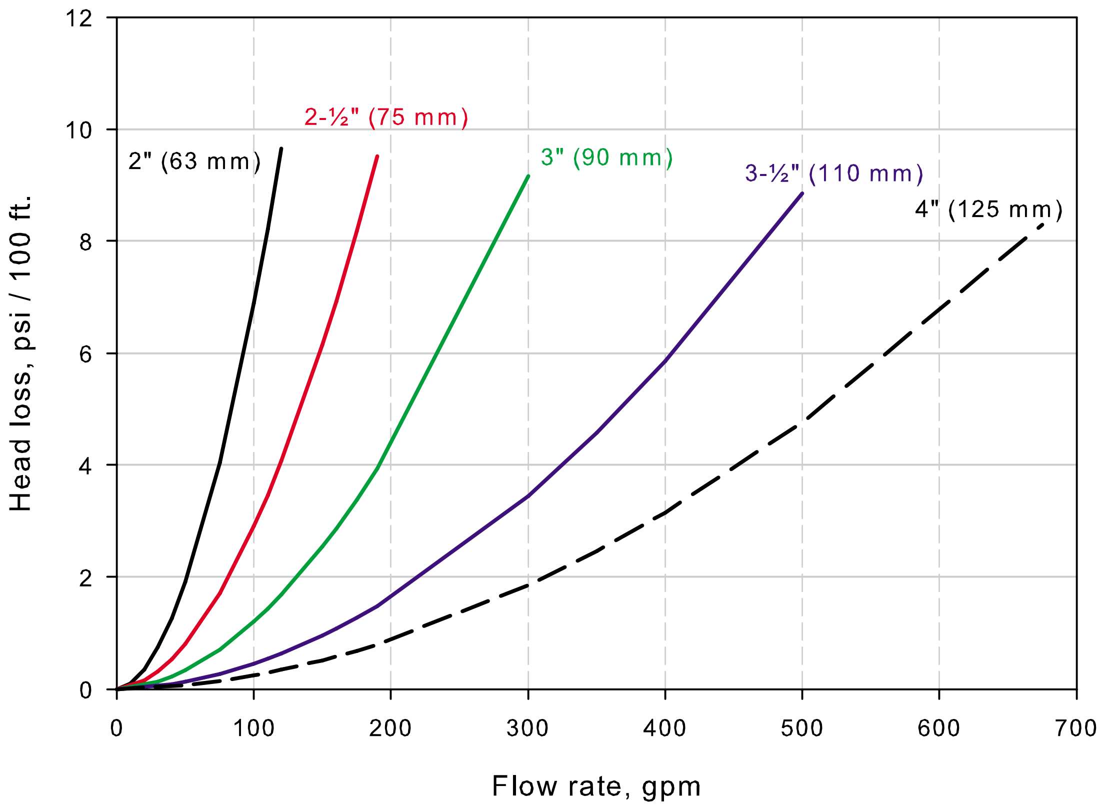
Q	Dimension	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
6000 US gpm	R					4.6	2.5	1.4	0.9	0.5	0.3
	v					16.0	12.6	9.9	8.0	6.4	5.1
6250 US gpm	R					4.9	2.7	1.5	0.9	0.5	0.3
	v					16.6	13.1	10.3	8.4	6.7	5.3
6500 US gpm	R						2.9	1.7	1.0	0.6	0.3
	v						13.6	10.8	8.7	6.9	5.5
6750 US gpm	R						3.2	1.8	1.1	0.6	0.3
	v						14.1	11.2	9.1	7.2	5.7
7000 US gpm	R						3.4	1.9	1.1	0.7	0.4
	v						14.6	11.6	9.4	7.5	5.9
7250 US gpm	R						3.6	2.0	1.2	0.7	0.4
	v						15.2	12.0	9.7	7.7	6.1
7500 US gpm	R						3.8	2.2	1.3	0.7	0.4
	v						15.7	12.4	10.1	8.0	6.3
7750 US gpm	R						4.1	2.3	1.4	0.8	0.4
	v						16.2	12.8	10.4	8.3	6.5
8000 US gpm	R						4.3	2.4	1.5	0.8	0.5
	v						16.7	13.2	10.7	8.5	6.8
8500 US gpm	R							2.7	1.6	0.9	0.5
	v							14.1	11.4	9.1	7.2
9000 US gpm	R							3.0	1.8	1.0	0.6
	v							14.9	12.1	9.6	7.6
9500 US gpm	R							3.3	2.0	1.2	0.7
	v							15.7	12.7	10.2	8.0
10000 US gpm	R							3.7	2.2	1.3	0.7
	v							16.5	13.4	10.7	8.4
10500 US gpm	R								2.4	1.4	0.8
	v								14.1	11.2	8.9
11000 US gpm	R								2.6	1.5	0.9
	v								14.8	11.8	9.3
11500 US gpm	R								2.9	1.6	0.9
	v								15.4	12.3	9.7
12000 US gpm	R								3.1	1.8	1.0
	v								16.1	12.8	10.1
12500 US gpm	R								3.3	1.9	1.1
	v								16.8	13.4	10.6
13000 US gpm	R									2.1	1.2
	v									13.9	11.0
13500 US gpm	R									2.2	1.3
	v									14.4	11.4
14000 US gpm	R									2.4	1.3
	v									15.0	11.8
14500 US gpm	R									2.5	1.4
	v									15.5	12.2
15000 US gpm	R									2.7	1.5
	v									16.0	12.7

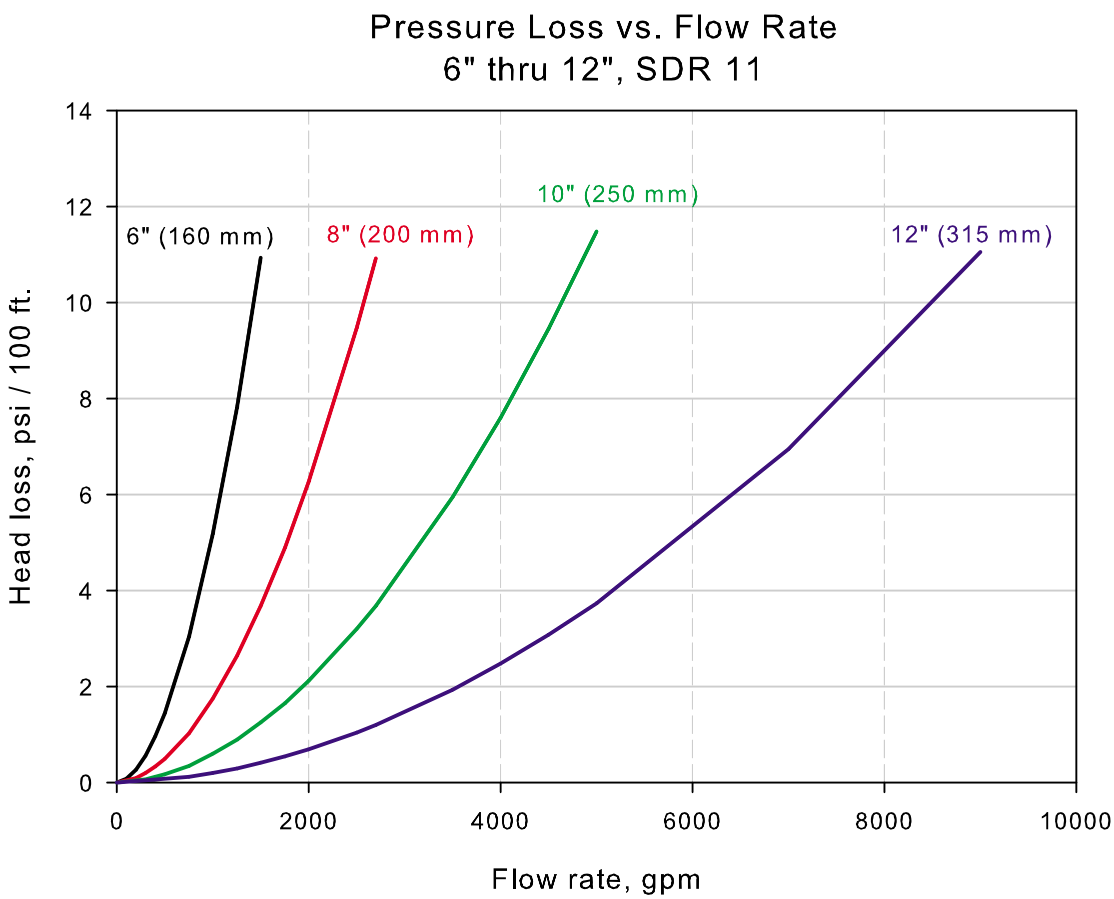
Q = flow rate (US gpm) R = feet of head per 100 ft. v = velocity (ft./ sec}

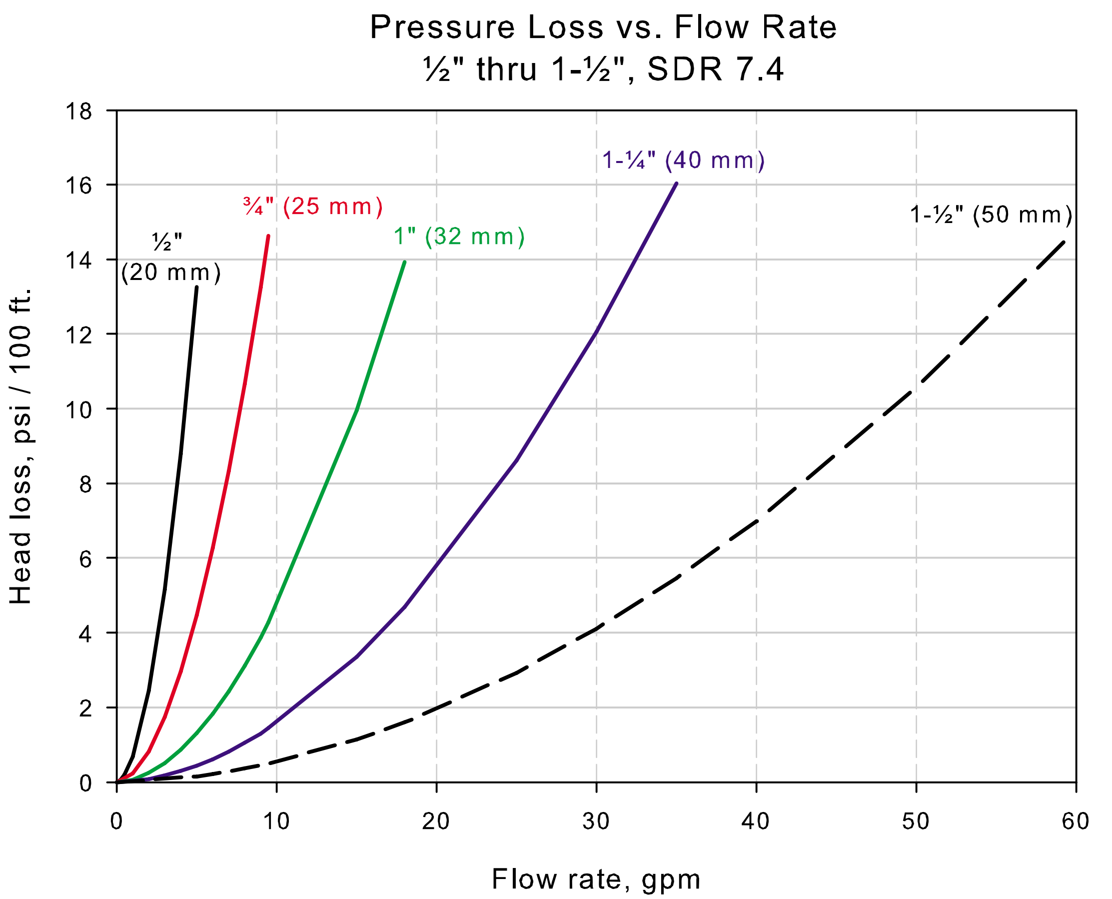
Pressure Loss vs. Flow Rate
1/2" thru 1-1/2", SDR 11

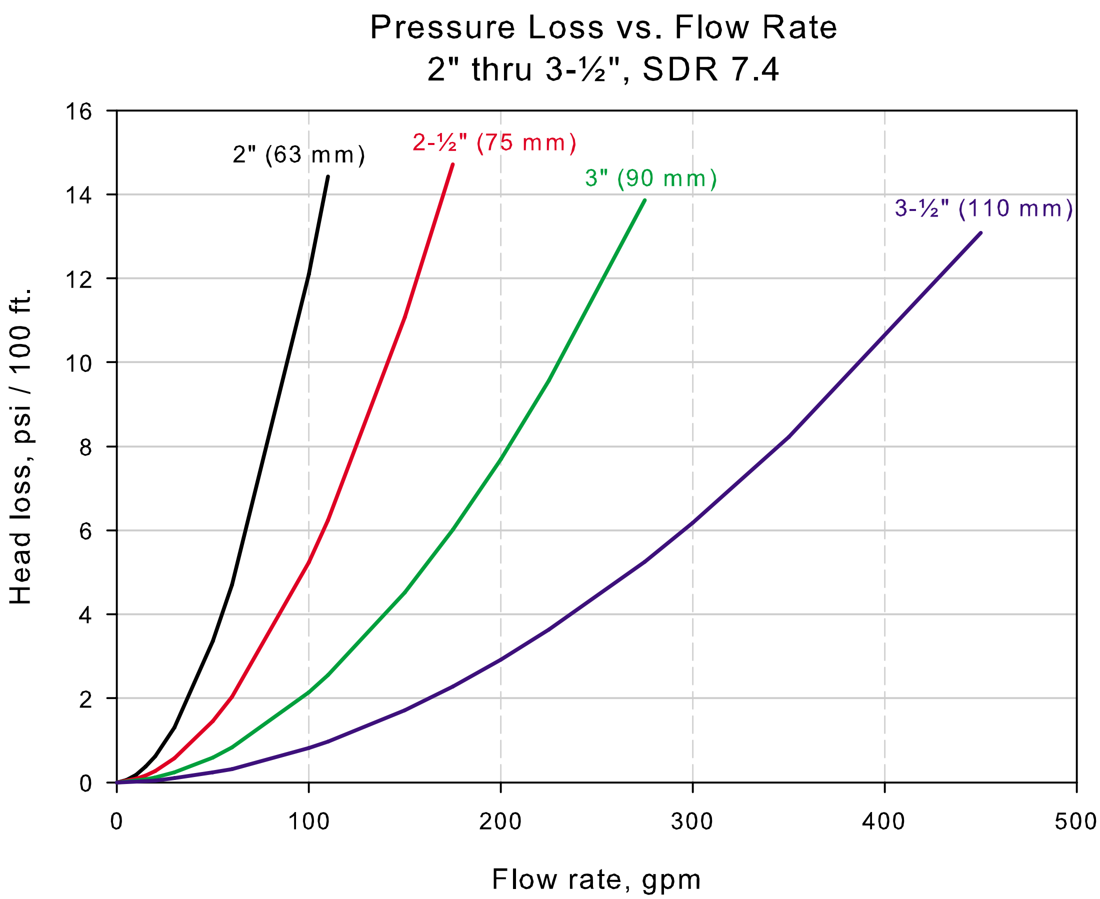


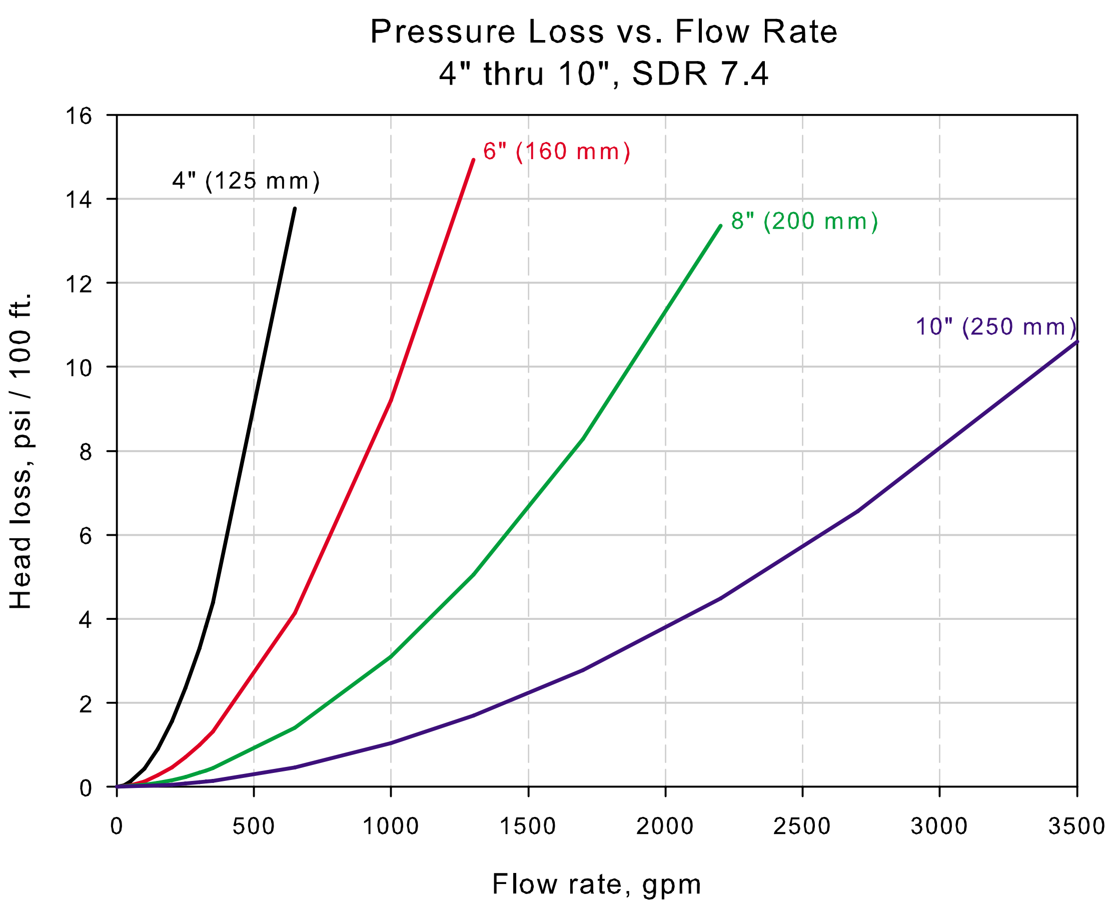
Pressure Loss vs. Flow Rate
2" thru 4", SDR 11

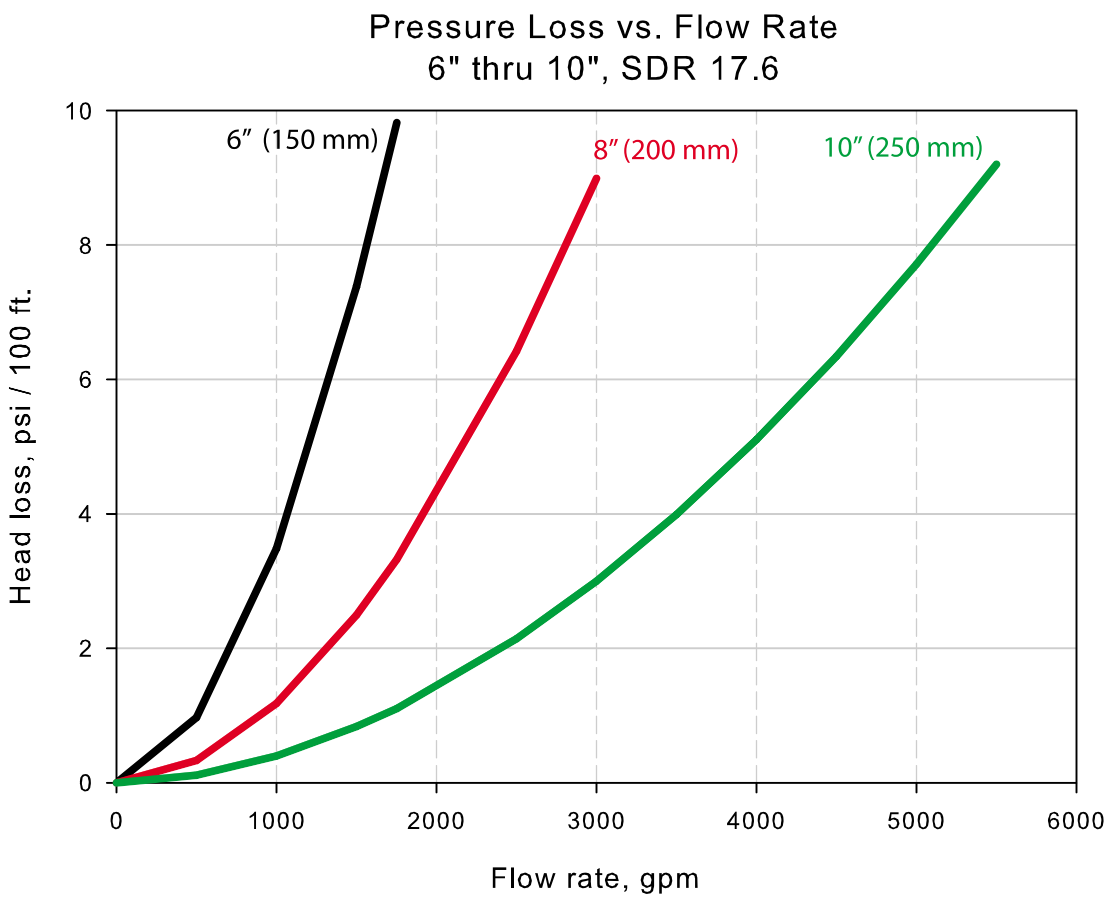


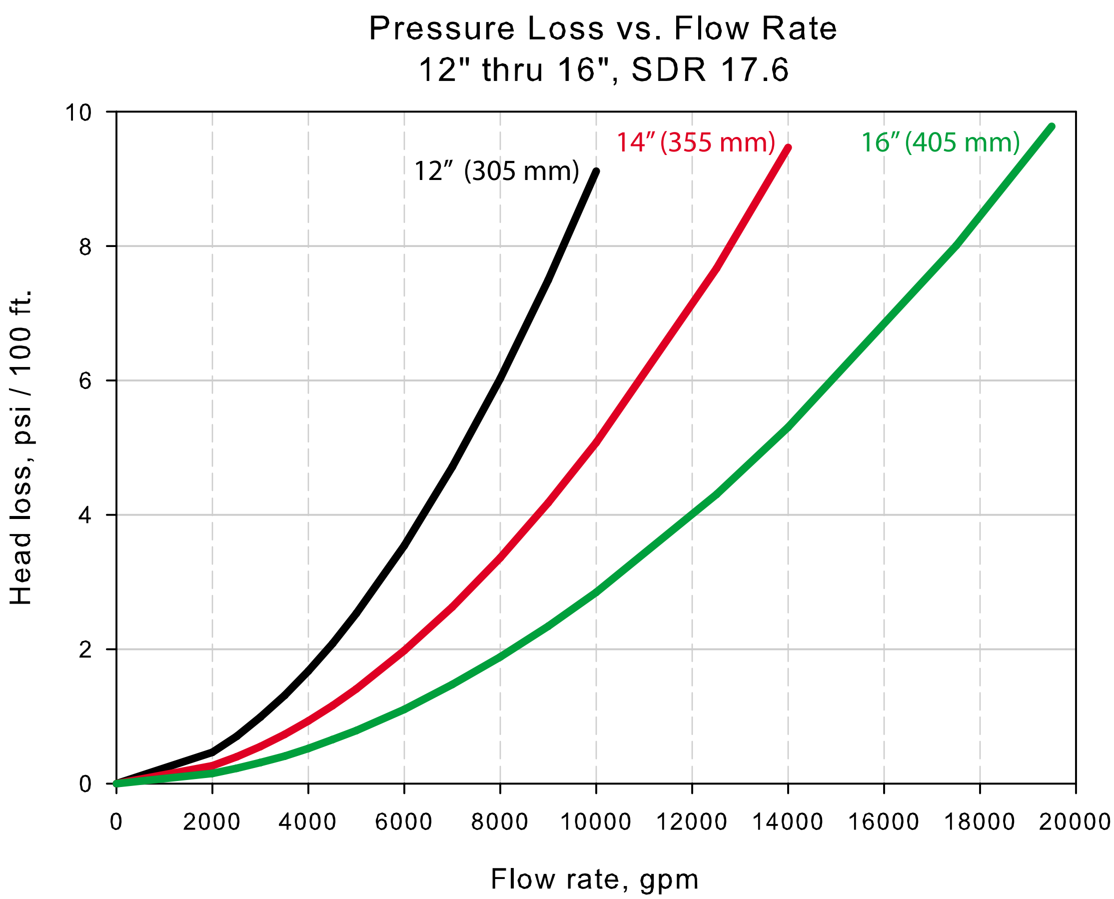

Pressure Loss vs. Flow Rate
6" thru 12", SDR 11
Head loss, psi / 100 ft.
Flow rate, gpm
0
2
4
6
8
10
12
14
0
2000
4000
6000
8000
10000
6" (160 mm)
8" (200 mm)
10" (250 mm)
12" (315 mm)

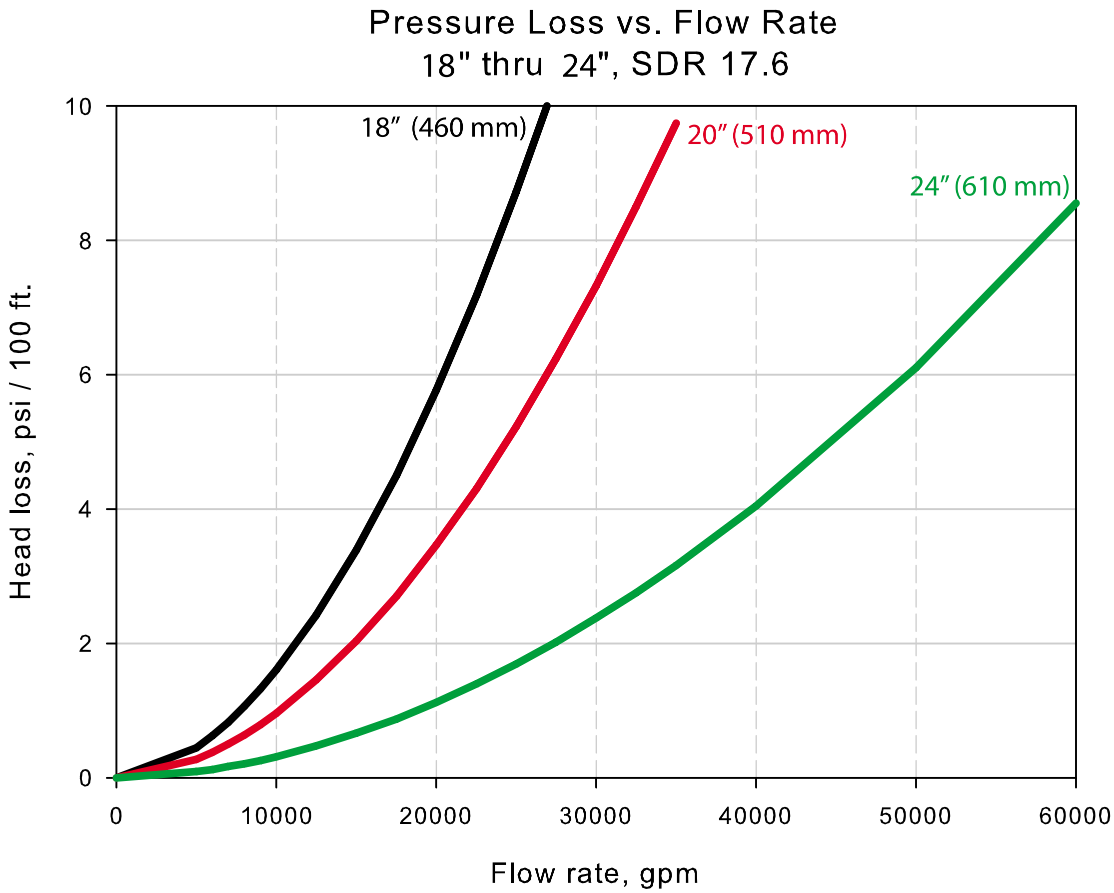

Pressure Loss vs. Flow Rate
½" thru 1-½", SDR 7.4
Head loss, psi / 100 ft.
Flow rate, gpm
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
½"
(20 mm)
¾" (25 mm)
1" (32 mm)
1-¼" (40 mm)
1-½" (50 mm)


Pressure Loss vs. Flow Rate
2" thru 3-½", SDR 7.4
Head loss, psi / 100 ft.
Flow rate, gpm
2" (63 mm)
2-½" (75 mm)
3" (90 mm)
3-½" (110 mm)
0
2
4
6
8
10
12
14
16
0
100
200
300
400
500


Pressure Loss vs. Flow Rate
4" thru 10", SDR 7.4
Head loss, psi / 100 ft.
Flow rate, gpm
4" (125 mm)
6" (160 mm)
8" (200 mm)
10" (250 mm)
0
2
4
6
8
10
12
14
16
0
500
1000
1500
2000
2500
3000
3500

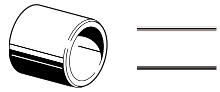

Pressure Loss vs. Flow Rate
6" thru 10", SDR 17.6
6″ (150 mm)
8″ (200 mm)
10″ (250 mm)
Head loss, psi / 100 ft.
Flow rate, gpm
0
2
4
6
8
10
0
1000
2000
3000
4000
5000
6000


Pressure Loss vs. Flow Rate
12" thru 16", SDR 17.6
12″ (305 mm)
14″ (355 mm)
16″ (405 mm)
Head loss, psi / 100 ft.
Flow rate, gpm
0
2
4
6
8
10
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000


Pressure Loss vs. Flow Rate
18" thru 24", SDR 17.6
Head loss, psi / 100 ft.
Flow rate, gpm
0
2
4
6
8
10
0
10000
20000
30000
40000
50000
60000
18″ (460 mm)
20″ (510 mm)
24″ (610 mm)

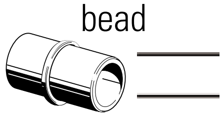
Equivalent lengths of fittings (ft)

Socket



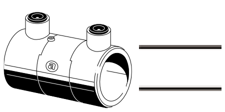
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	0.5	0.7	0.9	1.1	1.4	1.7	2.1	2.5	3.0	4.2

Butt fusion bead



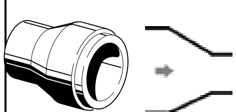
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	1.5	1.9	2.4	3.0	3.4	-	-	-	-	-
SDR 11	1.7	2.1	2.7	3.4	3.8	4.3	4.8	-	-	-
SDR 17.6	1.9	2.3	2.9	3.7	4.1	4.7	5.2	5.8	6.5	7.3

Electrofusion coupling



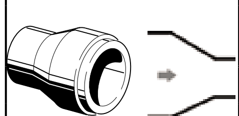
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	0.5	0.5	0.5	-	-	-	-	-	-	-
SDR 11	0.5	0.5	0.5	-	-	-	-	-	-	-
SDR 17.6	0.5	0.5	0.5	-	-	-	-	-	-	-

Bushing
(by 1 dimension)



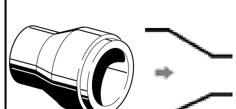
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	0.9	1.1	1.4	1.7	2.2	2.8	3.3	3.9	4.8	6.7
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	7.6	9.5	11.9	15.0	16.9	-	-	-	-	-
SDR 11	8.6	10.7	13.4	16.9	19.1	21.5	24.2	-	-	-
SDR 17.6	9.3	11.6	14.5	18.3	20.7	23.3	26.2	29.1	32.6	36.7

Bushing
(by 2 dimensions)



Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	-	1.4	1.7	2.2	2.7	3.4	4.1	4.9	6.0	8.4
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	9.5	11.9	14.9	18.8	21.1	-	-	-	-	-
SDR 11	10.7	13.4	16.8	21.1	23.8	26.9	30.2	-	-	-
SDR 17.6	11.6	14.5	18.2	22.9	25.8	29.1	32.7	36.4	40.7	45.8

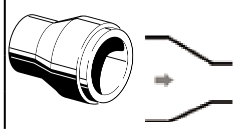
Bushing
(by 3 dimensions)



Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	-	-	2.1	2.6	3.3	4.1	4.9	5.9	7.2	10.1
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	11.4	14.3	17.9	22.5	25.4	-	-	-	-	-
SDR 11	12.9	16.1	20.1	25.4	28.6	32.2	36.2	-	-	-
SDR 17.6	14.0	17.4	21.8	27.5	31.0	34.9	39.3	43.6	48.9	55.0

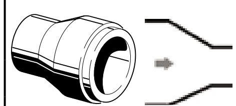
Equivalent lengths of fittings (ft)

Bushing
(by 4 dimensions)



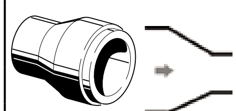
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	-	-	-	3.1	3.8	4.8	5.7	6.9	8.4	11.7
Butt welded	**6″ 160 mm**	**8″ 200 mm**	**10″ 250 mm**	**12″ 315 mm**	**14″ 355 mm**	**16″ 400 mm**	**18″ 450 mm**	**20″ 500 mm**	**22″ 560 mm**	**24″ 630 mm**
SDR 7.4	13.3	16.7	20.8	26.3	29.6	-	-	-	-	-
SDR 11	15.0	18.8	23.5	29.6	33.4	37.6	42.3	-	-	-
SDR 17.6	16.3	20.3	25.4	32.1	36.1	40.7	45.8	50.9	57.0	64.1

Bushing
(by 5 dimensions)



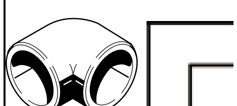
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	-	-	-	-	4.4	5.5	6.6	7.9	9.6	13.4
Butt welded	**6″ 160 mm**	**8″ 200 mm**	**10″ 250 mm**	**12″ 315 mm**	**14″ 355 mm**	**16″ 400 mm**	**18″ 450 mm**	**20″ 500 mm**	**22″ 560 mm**	**24″ 630 mm**
SDR 7.4	15.2	19.1	23.8	30.0	33.8	-	-	-	-	-
SDR 11	17.2	21.5	26.8	33.8	38.1	43.0	48.3	-	-	-
SDR 17.6	18.6	23.3	29.1	36.6	41.3	46.5	52.4	58.2	65.2	73.3

Bushing
(by 6 dimensions)



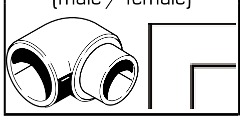
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	-	-	-	-	-	6.2	7.4	8.9	10.8	15.1
Butt welded	**6″ 160 mm**	**8″ 200 mm**	**10″ 250 mm**	**12″ 315 mm**	**14″ 355 mm**	**16″ 400 mm**	**18″ 450 mm**	**20″ 500 mm**	**22″ 560 mm**	**24″ 630 mm**
SDR 7.4	17.2	21.4	26.8	33.8	38.1	-	-	-	-	-
SDR 11	19.3	24.2	30.2	38.1	42.9	48.4	54.4	-	-	-
SDR 17.6	20.9	26.2	32.7	41.2	46.5	52.4	58.9	65.4	73.3	82.5

Elbow 90°



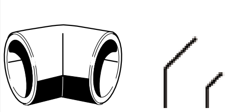
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	1.6	2.0	2.6	3.3	4.1	5.2	6.2	7.4	9.0	12.6
Butt welded	**6″ 160 mm**	**8″ 200 mm**	**10″ 250 mm**	**12″ 315 mm**	**14″ 355 mm**	**16″ 400 mm**	**18″ 450 mm**	**20″ 500 mm**	**22″ 560 mm**	**24″ 630 mm**
SDR 7.4	14.3	17.9	22.3	18.0	20.3	-	-	-	-	-
SDR 11	10.3	12.9	16.1	20.3	22.9	25.8	29.0	-	-	-
SDR 17.6	11.2	14.0	17.4	22.0	24.8	27.9	31.4	34.9	39.1	44.0

Elbow 90°
(male / female)



Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	1.6	2.0	2.6	3.3	-	-	-	-	-	-

Elbow 45°

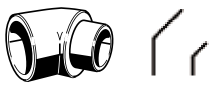


Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	0.9	1.1	1.4	1.7	2.2	2.8	3.3	3.9	4.8	6.7
Butt welded	**6″ 160 mm**	**8″ 200 mm**	**10″ 250 mm**	**12″ 315 mm**	**14″ 355 mm**	**16″ 400 mm**	**18″ 450 mm**	**20″ 500 mm**	**22″ 560 mm**	**24″ 630 mm**
SDR 7.4	7.6	9.5	11.9	11.3	12.7	-	-	-	-	-
SDR 11	6.4	8.1	10.1	12.7	14.3	16.1	18.1	-	-	-
SDR 17.6	7.0	8.7	10.9	13.7	15.5	17.5	19.6	21.8	24.4	27.5

(➡ = flow direction)

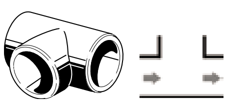
Equivalent lengths of fittings (ft)

Elbow 45°
(male / female)



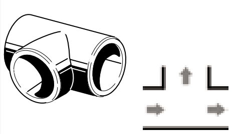
	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
Socket fusion	0.9	1.1	1.4	1.7	-	-	-	-	-	-

Tee
(thru-flow)



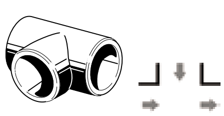
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	0.5	0.7	0.9	1.1	1.4	1.7	2.1	2.5	3.0	4.2
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	4.8	6.0	7.4	9.4	10.6	-	-	-	-	-
SDR 11	5.4	6.7	8.4	10.6	11.9	13.4	15.1	-	-	-
SDR 17.6	5.8	7.3	9.1	11.5	12.9	14.5	16.4	18.2	20.4	22.9

Tee
(separation of flow)



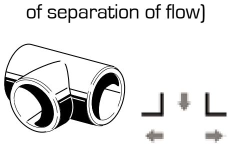
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	2.6	3.3	4.2	5.2	6.6	8.3	9.8	11.8	14.4	20.1
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	22.9	28.6	35.7	45.0	50.7	-	-	-	-	-
SDR 11	25.8	32.2	40.3	50.7	57.2	64.5	72.5	-	-	-
SDR 17.6	27.9	34.9	43.6	55.0	62.0	69.8	78.5	87.2	97.8	110.0

Tee
(conjunction of flow)



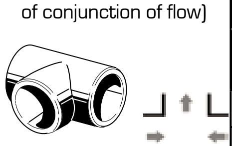
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	1.7	2.2	2.8	3.5	4.4	5.5	6.6	7.9	9.6	13.4
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	15.2	19.1	23.8	30.0	33.8	-	-	-	-	-
SDR 11	17.2	21.5	26.8	33.8	38.1	43.0	48.3	-	-	-
SDR 17.6	18.6	23.3	29.1	36.6	41.3	46.5	52.4	58.2	65.2	73.3

Tee
(counter current in case of separation of flow)



Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	3.9	4.9	6.3	7.9	9.9	12.4	14.8	17.7	21.7	30.2
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	34.3	42.9	53.6	67.5	76.1	-	-	-	-	-
SDR 11	38.7	48.3	60.4	76.1	85.8	96.7	108.7	-	-	-
SDR 17.6	41.9	52.3	65.4	82.4	93.0	104.7	117.8	130.9	146.6	164.9

Tee
(counter current in case of conjunction of flow)

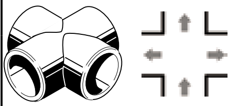


Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	5.2	6.5	8.2	10.4	13.1	16.4	24.6	29.5	36.1	50.3
Butt welded	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
SDR 7.4	57.2	71.5	89.3	112.5	126.8	-	-	-	-	-
SDR 11	64.4	80.5	100.7	126.9	143.0	161.2	181.2	-	-	-
SDR 17.6	69.8	87.2	109.1	137.4	154.9	174.5	196.4	218.1	244.4	274.9

(➡ = flow direction)

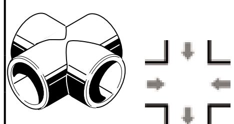
Equivalent lengths of fittings (ft)

Cross (separation of flow)



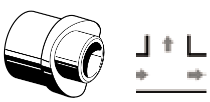
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	4.5	5.7	7.3	9.2	-	-	-	-	-	-
Butt welded	**6″ 160 mm**	**8″ 200 mm**	**10″ 250 mm**	**12″ 315 mm**	**14″ 355 mm**	**16″ 400 mm**	**18″ 450 mm**	**20″ 500 mm**	**22″ 560 mm**	**24″ 630 mm**
SDR 7.4	40.0	50.0	62.5	78.8	88.8	-	-	-	-	-
SDR 11	45.1	56.4	70.5	88.8	100.1	112.9	126.8	-	-	-
SDR 17.6	48.8	61.0	76.3	96.2	108.4	122.2	137.5	152.7	171.1	192.4

Cross (conjunction of flow)



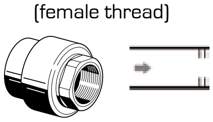
Socket fusion	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
	8.0	10.1	12.9	16.1	-	-	-	-	-	-
Butt welded	**6″ 160 mm**	**8″ 200 mm**	**10″ 250 mm**	**12″ 315 mm**	**14″ 355 mm**	**16″ 400 mm**	**18″ 450 mm**	**20″ 500 mm**	**22″ 560 mm**	**24″ 630 mm**
SDR 7.4	70.5	88.1	110.2	138.8	156.4	-	-	-	-	-
SDR 11	79.5	99.3	124.1	156.5	176.4	198.8	223.5	-	-	-
SDR 17.6	86.1	107.6	134.5	169.5	191.1	215.2	242.2	269.0	301.4	339.0

Fusion outlet (separation of flow)[a]



	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm
Side-wall fusion (based on branch size)	0.6	0.8	1.0	1.3	1.7	2.1	2.5	3.0	3.6	5.0	5.8	6.5

Transition (female thread)

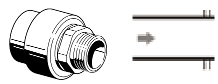


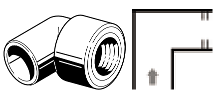
	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm
Socket fusion	1.1	1.4	1.7	2.2	2.7	3.4	4.1	-	-	-

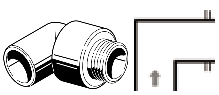
(➡ = flow direction)

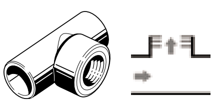
[a] Note: For reducing tees, add the "thru-flow" value in the main line to the configuration value in the branch size. For example, a 4" x 4" x ¾" reducing tee with flow separation would be 4.2 ft + 3.3 ft = 7.5 ft, while a conjunction of flow would be 4.2 ft + 2.2 ft = 6.4 ft.

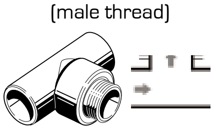
Equivalent lengths of fittings (ft)

Transition (male thread)		½" 20 mm	¾" 25 mm	1" 32 mm	1 ¼" 40 mm	1 ½" 50 mm	2" 63 mm	2 ½" 75 mm	3" 90 mm	3 ½" 110 mm	4" 125 mm
	Socket fusion	1.5	1.9	2.4	3.1	3.8	4.8	5.7	6.9	8.4	-

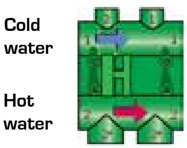
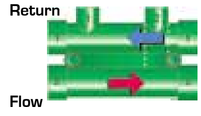
Elbow (female thread)		½" 20 mm	¾" 25 mm	1" 32 mm	1 ¼" 40 mm	1 ½" 50 mm	2" 63 mm	2 ½" 75 mm	3" 90 mm	3 ½" 110 mm	4" 125 mm
	Socket fusion	1.9	2.4	3.0	-	-	-	-	-	-	-

Elbow (male thread)		½" 20 mm	¾" 25 mm	1" 32 mm	1 ¼" 40 mm	1 ½" 50 mm	2" 63 mm	2 ½" 75 mm	3" 90 mm	3 ½" 110 mm	4" 125 mm
	Socket fusion	2.2	2.7	3.5	-	-	-	-	-	-	-

Tee (female thread)		½" 20 mm	¾" 25 mm	1" 32 mm	1 ¼" 40 mm	1 ½" 50 mm	2" 63 mm	2 ½" 75 mm	3" 90 mm	3 ½" 110 mm	4" 125 mm
	Socket fusion	3.5	4.4	5.6	-	-	-	-	-	-	-

Tee (male thread)		½" 20 mm	¾" 25 mm	1" 32 mm	1 ¼" 40 mm	1 ½" 50 mm	2" 63 mm	2 ½" 75 mm	3" 90 mm	3 ½" 110 mm	4" 125 mm
	Socket fusion	3.9	-	-	-	-	-	-	-	-	-

Equivalent lengths of distribution blocks

<table>
<tr><th>Picture</th><th>Comment</th><th>Picture</th><th>Comment</th><th>Equivalent length (ft)</th></tr>
<tr><td rowspan="2">Potable water installation

</td><td>Reduced ¾" (25 mm) passage for separation of flow</td><td rowspan="2">Heating installation

</td><td>Reduced ½" (20 mm) passage for separation of flow</td><td>2.0</td></tr>
<tr><td>¾" (25 mm) passage for separation of flow</td><td>½" (20 mm) passage for separation of flow</td><td>0.5</td></tr>
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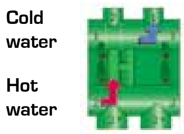
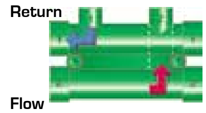
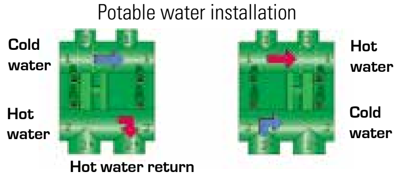

</td><td>½" (20 mm) passage for separation of flow</td><td rowspan="3">Heating installation

</td><td>⅜" (16 mm) branch for separation of flow</td><td>1.6</td></tr>
<tr><td>½" (20 mm) branch for conjunction of flow</td><td>⅜" (16 mm) branch in case of conjunction of flow</td><td>3.2</td></tr>
<tr><td>Reduced ½" (20 mm) passage for separation of flow</td><td>⅜" (16 mm) branch for separation of flow</td><td>4.4</td></tr>
<tr><td colspan="3" rowspan="2">Potable water installation

</td><td>¾" (25 mm) branch for separation of flow</td><td>2.4</td></tr>
<tr><td>⅜" (16 mm) branch for conjunction of flow</td><td>1.6</td></tr>
</table>

Maximum pull force

A major advantage of using PP-R is that the pipes have a very high tensile strength. And because Aquatherm uses heat-fused connections, that tensile strength is consistent through the connections. The result is a system that can be assembled in large sections and moved without the risk of damaging the pipe or the connections.

The following tables give the maximum pull force that can be exerted on the pipe before stretching it (and thus weakening it). Vertically, the pull force is based on the weight of the attached pipe and fittings. Horizontally, the friction of the ground must also be considered. Wetting the ground before dragging the pipe can help reduce the friction.

Their physical strength makes Aquatherm pipes exceptionally well suited for directional boring. However, it is important to use pull heads that are compatible with metric pipe. When selecting a pull head, use the metric size of the pipe, not the nominal imperial size.

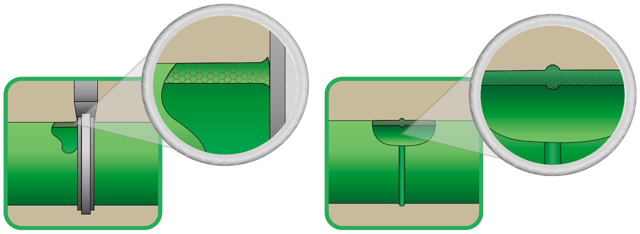
Pipe diameter	Max pull force (lb)		
	SDR 7.4	SDR 11	SDR 17.6
6" — 160 mm	16,055	11,353	7,362
8" — 200 mm	25,087	17,739	11,503
10" — 250 mm	39,198	27,718	17,973
12" — 315 mm	62,230	44,005	28,534
14" — 355 mm	79,038	55,890	36,241
16" — 400 mm	100,346	70,958	46,012
18" — 450 mm	127,001	89,806	58,233
20" — 500 mm	156,791	110,871	71,893
22" — 560 mm	196,678	139,077	90,183
24" — 630 mm	248,921	176,019	114,137

CHAPTER 4
INSTALLATION PRINCIPLES

Heat fusion connections

All Aquatherm piping products are made from the same reliable PP-R material and are engineered to be heat fused together. Since pipes and fittings come in sizes ranging from ½" to 24" in diameter, the fusion process, equipment required, and installation time will vary, but the principles of heat fusion remain the same.

For a proper heat fusion connection, the two surfaces being fused are heated to a melting temperature, pressed together, and allowed to cool under pressure. This process allows the PP-R chains to reform as one, joining the pieces together without the need for glues, solders, gaskets, or other foreign materials.
By eliminating the foreign materials in the connection, heat fusion removes the most likely source of leaks and failures. The fused portion of the pipe also retains its flexibility and resistance to impact, making the connection easier and safer to prefabricate and transport. In short, a properly fused joint behaves as if it were manufactured that way.



There are several methods of fusion used in joining Aquatherm pipes. Each of these methods, if properly executed, will provide a connection that is stronger than the pipe itself. A final pressure test will help verify the integrity of the connections, and drastically reduce the risk of failure due to improper installation. Aquatherm's heat fusion training courses are designed to help installers know when to employ each of these different methods and to become skilled in using them.

Training and installation

Aquatherm offers detailed training courses to prepare installers for using Aquatherm PP-R products and approved tools. These courses are intended to help supplement the skills of licensed plumbers and pipe fitters. They are designed to minimize the learning curve associated with installing a new piping system, and prevent potentially costly on-the-job mistakes.

The available courses are as follows:

- Aquatherm Installer Course: a comprehensive course that covers the PP-R material, the heat fusion process, and how to fuse pipe from ½" to 4" OD. The course focuses heavily on socket fusion with hand irons, including fusion outlets, and includes some practice with an assisted fusion machine. This course is required before taking the other courses.

- Aquatherm Butt Welding Course: this course focuses on fusing pipe sizes 6" OD and larger. It gives a generic explanation of butt fusion, which can be applied to a variety of machine styles. Specific training from the manufacturer for the machines being used is still recommended.

- Aquatherm Electrofusion Course: a course designed for an alternative socket fusion method using electrical resistance heat rather than contact heat. A common alternative for risers, repairs, and other tough-to-reach applications.

These courses are taught by authorized Aquatherm trainers. Installers are required to take the appropriate course for the type of fusions they will be performing. Training is available through local wholesalers and manufacturer's representatives. All coursework should be completed before beginning installation. Failure to follow proper installation procedures will void the warranty.

The information provided in this product catalog regarding proper fusion and installation procedures has been summarized and is for general reference only. It is not intended for use as the installation instructions. Full installation instructions can be found in the Aquatherm Installer Manual. The information in the Installer Manual is supplemented by Technical Bulletins, which can be found at **www.aquatherm.com/bulletin and are distributed with the Aquatherm newsletter.**

The Aquatherm Installer Manual is distributed with training, and is available upon request. Visit www.aquatherm.com/technical-documents for the most up-to-date version.

Socket fusion

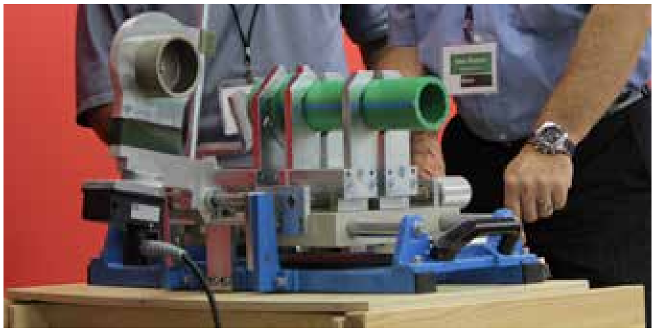
Socket fusion is used for pipe and fittings from ½" to 4" in diameter. To perform a proper fusion, the pipe is cut, marked for insertion depth, and heated along with the socket fitting for a specified time. The pipe and fitting are then pushed together and allowed to cool. The pressure for these connections comes from the OD of the pipe being slightly larger than the ID of the fitting. Marking the pipe to the proper welding depth helps bring the connection to its maximum strength without flow restriction.

Butt fusion

Butt fusion (or butt welding) is used for pipe and fittings from 6" to 24" in diameter. The process consists of planing the ends of the pipe smooth, pressing them against a heating plate, and then pressing them together to cool. This allows larger sizes of pipe to be assembled without the need for additional couplings. Butt fusion fittings are either made from the pipe itself, or to the same OD as the pipe, so they can be fused directly to the face of the pipe.

Mechanically assisted fusions

For socket fusions in sizes larger than 2", it can be difficult for one installer to make a proper connection by hand. Fusion machines can act as a second pair of hands to hold the pipe, speed up the connection process, and even assist with alignment and insertion depth.



Fusion machines come in a variety of designs. Bench-style machines (shown above) offer greater support and alignment control. Jig-style machines (show below) are lighter and offer more workspace flexibility. Some installers use a variety of machines, depending on the application.

Outlet fusion

As an easy and reliable alternative to reducing tees, Aquatherm offers fusion outlets that can be installed directly onto the outside of the pipe. This allows for increased design flexibility and simplified installation. Fusion outlets are socket fused using welding heads and heating irons.

Electrofusion

This alternative to socket fusion is commonly used when space is very limited, or the pipe cannot be moved laterally in order to perform a fusion. Heat is generated by a current run through electrical coils inside the fittings.

A new way of thinking

Aquatherm piping systems offer many innovative technologies and advantages that can greatly improve the speed and ease of installation. These advantages include:

- Fusion connections
- Fusion outlets
- Lightweight material
- Resilient, slightly flexible pipe and connections
- Reduced expansion and contraction

To fully utilize these advantages, a different mind-set from metal or even other plastic systems is required.

A craftsman's pipe

As a company, Aquatherm takes pride in the systems they manufacture and expects the same from those installing it. No matter the quality of the material, the performance of a system will always depend on how carefully and professionally it is installed. Aquatherm piping systems are designed to look neat and clean when installed, making it easier to expand the system or trace lines. Square fittings and rigid pipe provide a traditional layout, such as an installer would use with copper or steel.

Planning

As with any piping system, the speed and accuracy of an Aquatherm installation is improved with careful planning. Planning will allow for a greater amount of prefabrication and a lower probability of error.

All fusion connections require a certain amount of space and mobility around each joint. When installing an Aquatherm piping system, it is important to be conscious of the workspace in which each fusion will be performed. The amount of space needed for a fusion machine to operate varies by manufacturer and machine type. It is best to confirm that there will be enough space for the machine to operate while planning the installation.

Prefabrication

Aquatherm piping systems are light, strong, and somewhat flexible, making them ideal for prefabrication. When installing Aquatherm pipe, identify the more complicated assemblies such as drop 90s, flange adapters, branch lines, and headers, and assemble them in-shop or at a prefabrication station on the job site. Many installers will assemble whole mechanical rooms in-shop and move the entire assembly to the job site. If a pipe will pass through an area that is difficult to access, Aquatherm recommends prefabricating all the connections in that area. This can be done offsite or onsite, depending on installer preference.

On-site prefabrication

Polypropylene is lighter than most other piping materials, and fusion joints adjust easily to reasonable levels of stress from being carried. To take advantage of this, many installers set up a prefab station on the job site, including a workbench, technical drawings, a welding jig or bench machine and the appropriate welding tools. This station is used to measure, cut, and prefabricate pipe and fittings for the installation. Use of this station ensures adequate space for tool operation.

Pre-assembly

Connections done in a shop or at the prefab station on the job site are easier and faster to assemble than connections done on pipe that is already in place. It is possible to greatly speed up installation by attaching the appropriate fittings to one end of the pipe before hanging it. Identify the fittings (couplings, elbows, tees, valves, etc) that will go with each length of pipe and fuse them together before hanging the pipe in its proper place. This will allow you to assemble as many as half your connections without any of the complications associated with in-line or overhead fusions.

Technical bulletins

Due to the wide variety of applications that Aquatherm pipe is used in, and the ongoing development of third-party tools, clamps, insulations, and other solutions, the recommendations for installing Aquatherm products are regularly improved and updated. Aquatherm releases regular technical bulletins to fill in the gaps between editions of the catalog and installer manual.

Aquatherm recommends reading both past and new technical bulletins, in addition to this catalog. Notifications regarding new technical bulletins are sent out monthly with the Aquatherm Newsletter. Technical bulletins are sent to Aquatherm's installers and trainers at least quarterly.

Supporting the pipe

There are two types of Aquatherm pipes: faser-composite pipes and non-faser pipes. Faser-composite pipes are designed for hot water installations and non-faser pipes are intended only for use in cold water installations. The faser-composite layer reduces expansion in the pipe and provides linear support. As a result, the support spacing for faser-composite pipe is wider than other plastics in most cases and is dependent on the temperature of the fluid it is carrying. The hanger spacing for cold water pipes is generally uniform.

The installer should base hanger spacing on the intended temperature of the pipes, taking into account the temperature of the pipes at the time of installation.

Hangers and clamps

When installing Aquatherm pipes, use only rubber-lined or felt-lined clamps. You may use tape to pad the space between the PP-R and the metal on non-clamping hangers, such as clevis hangers.

Metal clamps (even plastic-safe clamps) can damage hot water pipes, and can condensate when used on cold water pipe. When installing chilled water lines in high-humidity areas, use a non-crushable pipe shield. Metal that is in direct contact with the Aquatherm pipe may sweat in certain chilled applications, even if the pipe itself shows no signs of condensation.

When securing the pipe in place, it is important to distinguish between fixed points and sliding points. Fixed points are clamped tightly against the pipe and prevent any expansion or movement through that point. Sliding points are clamped loosely or simply hung and do not restrict expansion or movement. The proper application of each is explained in the next two sections.

Fixed (anchor) points

Fixed points are used to divide the pipe into sections, restricting any uncontrolled movement of the pipe. Fixed points must be measured and installed to accommodate the forces of expansion in the pipe as well as probable additional loads.

When using threaded rods or threaded screws, the drop from the ceiling should be as short as possible. Swinging clamps should not be used as fixed points.

Vertical distributions can be installed using only fixed points. Faser-composite risers do not require expansion loops, provided that fixed points are located immediately before or after a branch. Pipe clamp distances of vertically installed pipes can be increased by 20% of the tabular values on the following page, (i.e., multiply the tabular value by 1.2).

Sliding (guide) points

Sliding points must allow axial pipe movement without damaging the pipe. When positioning a sliding point, make sure that movement of the pipe is not blocked by walls, fittings, or mechanical equipment installed next to the clamp or hanger.

Clamp and hanger sizing

Use the following table to find the approximate imperial OD for supporting bare pipe. Larger clamps will be needed to go over insulation and/or pipe shields.

Pipe size	Clamp size
½″ (20 mm)	¾″
¾″ (25 mm)	1″
1″ (32 mm)	1 ¼″
1 ¼″ (40 mm)	1 ½″
1 ½″ (50 mm)	2″
2″ (63 mm)	2 ½″
2 ½″ (75 mm)	3″
3″ (90 mm)	3 ½″
3 ½″ (110 mm)	4 ½″
4″ (125 mm)	5″

Pipe size	Clamp size
6″ (160 mm)	6 ½″
8″ (200 mm)	8″
10″ (250 mm)	10″
12″ (315 mm)	12 ½″
14″ (355 mm)	14″
16″ (400 mm)	15 ¾″
18″ (450 mm)	17 ¾″
20″ (500 mm)	19 ¾″
22″ (560 mm)	22″
24″ (630 mm)	24 ¾″

Increasing hanger spacing

Installers can increase the hanger spacing by running hot water through the pipes before fixing them in place. This reduces the temperature difference between installation and operation. Installers may also use in-line supports to increase the acceptable distance between hangers.

Support intervals

aquatherm green pipe® faser-composite pipe SDR 7.4 & aquatherm blue pipe® SDR 7.4 & 11 faser-composite pipe

These tables provide the support intervals based on pipe size and the difference between the operating fluid temperature and the ambient temperature.

ΔT Difference in temp.	Pipe diameter																
	½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm
	Support intervals (ft)																
0 °F (0 °C)	4	4.6	5.2	5.9	6.7	7.5	8	8.5	9.5	10.5	11.2	11.3	11.5	12.5	13.5	15	16
36 °F (20 °C)	4	4	4	4.4	5.1	5.7	6.1	6.4	7.1	7.9	8.9	9	9.2	10.1	11	14	15
54 °F (30 °C)	4	4	4	4.4	5.1	5.7	6.1	6.4	6.9	7.4	8	8.2	8.4	9.2	10	12	13
72 °F (40 °C)	4	4	4	4.1	4.8	5.4	5.7	6.1	6.6	7.1	7.7	7.9	8	8.7	9.5	11	12
90 °F (50 °C)	4	4	4	4.1	4.8	5.4	5.7	6.1	6.2	6.4	6.7	6.9	7.1	7.8	8.5	10	11
108 °F (60 °C)	4	4	4	4	4.4	5.1	5.4	5.7	5.9	6.1	6.4	6.6	6.7	7.1	7.5	9	10
126 °F (70 °C)	4	4	4	4	4.3	4.8	5.1	5.4	5.6	5.7	6.1	6.2	6.4	6.7	7	8	8

Support intervals

aquatherm green pipe SDR 11 & aquatherm lilac pipe® SDR 11

Pipe diameter																
½″ 20 mm	¾″ 25 mm	1″ 32 mm	1 ¼″ 40 mm	1 ½″ 50 mm	2″ 63 mm	2 ½″ 75 mm	3″ 90 mm	3 ½″ 110 mm	4″ 125 mm	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm
Support intervals (ft)																
4	4	4	4	4	4.6	4.9	5.2	5.9	6.6	7.2	7.5	7.9	8.4	9.5	10.5	11.2

Support intervals

aquatherm blue pipe SDR 17.6 faser-composite pipe

ΔT Difference in temp.	Pipe diameter									
	6″ 160 mm	8″ 200 mm	10″ 250 mm	12″ 315 mm	14″ 355 mm	16″ 400 mm	18″ 450 mm	20″ 500 mm	22″ 560 mm	24″ 630 mm
	Support intervals (ft)									
0 °F (0 °C)	8.5	8.7	9.0	9.2	9.4	9.7	10.0	10.3	10.7	10.8
36 °F (20 °C)	6.2	6.6	6.7	6.9	7.1	7.5	7.9	8.4	8.9	9.2
54 °F (30 °C)	5.9	6.2	6.4	6.6	6.7	7.2	7.5	8.0	8.5	9.0
72 °F (40 °C)	5.7	5.9	6.2	6.2	6.4	6.9	7.4	7.7	8.2	8.7
90 °F (50 °C)	5.4	5.7	5.9	6.1	6.1	6.6	7.1	7.5	7.9	8.4
108 °F (60 °C)	5.1	5.4	5.6	5.7	5.7	6.1	6.6	7.1	7.5	7.9
126 °F (70 °C)	4.8	5.1	5.2	5.6	5.7	5.7	6.2	6.7	7.2	7.5

Linear expansion

The linear expansion of pipe depends on the difference between the installation temperature and the operating temperature:

$\Delta T = T_{\text{operating temperature}} - T_{\text{installation temperature}}$

Therefore, cold water pipes have practically no linear expansion. They can experience some contraction, but this is not a concern. The heat-fused connections cannot be pulled apart.

Hot water installations can expand visibly and may require expansion loops or sliding elbows to prevent bowing or curving. Aquatherm has significantly reduced the issues related to heat expansion with the introduction of patented faser-composite pipes.

aquatherm faser-composite pipes

The faser-composite layer is a unique feature of Aquatherm piping systems. Made from a blend of the fusiolen® **PP-R** material and e-glass fibers, this layer is perfectly integrated into the center of the Aquatherm pipes. By extruding this special layer into the center of the pipe, the exterior and interior layers remain unaltered.

The e-glass fibers expand less than the PP-R material when heated, which prevents the material they are bonded to from expanding. Because the faser-composite layer does not expand, the outside and inside layers can't either, reducing the overall expansion and contraction of the pipe by 75% when compared to non-faser plastic pipes.

The faser-composite layer uses a low concentration of glass fibers, so the fusion properties of the pipe remain the same. There is also no issue with recycling the pipe, as the fibers can be removed during the process.

Concealed installation

Unlike most piping materials, PP-R is able to absorb the stress caused by expansion within certain limits. The faser-composite layer helps keep the pipe within these limits for most applications.

Concealed installations generally do not require additional consideration for the expansion of faser-composite pipes. Most insulations give enough expansion space for the pipe. In the case where the expansion is greater than the room to move in the insulation, the material absorbs any stress arising from a residual expansion.

The same applies to pipes which do not have to be insulated according to current regulations. The expansion on pipes that don't need to be insulated is minimal because of the lower difference in temperature. The pipe itself can absorb the remaining stress.

Embedding the pipe in concrete or plaster will negate most of the linear expansion. The compressive strain and tensile stress arising from this are no longer critical, as the extra forces are absorbed by the pipe itself. This is also true of pipe that is buried in soil or sand.

Open installation

In the case of exposed installations, it is important to maintain the visual trueness of the pipe as well as compensate for any expansive forces. Aquatherm's faser-composite pipes make this an easy process.

It is important to calculate the expansion of the system and allow the piping to expand. Expansion can be compensated for using sliding elbows and expansion loops. The flexible heat fusion joints will not crack or leak from the tension of expanding and contracting if the bending side is long enough.

Calculation of linear expansion

The coefficient (α) of linear expansion of Aquatherm faser-composite pipes is comparable to the linear expansion of metal pipes and is only:

α faser-composite = 0.035 mm/mK = 2.367 • 10^{-4} in/ft°F

The coefficient of linear expansion of Aquatherm piping systems without the fiber-composite layer is comparable to other plastic pipes:

α non-faser= 0.150 mm/mK = 1.008•10^{-3} in/ft°F

While Aquatherm faser-composite pipes can absorb most of their own expansion stresses, this can cause the pipe to bow or bend. Fixed points should be installed at least every 120 feet, with some form of expansion control between each fixed point. The expansion control must be able to absorb the stress of all the expansion between the two fixed points.

Non-faser pipes used for hot applications should have expansion controls at every 30 feet for straight runs.

Risers of faser-composite pipes may be installed rigidly without expansion compensation. The risers will need to be anchored at each floor. It is recommended to anchor near any branch lines to minimize vertical movement.

The following formula, calculation examples, data tables and diagrams help to determine the linear expansion. The difference between working temperature and maximum or minimum installation temperature is essential for the calculation of linear expansion.

Calculation of linear expansion

Calculation example: Linear expansion

Given and required values

Symbol	Meaning	Value	Measuring unit
ΔL	Linear expansion	?	in/ft °F
			mm/m °K
α_1	Coefficient of linear expansion Aquatherm faser-composite pipe	2.367•10^{-4}	in/ft °F
		0.035	mm/m °K
α_2	Coefficient of linear expansion Aquatherm non-faser pipe	1.008•10^{-3}	in/ft °F
		0.15	mm/m °K
L	Pipe length	100	ft
		30.5	m
T_W	Working temperature	160	°F
		71.0	°C
T_M	Installation temperature	60	°F
		15.6	°C
ΔT	Temperature difference between working and installation temperature ($\Delta T = T_W - T_M$)	100	°F
		38.0	°K

ΔT [°F] • 5/9 = ΔT [°K]

The linear expansion ΔL is calculated according to the following formula:

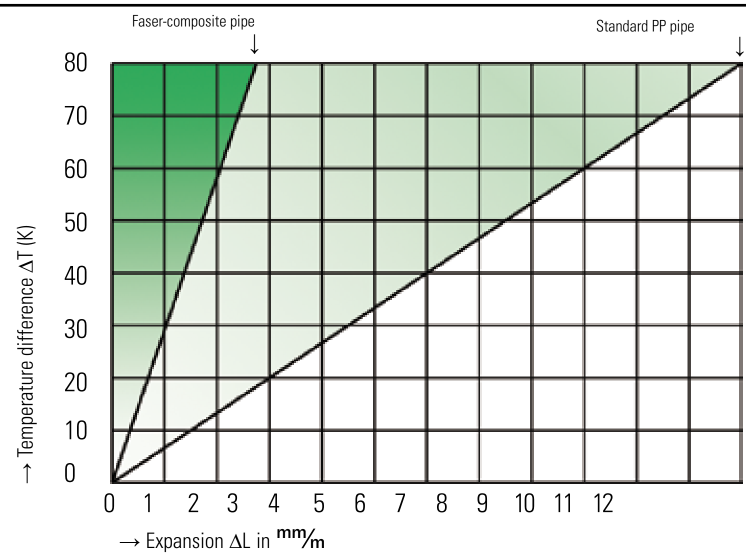
$$\Delta L = \alpha \bullet L \bullet \Delta T$$

Material: Aquatherm faser-composite pipe
(α_1 = **2.367 • 10^{-4} in/ft°F**)

$$\Delta L = 2.367 \bullet 10^{-4} \bullet 100 \text{ ft} \bullet 100\ °F$$

$$\Delta L = 2.4 \text{ in}$$

Linear expansion comparison: faser-composite to standard PP pipe

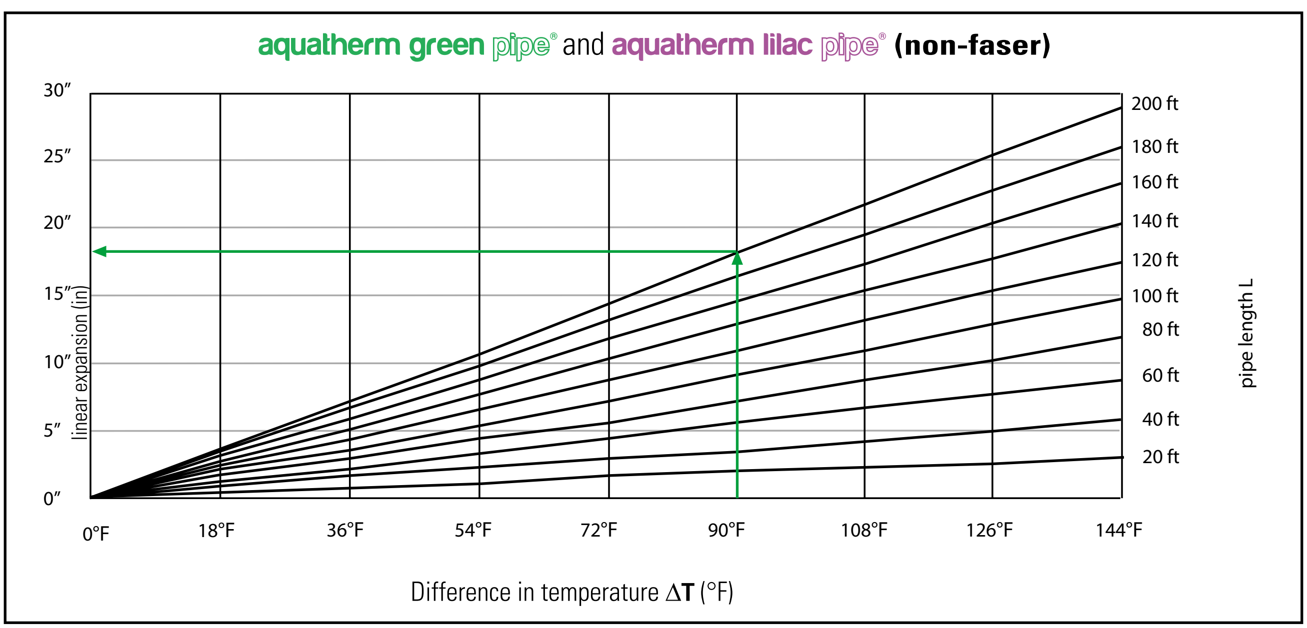


Linear expansion for aquatherm non-faser PP-R pipes

The linear expansion described on the preceding pages can be taken from the following tables and graphs.

Linear expansion ΔL (in):
aquatherm non-faser pipe - $\alpha_2 = 0.150\ ^{mm}/_{mK} = 1.008 \bullet 10^{-3}$ in/ft°F

Pipe length	Difference in temperature $\Delta T = T_{operating\ temperature} - T_{installation\ temperature}$							
	10 °F	**20 °F**	**30 °F**	**40 °F**	**50 °F**	**60 °F**	**80 °F**	**100 °F**
	Linear expansion ΔL (in)							
10 ft	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0
20 ft	0.2	0.4	0.6	0.8	1.0	1.2	1.6	2.0
30 ft	0.3	0.6	0.9	1.2	1.5	1.8	2.4	3.0
40 ft	0.4	0.8	1.2	1.6	2.0	2.4	3.2	4.0
50 ft	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0
60 ft	0.6	1.2	1.8	2.4	3.0	3.6	4.8	6.0
70 ft	0.7	1.4	2.1	2.8	3.5	4.2	5.6	7.0
80 ft	0.8	1.6	2.4	3.2	4.0	4.8	6.4	8.0
90 ft	0.9	1.8	2.7	3.6	4.5	5.4	7.2	9.0
100 ft	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
150 ft	1.5	3.0	4.5	6.0	7.5	9.0	12.0	14.9
200 ft	2.0	4.0	6.0	8.0	10.0	12.0	15.9	19.9

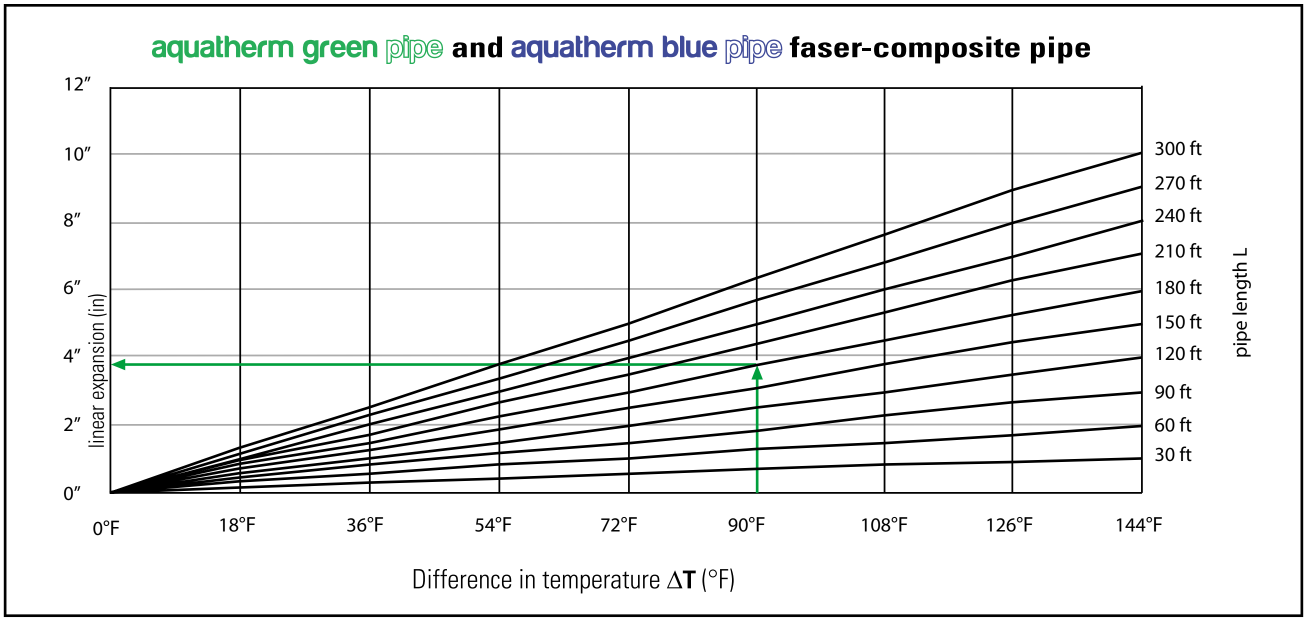


Linear expansion for aquatherm faser-composite PP-R pipes

Due to the integration and positive bond of the different materials, the **aquatherm green pipe**® and **aquatherm blue pipe**® faser-composite pipes offer much higher stability. The linear expansion is reduced to almost 1/5 the value of the standard PP-R pipes.

Linear expansion ΔL (in):
aquatherm faser-composite pipe - $\alpha_1 = 0.035$ mm/mK = 2.367 • 10^{-4}"/ft°F

Pipe length	Difference in temperature $\Delta T = T_{\text{operating temperature}} - T_{\text{installation temperature}}$							
	10 °F	**20 °F**	**30 °F**	**40 °F**	**50 °F**	**60 °F**	**80 °F**	**100 °F**
	Linear expansion ΔL (in)							
10 ft	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2
20 ft	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5
30 ft	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.7
40 ft	0.1	0.2	0.3	0.4	0.5	0.5	0.7	0.9
50 ft	0.1	0.2	0.3	0.5	0.6	0.7	0.9	1.1
60 ft	0.1	0.3	0.4	0.5	0.7	0.8	1.1	1.4
70 ft	0.2	0.3	0.5	0.6	0.8	1.0	1.3	1.6
80 ft	0.2	0.4	0.5	0.7	0.9	1.1	1.5	1.8
90 ft	0.2	0.4	0.6	0.8	1.0	1.2	1.6	2.1
100 ft	0.2	0.5	0.7	0.9	1.1	1.4	1.8	2.3
150 ft	0.3	0.7	1.0	1.4	1.7	2.1	2.7	3.4
200 ft	0.5	0.9	1.4	1.8	2.3	2.7	3.6	4.6



Expansion controls

Linear expansion from the temperature difference between operating temperature and installation temperature can be addressed with the controls shown here.

Bending side

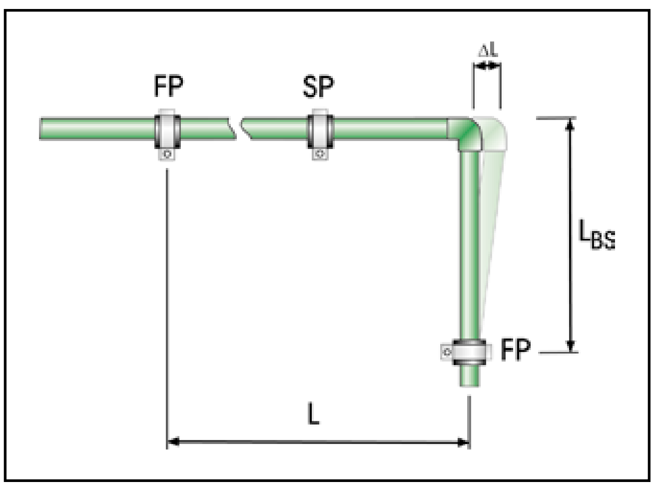
In most cases, directional changes can be used to compensate for linear expansion in pipes. The values of the bending side can be determined using the following tables and diagrams.

Symbol	Meaning		
L_{BS}	Length of the bending side	(in)	(mm)
K	Material-specific constant	2.98*	15
d	Outside diameter	(mm)	(mm)
ΔL	Linear expansion	(in)	(mm)
L	Pipe Length	(ft)	(m)
FP	Fixed point		
SP	Sliding point		

*Includes metric to imperial conversion factor

Calculation of the bending side length:

$$L_{BS} = K \bullet \sqrt{d \bullet \Delta L}$$



Expansion loop

If the linear expansion cannot be compensated for by a change in direction, it may be necessary to install an expansion loop.

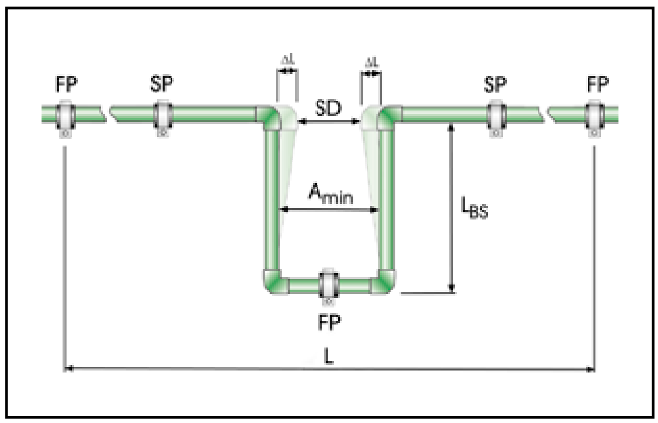
In addition to the length of the bending side L_{BS}, the width of the pipe bend A_{min} must be considered.

Symbol	Meaning	
A_{min}	Width of the expansion loop	(in)
SD	Safety distance	6 in

The pipe bend A_{min} is calculated according to the following formula:

$$A_{min} = 2 \bullet \Delta L + SD$$

For example, with
$\Delta L = 1.4$ in
the width of the expansion loop should be at least
(2 • 1.4) + 6 = 8.8 in



Pre-expansion

In applications where the system will be continuously running hot, the installer can fill the pipes and begin operation to expand the system before tightening down the clamps. This eliminates concerns about fixed and sliding points. If the system is turned off and the pipes contract, the fittings will not pull apart.

Pre-stress

Where space is limited, it is possible to shorten the total width A_{min} as well as the length of the bending side L_{BSV} by pre-stressing the pipe.

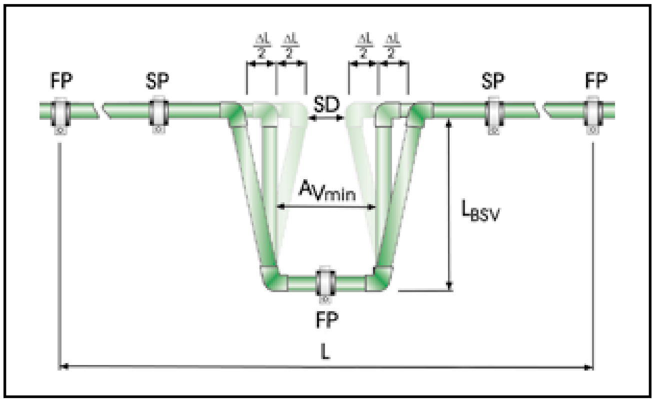
Pre-stressing the pipe during installation can help reduce the length of the bending side. It can also be used to make the operating system look visually square by using ΔL in the equation rather than $\Delta L/2$.

When shortening the length of the bending side, the new value is defined as:

Symbol	Meaning
L_{BSV}	Length of pre-stress (in)

The bending side length of expansion loops with pre-stress is calculated according to the following equation:

$$L_{BSV} = K \bullet \sqrt{d \bullet \Delta L/2}$$



As noted previously, the value of K is a material constant (2.98), d is the pipe outside diameter in mm, and ΔL is the previously calculated thermal expansion.

Bellows expansion joint

All corrugated metal bellows expansion joints are unsuitable for use with Aquatherm piping systems. Joints made from elastomeric materials are acceptable. When using axial expansion joints, observe the manufacturer's instructions.

Vertical installation:

Due to the different linear expansion coefficients of the faser and non-faser pipes, the installation of pipe branches in risers has to be made according to the type of pipe.

with faser-composite pipe

The linear expansion of Aquatherm faser-composite pipes in vertical risers can be ignored. The positioning of a fixed point directly before each branch is sufficient to keep the branch line from shifting under expansion.

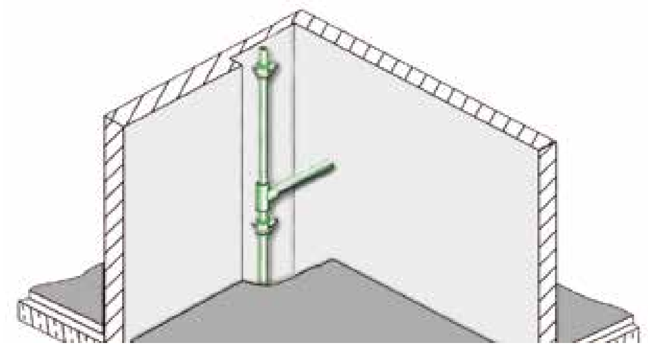
In general, it is possible to install risers rigidly without expansion joints. This directs the expansion on the distance between the fixed points, where it becomes negligible.

It is important to maintain 10 feet of space between two fixed points, and mid-story guides may be necessary for sizes 2" and below.

with non-faser pipe

The installation of risers using Aquatherm pipes without faser-composite requires that branch lines be installed in such a manner as to accommodate linear expansion of the vertical riser. Non-faser pipes in a heated application cannot absorb their own stresses. Adequate expansion controls will need to be added according to the guidelines given earlier in this chapter.

This can be done by installing a fixed point directly before or after each branch line, which prevents the line from moving. Using a large pipe sleeve that can accommodate the movement will also work. A swing joint may also be used to absorb vertical stresses.



Positioning of the fixed point clamp.

Length of bending side for Aquatherm piping systems

The length of the bending side L_{BS} can be taken from the following tables and diagrams with consideration of the applied pipe dimensions and determined linear expansion.

Pipe dimension in inches (mm)	Linear expansion											
	1″	**2″**	**3″**	**4″**	**5″**	**6″**	**7″**	**8″**	**9″**	**10″**	**11″**	**12″**
	Length of bending side (in)											
½″ (20)	13	19	23	27	30	33	35	38	40	42	44	46
¾″ (25)	15	21	26	30	34	37	40	42	45	47	50	52
1″ (32)	17	24	29	34	38	42	45	48	51	54	56	59
1¼″ (40)	19	27	33	38	42	46	50	54	57	60	63	66
1 ½″ (50)	21	30	37	42	47	52	56	60	64	67	70	73
2″ (63)	24	34	41	48	53	58	63	67	71	75	79	82
2 ½″ (75)	26	37	45	52	58	64	69	73	78	82	86	90
3″ (90)	28	40	49	57	64	70	75	80	85	90	94	99
3 ½″ (110)	31	44	54	63	70	77	83	89	94	99	104	109
4″ (125)	34	47	58	67	70	82	89	95	101	106	111	116
6″ (160)	38	54	66	76	85	93	100	107	114	120	126	131
8″ (200)	42	60	73	85	95	104	112	120	127	134	141	147
10″ (250)	47	67	82	95	106	116	125	134	142	150	157	164
12″ (315)	53	75	92	106	119	130	141	151	160	168	177	184
14″ (355)	56	79	97	112	126	138	149	159	168	178	186	194
16″ (400)	60	84	103	119	133	146	158	169	179	188	198	206
18″ (450)	63	89	109	126	141	155	167	178	190	200	210	219
20″ (500)	67	94	115	133	149	163	176	188	200	211	221	231
22″ (560)	71	100	122	141	158	173	187	199	212	223	234	244
24″ (630)	75	106	130	150	167	183	198	212	224	237	248	259

Length of bending side with pre-stress for Aquatherm piping systems

The length of the bending side with pre-stress L_{BSV} can be taken from the following tables and diagrams with consideration of the applied pipe dimensions and determined linear expansion.

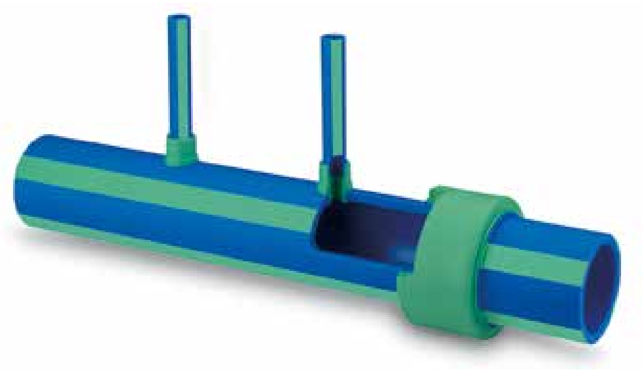
Pipe dimension in inches (mm)	Linear expansion											
	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″	12″
	Length of bending side (in)											
½″ (20)	9	13	16	19	21	23	25	27	28	30	31	33
¾″ (25)	11	15	18	21	24	26	28	30	32	34	35	37
1″ (32)	12	17	21	24	27	29	32	34	36	38	40	42
1¼″ (40)	13	19	23	27	30	33	35	38	40	42	44	46
1 ½″ (50)	15	21	26	30	34	37	40	42	45	47	50	52
2″ (63)	17	24	29	34	38	41	45	48	51	53	56	58
2 ½″ (75)	18	26	32	37	41	45	49	52	55	58	61	64
3″ (90)	20	28	35	40	45	49	53	57	60	64	67	70
3 ½″ (110)	22	31	39	44	50	54	59	63	67	70	74	77
4″ (125)	24	34	41	47	53	58	63	67	71	75	79	82
6″ (160)	27	38	46	54	60	66	71	76	80	85	89	93
8″ (200)	30	42	52	60	67	73	79	85	90	95	99	104
10″ (250)	34	47	58	67	75	82	89	95	101	106	111	116
12″ (315)	38	53	65	75	84	92	100	106	113	119	125	130
14″ (355)	40	56	69	79	89	97	105	112	119	126	132	138
16″ (400)	42	60	73	84	94	103	112	119	126	133	140	146
18″ (450)	45	63	77	89	100	109	118	126	134	141	148	155
20″ (500)	47	67	82	94	105	115	125	133	141	149	156	163
22″ (560)	50	71	86	100	112	122	132	141	150	158	165	173
24″ (630)	53	75	92	106	118	130	140	150	159	167	175	183

Fusion outlets

For installations with branch lines, fusion outlets offer many advantages over traditional reducing tees. Fusion outlets are installed directly onto the side of the pipe and can be added after the main lines are already in place. Fusion outlets also generate less friction than a reducing tee, lowering the pressure loss of the entire system.

Fusion outlets are installed by drilling out a properly sized hole and then fusing the fitting in place using socket fusion tools. The drilling bores offered by Aquatherm will produce properly sized holes, but the bits larger than 2″ require a drill press to operate. Bores produced by other companies must be at least 1 mm smaller than the intended branch, and should be no more than 3 mm smaller.

The table below can help determine if a fusion outlet is available for a particular branch size. The table to the right helps determine if a threaded outlet is available for a particular branch size.



Branching options

Pipe size	Outlets available
1 ¼″ (40 mm)	½″ (20 mm) — ¾″ (25 mm)
1 ½″ (50 mm)	½″ (20 mm) — ¾″ (25 mm)
2″ (63 mm)	½″ (20 mm) — 1″ (32 mm)
2 ½″ (75 mm)	½″ (20 mm) — 1 ¼″ (40 mm)
3″ (90 mm)	½″ (20 mm) — 1 ¼″ (40 mm)
3 ½″ (110 mm)	½″ (20 mm) — 1 ½″ (50 mm)
4″ (125 mm)	½″ (20 mm) — 2″ (63 mm)
6″ (160 mm)	½″ (20 mm) — 3″ (90 mm)
8″ (200 mm)	½″ (20 mm) — 4″ (125 mm)
10″ (250 mm)	½″ (20 mm) — 4″ (125 mm)
12″ (315 mm)	2″ (63 mm) — 6″ (160 mm)
14″ (355 mm)	2″ (63 mm) — 8″ (200 mm)
16″ (400 mm)	2″ (63 mm) — 10″ (250 mm)
18″ (450 mm)	2 ½″ (75 mm) — 12″ (315 mm)
20″ (500 mm)	2 ½″ (75 mm) — 12″ (315 mm)
22″ (560 mm)	2 ½″ (75 mm) — 12″ (315 mm)
24″ (630 mm)	2 ½″ (75 mm) — 12″ (315 mm)

Fusion outlets with threaded transitions

Pipe size	Thread size		
	½″	¾″	1″
1 ¼″ (40 mm)	**M/F**	**M/F**	
1 ½″ (50 mm)	**M/F**	**M/F**	
2″ (63 mm)	**M/F**	**M/F**	
2 ½″ (75 mm)	**M/F**	**M/F**	**F**
3″ (90 mm)	**M/F**	**M/F**	**F**
3 ½″ (110 mm)	**M/F**	**M/F**	**F**
4″ (125 mm)	**M/F**	**M/F**	**F**
6″ (160 mm)	**M/F**	**M/F**	**F**
8″ (200 mm)	**F**	**F**	**F**
10″ (250 mm)	**F**	**F**	**F**

M = male thread available, F = female thread available

Fusion outlets installed on a pipe for use as an extended manifold.

Transition fittings

Copper stub outs

To facilitate transitions to fixture units or copper components, Aquatherm offers a PP-R to copper stub out, intended for use with angle stops, flush valves, and other terminations. It is compatible with both compression and solder-type connections.

These fittings are combination of a custom Aquatherm PP-R socket with a gasket and copper stub added by Sioux Chief Manufacturing. The fused PP-R portion is covered under Aquatherm's warranty. The copper portion and gasket are covered under a warranty from Sioux Chief.

These fittings are available in ½", ¾" and 1" sizes. Instructions are included with the fitting. Always follow these directions to avoid damaging the fitting.

Brass transitions

To make integration with non-fusible system components easier, Aquatherm offers a wide range of threaded transitions. These transitions consist of a PP-R base that has been mold-injected around a machined brass or stainless steel thread for maximum strength.

These fittings are available in male and female thread types. They can include a hex head for ease of installation. Installation instructions can be found in the Aquatherm Installer Manual.

The standard lead-free brass fittings are made with marine-grade DZR brass and are acceptable under the Safe Drinking Water Act and NSF 61.

The zero-lead fittings are compliant with the new Reduction of Lead in Drinking Water Act and are recommended for areas specifically requiring 0.25% lead content or less.

Stainless steel fittings are made from Type 316 stainless steel, and are recommended for all chemically sensitive applications.

Stainless steel

Lead-free brass

Zero-lead brass

PEX transitions

Featuring a PP-R socket on one end and a barbed brass end for PEX tubing, the PEX transition fitting has been manufactured to ASTM F1807 standards and offers a simple solution for installing a system with both PP-R and PEX via a crimped connection without the need for threads, nipples, gaskets, or other failure-prone methods.

Aquatherm does not currently offer a PEX or PERT line to use with these fittings in North America. As always, the Aquatherm warranty covers the PP-R and brass portions of this fitting. Any tubing that is attached to this fitting is considered to be covered under its own manufacturer's warranty, as is the crimp ring. Brass portion may not be acceptable for chemically aggressive applications.

Flanges

For transitioning between larger sizes of pipe, attaching pre-fabricated sections, or connecting to pumps, valves, and other mechanical equipment, Aquatherm produces fusible flange adapters with steel flange rings. The rings are designed to match up metric pipes with ANSI bolt patterns.

Aquatherm recommends using a full face rubber (black EPDM or red SBR) gasket with its flanges. Viton® gaskets may also be used if needed for chemical resistance. Ring gaskets may be used for lower pressure systems and smaller diameters (4" and down), but there may be blow-outs during pressure testing. Ring gaskets are also more susceptible to leaking if the flanges and connected piping are not aligned properly during installation.

As of 2013, Aquatherm will only produce flange adapters that are compatible with ANSI butterfly valves. Some older flange adapters may not be compatible with all ANSI butterfly valves, but will work with other types of equipment. These older flange adapters may be exchanged for the new style through Aquatherm.

Aquatherm distribution blocks

Aquatherm distribution blocks are designed to help save time and space for parallel hot and cold water lines. The distribution block allows for ¾" hot and cold lines to run through the block with outlets for ½" branches. This eliminates the need to use a cross-over or bridge and keeps the installation simple, square, and clean.

The stamped numbers 1 and 2 indicate the proper connection of the Aquatherm distribution block and provide assistance with the installation. Branches with the same number are connected by channels inside the distribution block. The natural insulation value of the PP-R block helps prevent heat exchange between the hot and cold lines.

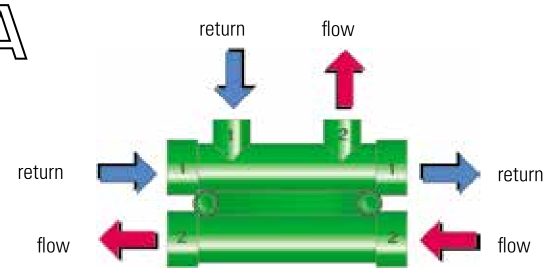
For a heating or cooling connection, the return is connected to the channel marked 1 and the supply to the channel marked 2 (fig. A). The connections can also be used in reverse (fig. B).

For a potable water connection, channel 1 is intended for the cold water pipe and channel 2 for the hot water pipe connection. In factory condition, the lower outlets are closed. A return connection with channel 2 can be made by drilling out the opening with a ½" outlet drill bit, allowing an additional pipe to be connected (fig. C).

The block can be reversed to match up with existing or planned fixture units. The order of the hot and cold or supply and return lines does not matter as long as the number remains consistent (fig. D).

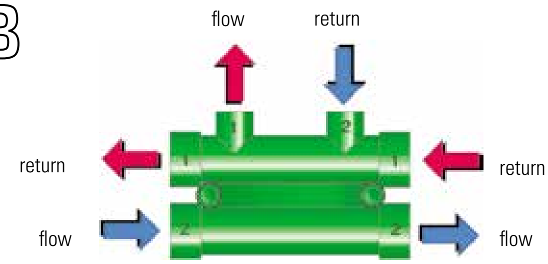
The distribution blocks are designed for use with ½" and ¾" Aquatherm pipes and can be used with **aquatherm green pipe®**, **aquatherm blue pipe®**, and **aquatherm lilac pipe®**. If smaller sizes of piping are needed, bushings can be fused directly into the distribution block.

A



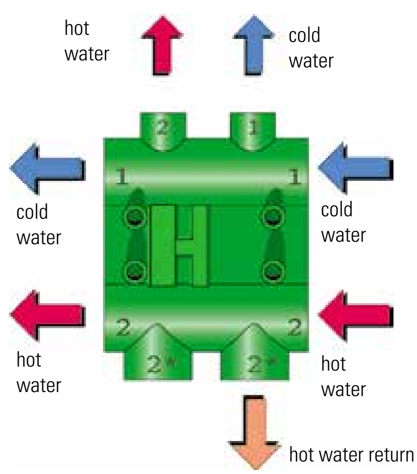
Heating

B



Heating

C



Plumbing

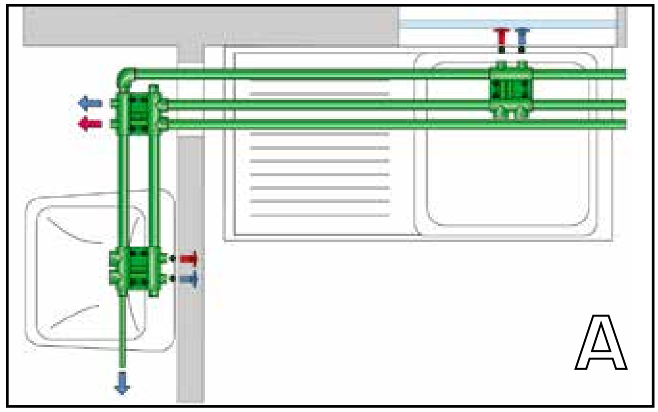
D

Heating

Aquatherm distribution blocks

With careful planning, the distribution blocks can be turned, drilled out, connected, reduced, and even capped off to accommodate a wide variety of fixtures and layouts in limited spaces (fig. A). Each block has two sets of ¾" connections and two sets of ½" connections, allowing the blocks to have up to three branches from a single supply. Effective use of the distribution block can help improve overall design efficiency and simplify installation.

The distribution block comes from the factory with the inlets and outlets sealed. Leaving the outlets sealed can act as a cap for a particular line (fig. B). The ¾" outlets can also be reduced and used to directly supply the last fixture unit in the line.



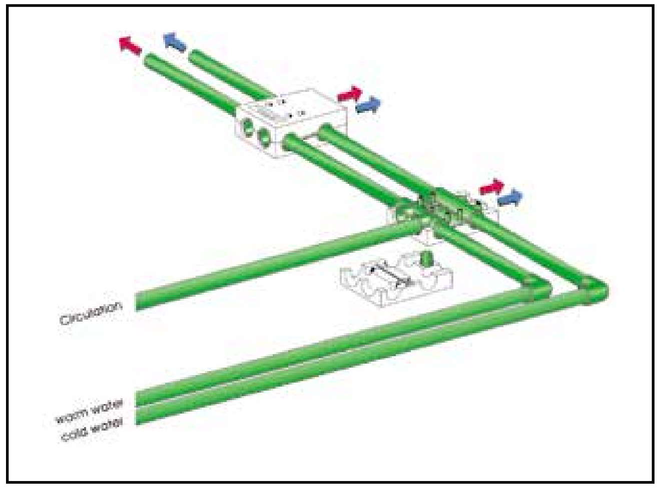
Distribution block insulation

Because the unique shape of the distribution block makes it difficult to insulate with regular insulation, Aquatherm has developed a special insulation block that is designed to fit perfectly over the distribution block. The insulation for the distribution block is made from high-quality PPO/PS rigid expanded polyurethane.

Dimensions of insulation:

- Thermal conductivity: 0.28 BTU-in/hr • °F • ft^2
- Length: 7.25 in
- Width: 4.69 in
- Height: 2.76 in

The accessories (1 plug, 2 fastening plugs) are integrated in the insulation of an Aquatherm distribution block with insulation tray.



Flushing the pipes

All piping systems, regardless of their intended medium, should be flushed thoroughly after installation. The following concerns should be addressed before the installation can be put into service:

- protection of the water quality
- avoidance of corrosion damage
- avoidance of malfunctions of pumps and equipment
- cleanliness of the inner surface of the pipe

These requirements can be met by:

- flushing the system with water
- flushing the system with a mixture of air and water

The flushing medium may be determined by local codes, engineering specifications, or the needs of the mechanical equipment used.

Where no requirements are established, potable water is sufficient for flushing Aquatherm piping materials.

UV protection

In applications where the installed pipe will be exposed to UV radiation (such as outdoor applications), it is recommended that Aquatherm UV pipe be used. This pipe is engineered with an outer coating of black polyethylene that protects the pipe from the aging and discoloration that can occur from prolonged exposure to UV radiation. This coating must be removed at the points of connection prior to heat fusion. Instructions can be found in the Installer Manual.

Aquatherm pipes come from the factory packed in UV-resistant bags, which protect the pipes until they are removed. All Aquatherm pipes and fittings have UV stabilizers to bridge transport and installation times. Maximum recommended storage time exposed to UV radiation is six months.

Plastic-safe paint can be used to protect the pipe from UV damage, but most paints will not adhere well to PP-R. Painted pipe may need to be re-coated or maintained, and this is the responsibility of the installer or owner. Aquatherm recommends using an elastomeric paint, which will expand and contract with the pipes, but does not endorse any particular brand of paint. The pipe may also be painted for reasons unrelated to UV protection, if needed.

Painting the pipe is considered an aftermarket modification to the Aquatherm pipe, so Aquatherm does not assume any responsibility for the performance of the paint. Always use a paint that is safe with PP-R. Damage caused by painting is not covered under the Aquatherm warranty.

Freeze protection

Aquatherm piping systems can be installed in applications and conditions where freezing may occur.

Generally, freezing the pipes and the water in them will not cause problems for the piping materials. However, freezing may cause problems for the user if the system is required to be operational during these freezing periods.

To avoid this, anti-freeze (glycerin or glycol are safe at any concentration) or heating cables applied externally or inside the pipe may be used to ensure that the system does not freeze. Alternatively, providing a means for a minimum constant flow even during a power outage will prevent freezing.

Regardless of the method chosen, all products must be used in accordance with the freeze protection system manufacturer's recommendations, the product listings, and in compliance with all applicable local codes.

When using any type of external heat source applied to the piping such as heat tape or heating cables, the product must be suitable for use with plastic piping. Additionally, the heat system must be self-regulating and ensure the surface temperature of the Aquatherm pipe and fittings will not exceed 160 °F (71 °C).

Grounding

Most building codes require that grounding be provided for all conductive components inside the structure. It is important to note that Aquatherm pipes do not carry electrical currents and cannot be used to provide grounding. Where metal pipes are replaced by PP-R pipes, the ground cannot be created by the piping system. An alternative ground system must be installed. The grounding system should be inspected by a qualified electrician.

Transport and storage

Aquatherm pipes may be stored outside at any temperature, but it is preferable to store the pipes inside. Providing a solid, flat, and level base for the pipe is very important to avoid a deformation of the pipes during transport and storage. Improper storage of the pipe can cause bowing.

The pipe should always be handled with care, particularly in cold weather. Cold temperatures reduce the flexibility of the pipe, making it brittle and increasing the chances of it cracking or breaking

Additional instructions regarding care and handling can be found on page <?> and in the Aquatherm Installer Manual.

Pressure test

While still accessible, all pipelines must be pressure tested using water, air, or a mix of the two. The test pressure must be 1.5 times the operating pressure or 150 psi, whichever is higher. If the system has a low operating pressure and is comprised of SDR 17.6, the required minimum pressure can be reduced to 100 psi or 1.5 times operating pressure, whichever is higher. Testing below 150 psi may not reveal joints that have been improperly fused. Please note that when testing with only air, restraining the pipe within 3 ft of each connection being tested is required.

When performing the pressure test, the material properties of Aquatherm pipes can lead to an expansion of the pipe. This influences the test results. The coefficient of thermal expansion of Aquatherm pipes can also further influence the test results. Different temperatures of the pipe and the test medium lead to alterations of pressure. A temperature change of 18 °F corresponds to a pressure difference of 7.25 to 14.5 psi (0.5 to 1 bar). Therefore the highest possible constant temperature of the test medium must be measured during the pressure test. If possible, allow for the temperature between the pipes and the test medium to reach equilibrium before reading the meter. Remove all fusion equipment and tool clamps before testing the system.

The pressure test consists of a preliminary, principal, and final test. For the preliminary test, pressurize the system to the test pressure. Expansion of the pipe and changes in temperature may cause the system to drop below test pressure during this test. If necessary, the tester may add pressure until the system stabilizes at the test pressure. Once the system is stable, begin timing 30 minutes. The system must not lose more than 9 psi (0.6 bar) in that time. If any leakage appears, stop the test and repair the leaks before proceeding.

Immediately after successfully completing the preliminary test, begin the primary test. For the primary test, monitor the system for 2 hours, making sure that it does not lose more than 3 psi (0.2 bar) in that time.

Following a successful completion of the primary test, bring the pressure down to 0. Then repressurize the system to test pressure again. After 2 minutes, bring the system down to 15 PSI. After 2 more minutes, bring the system back to 0 and repeat this process 3 more times, with a final interval of 5 minutes. This rapid cycling of the pressure will help ensure that all the fused connections were properly installed.

The times for the preliminary and primary tests are based on large installations, where small leaks may take longer to manifest as a pressure loss. For smaller installations such as single family homes, the times may be reduced up to 50% if no loss of pressure is detected in that time. The times on the final test do not change in any circumstances. A similar principle applies for the pressure loss tolerances. In a smaller installation, a small loss of pressure (3-9 psi) is likely indicative of a leak and the system should be inspected before proceeding.

Measuring the test pressures

Measuring must be done with a pressure gauge allowing a reading to 0.5 psi. When a multi-story installation with water only, the pressure test should be conducted at the lowest point in the building that can be easily accessed.

Test record

A record of the pressure test must be prepared and signed by the client and contractor stating place, contractor installer number (found on the training certificate), and date. For an example, see page 4.22. A system can be tested in phases provided that every heat-fused connection is eventually tested and that the tests are properly documented upon completion. The most recent version of the test record can be found at the Aquatherm website at **www.aquatherm.com/pressure-test**

This test is designed to identify damaged pipe, manufacturer's defects, and poor workmanship. It is required by the manufacturer for the validation of the Aquatherm warranty*. This does not supersede or replace regulations placed by the local code authority having jurisdiction. To prevent back-dating, Aquatherm requires that this test be submitted before the system begins full operation.

Test should be faxed to Aquatherm at:

- **801-847-6554**

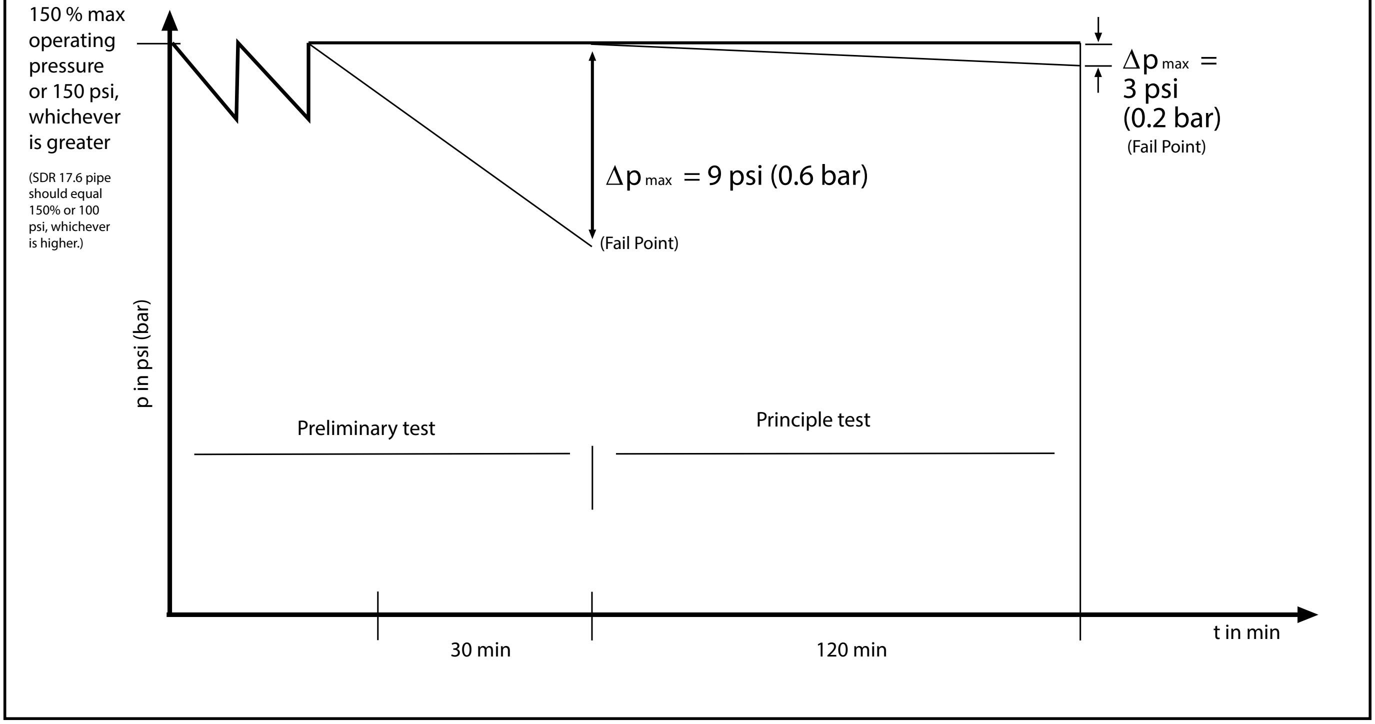
Tests may also be e-mailed to:
technical@aquatherm.com

*Aquatherm's warranty does not cover failures caused by improper installation, operation outside of the recommended parameters, or damage from mishandling after the pipe has left possession of the manufacturer. Completing the pressure test does not guarantee coverage in the event of a failure caused by improper installation.

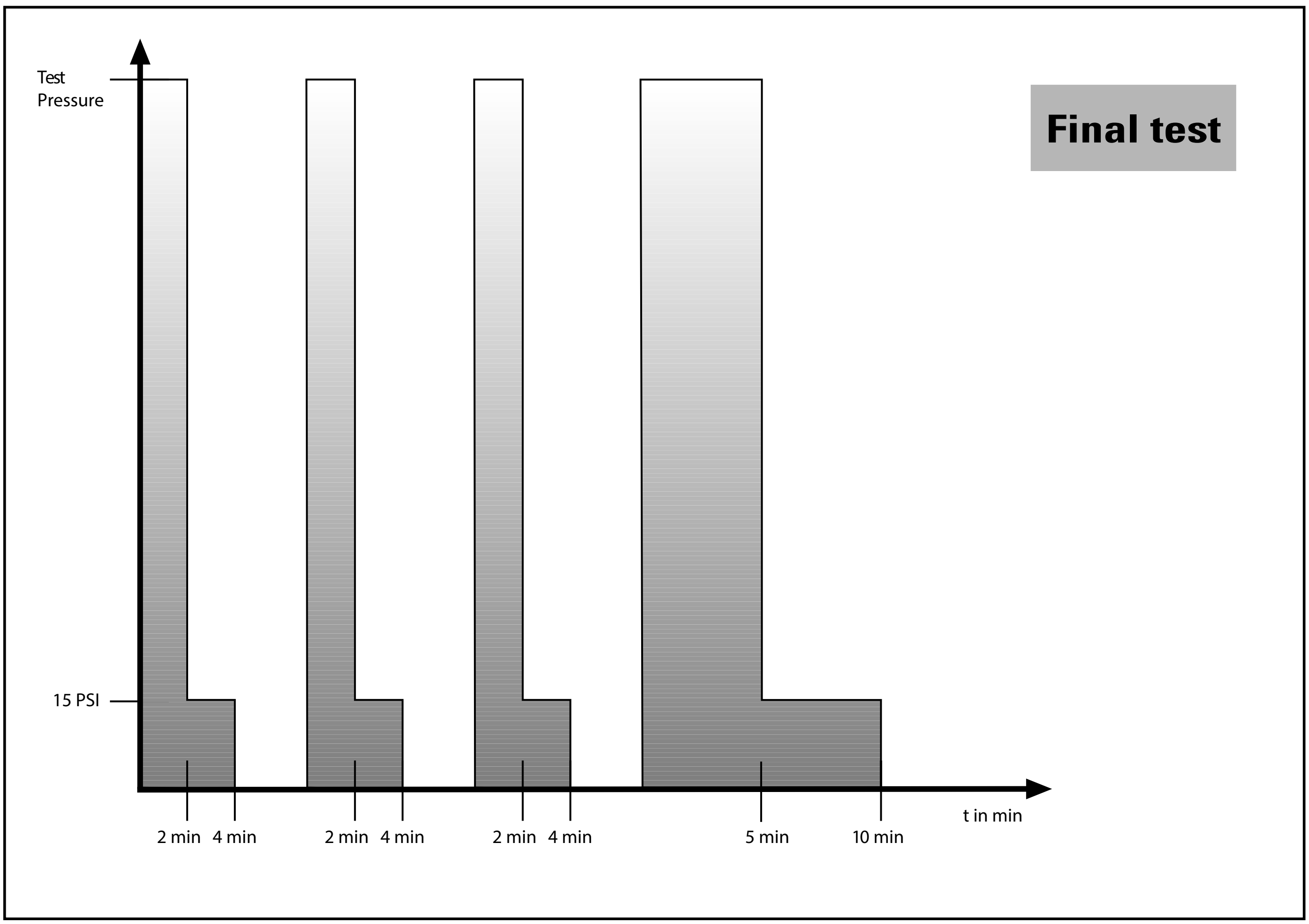
Additional testing

For larger systems, Aquatherm recommends performing a sustained pressure test. This test is performed by leaving the system at operating pressure (or higher) for a period of at least 24 hours. The air temperature around the system should be the same at the start and the completion of the test. Any drop in pressure over that time may be indicative of a slow leak in the system, which could cause damage over time. This test, while not required by Aquatherm, is recommended for the protection of the installer and the building owner. Slow leaks are very rare, but they can occur and are generally the result of avoidable installation error.

Preliminary and principal test



Final test



Preliminary & principal test:

1. Bring pressure in system up to 150% of the maximum operating pressure, or 150 psi, whichever is higher. This is now the "Test Pressure".

2. Wait 10 minutes then read pressure. If there has been any decrease due to expansion of the piping, raise system back to Test Pressure.

3. Repeat step 2 until the system has stabilized. Small systems should stabilize quickly, while larger systems may take longer. If the system pressure does not stabilize, inspect the system for leaks or air pockets when hydrostatic testing.

4. Wait 30 minutes then read pressure. Pressure must not drop more than 9 psi (0.6 bar) below the Test Pressure. Reduce tolerance for smaller installations.

5. Wait 120 minutes (2 hours) then read pressure. Pressure must not drop more than 3 psi (0.2 bar) from previous reading in step 4.

6. If the system has met the requirements of steps 4 and 5, continue to the final test.

7. If the system pressure cannot be stabilized or fails to meet the requirements of steps 4 and 5, inspect the system for leaks. Make any necessary repairs and begin test again. Take any major variations in temperature into consideration when performing these tests.

Final test:

1. Bring the system pressure up to Test Pressure and wait 2 minutes.

2. Reduce system to 15 PSI and wait 2 minutes. Drop pressure to 0.

3. Bring system back up to Test Pressure and wait 2 minutes.

4. Reduce system to 15 PSI and wait 2 minutes. Drop pressure to 0.

5. Bring system back up to Test Pressure and wait 2 minutes.

6. Reduce system to 15 PSI and wait 2 minutes. Drop pressure to 0.

7. Bring system back up to Test Pressure and wait 5 minutes.

8. Reduce system to 15 PSI and wait 5 minutes. Drop pressure to 0.

No leakage may appear at any point of the tested installation. This test is designed to expose cracks and break open faulty fusions. Installer may also want to preform a sustained pressure test at this point to verify the system integrity.

Description of the installation

Project Name:________________________

Systems installed:________________________

____

Units used on report:

- ❑ ft. or ❑ m
- ❑ psi or ❑ bar

Length of pipe used:

½" (20 mm)	______	6" (160 mm)	______
¾" (25 mm)	______	8" (200 mm)	______
1" (32 mm)	______	10" (250 mm)	______
1 ¼" (40 mm)	______	12" (315 mm)	______
1 ½" (50 mm)	______	14" (355 mm)	______
2" (63 mm)	______	16" (400 mm)	______
2 ½" (75 mm)	______	18" (450 mm)	______
3" (90 mm)	______	20" (500 mm)	______
3 ½" (110 mm)	______	22" (560 mm)	______
4" (125 mm)	______	24" (630 mm)	______

Highest point:______________
(over pressure gauge)

Start time:________________________

End time:________________________

Test duration:________________________

Building address:

____

____

____

____

Contractor contact information:

____

____

Installer number (found on training certificate)

____

Building owner/manager:________________________

Date:________________________

____

Stamp / Signature

Preliminary test

Test pressure: ____________
(use min.150 psi)

Pressure drop after 30 minutes: ____________
(max. 8.7psi / 0.6 bar)

Principal test

Principal test pressure: ____________

Time elapsed: ____________

Pressure after: ____________

Final test*

1. Test Pressure: ____________
at least 2 minutes, then
15 PSI : ____________
at least 2 minutes

2. Test Pressure: ____________
at least 2 minutes, then
15 PSI: ____________
at least 2 minutes

3. Test Pressure: ____________
at least 2 minutes, then
15 PSI : ____________
at least 2 minutes

4. Test Pressure: ____________
at least 5 minutes, then
15 PSI : ____________
at least 5 minutes

*Depressurize the pipe between each cycle.

All fields are required on this test record.

Test should be faxed to **aquatherm** at:

- 801-847-6554

Tests may also be e-mailed to:
technical@aquatherm.com.

Chapter 5
Product Range

Note: Dimensional data for the fittings has been added to this edition of Aquatherm catalog. However, due to the ongoing expansion and improvement of the Aquatherm line, the dimension data was not completed at the time of printing. The dimensional data here is derivative of other documents and should not be considered absolute. It is included in this catalog for the user's convenience. If an error is found between this chapter and an actual part, please inform Aquatherm so that this, and the documents it derives from, can be updated and corrected.

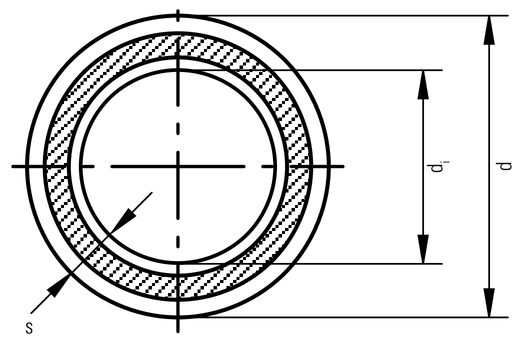
aquatherm green pipe®

faser-composite pipe SDR 7.4

Material: fusiolen® PP-R faser-composite

In accordance with:

- NSF 14, 51 & 61
- CSA-B137.11
- ICC AC 122
- ICC ESR 1613
- ASTM F2389
- CFIA #A508
- FM 1635
- NFPA 13D



Appearance: Light green with dark green stripe.

NSF system certification: Including fittings, connection pieces, and connection techniques.

Fields of application: For high temperature, moderate pressure systems, particularly domestic hot water systems.

Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	gal/ft	lb/ft
0670708	½″ — 20 mm	25	20	2.8	14.4	0.013	0.11
0670710	¾″ — 25 mm	25	25	3.5	18	0.024	0.17
0670712	1″ — 32 mm	10	32	4.4	23.2	0.034	0.27
0670714	1 ¼″ — 40 mm	10	40	5.5	29	0.053	0.41
0670716	1 ½″ — 50 mm	5	50	6.9	36.2	0.083	0.64
0670718	2″ — 63 mm	5	63	8.6	45.8	0.133	1.01
0670720	2 ½″ — 75 mm	5	75	10.3	54.4	0.187	1.44
0670722	3″ — 90 mm	3	90	12.3	65.4	0.270	2.06
0670724	3 ½″ — 110 mm	2	110	15.1	79.8	0.402	3.08
0670726	4″ — 125 mm	1	125	17.1	90.8	0.521	3.96
0670730	6″ — 160 mm	1	160	21.9	116.2	0.854	6.41
0670734	8″ — 200 mm	1	200	27.4	145.2	1.333	10.11
0670738	10″ — 250 mm	1	250	34.2	181.6	2.084	15.78
0070742	12″ — 315 mm	1	315	42.6	229.8	3.340	25.05
0070744	14″ — 355 mm	1	355	48.0	259.0	4.242	31.82

[a] ½″ - 4″ pipes come in standard 13 ft lengths (4 m). 6″ - 14″ pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.

aquatherm green pipe® pipe SDR 11

Material: fusiolen® **PP-R**

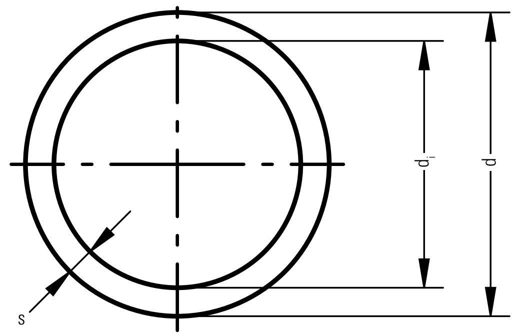
In accordance with:

- NSF-14
- NSF-51
- NSF-61
- CSA-B137.11
- ICC AC 122
- ICC ESR 1613
- ASTM F 2389
- CFIA #A508

Appearance: Light green with light blue stripe.

NSF system certification: Including fittings, connection pieces, and connection techniques.

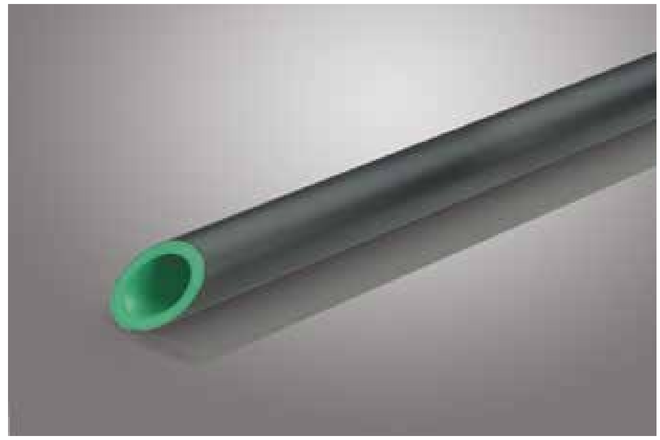
Fields of application: Potable water, preferably domestic cold. Low pressure installations, such as well casings, food processing, etc.



Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	gal/ft	lb/ft
0610208	½" — 20 mm	25	20	1.9	16.2	0.017	0.07
0610210	¾" — 25 mm	25	25	2.3	20.4	0.026	0.11
0610212	1" — 32 mm	10	32	2.9	26.2	0.043	0.18
0610214	1 ¼" — 40 mm	10	40	3.7	32.6	0.067	0.28
0610216	1 ½" — 50 mm	5	50	4.6	40.8	0.105	0.43
0610218	2" — 63 mm	5	63	5.8	51.4	0.167	0.68
0610220	2 ½" — 75 mm	5	75	6.8	61.4	0.237	0.95
0610222	3" — 90 mm	3	90	8.2	73.6	0.343	1.37
0610224	3 ½" — 110 mm	2	110	10.0	90.0	0.512	2.11
0610226	4" — 125 mm	1	125	11.4	102.2	0.661	2.64
0610230	6" — 160 mm	1	160	14.6	130.8	1.082	4.31
0610234	8" — 200 mm	1	200	18.2	163.6	1.692	6.71
0610238	10" — 250 mm	1	250	22.7	204.6	2.646	10.44
0010242	12" — 315 mm	1	315	28.6	257.8	4.201	16.56
0010244	14" — 355 mm	1	355	33.3	290.5	5.340	21.03
0010246[d]	16" — 400 mm	19	400	36.3	327.6	6.787	26.74
0010248[d]	18" — 450 mm	19	450	40.9	368.2	8.573	33.84
The following items are supplied in coils:							
0010308	½" — 20 mm	328 ft	20	1.9	16.2	0.017	0.73
0010310	¾" — 25 mm	328 ft	25	2.3	20.4	0.026	0.11
0010312	1" — 32 mm	164 ft	32	2.9	26.2	0.043	0.17

[a] ½" - 4" pipes come in standard 13 ft lengths (4 m). 6" - 14" pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.
[d] Mechanically stabilized with a faser-composite layer in the center of the pipe.

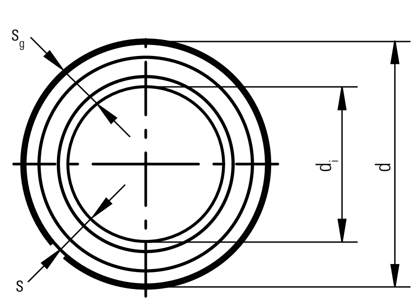
aquatherm green pipe® UV faser-composite pipe SDR 7.4

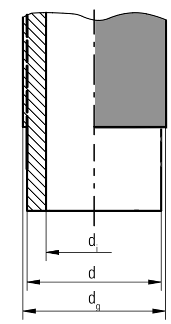


Material: fusiolen® PP-R faser-composite

In accordance with:

- NSF-14
- NSF-51
- NSF-61
- CSA-B137.11
- ICC AC 122
- ICC ESR 1613
- ASTM F 2389
- CFIA #A508





Appearance: Light green with black exterior.

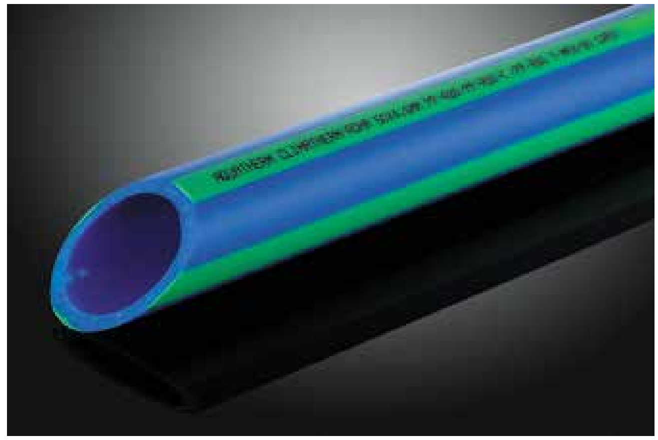
NSF system certification: Including fittings, connection pieces and connection techniques.

Fields of application: All the same applications as the standard aquatherm green pipe® SDR 7.4 faser-composite, but for installations where the pipe is exposed to UV radiation.

Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	(d) total	(s) total	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	d_g (mm)	s_g (mm)	gal/ft	lb/ft
0670758	½″ — 20 mm	25	20	2.8	14.4	22	3.8	0.013	0.14
0670760	¾″ — 25 mm	25	25	3.5	18	27	4.5	0.024	0.21
0670762	1″ — 32 mm	10	32	4.4	23.2	34	5.4	0.034	0.32
0670764	1 ¼″ — 40 mm	10	40	5.5	29	42	6.5	0.053	0.48
0670766	1 ½″ — 50 mm	5	50	6.9	36.2	52	7.9	0.083	0.72
0670768	2″ — 63 mm	5	63	8.6	45.8	65	9.6	0.133	1.10
0670770	2 ½″ — 75 mm	5	75	10.3	54.4	77	11.3	0.187	1.53
0670772	3″ — 90 mm	3	90	12.3	65.4	92	13.3	0.270	2.21
0670774	3 ½″ — 110 mm	2	110	15.1	79.8	113	16.1	0.402	3.31
0670776	4″ — 125 mm	1	125	17.1	90.8	127	18.1	0.521	4.19
0670780	6″ — 160 mm	1	160	21.9	113.2	162	22.9	0.810	6.81
0670784	8″ — 200 mm	1	200	27.4	141.8	202	28.4	1.271	10.59
0670788	10″ — 250 mm	1	250	34.2	177.6	252	35.2	1.994	16.48

[a] ½″ - 4″ pipes come in standard 13 ft lengths (4 m). 6″ - 14″ pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.

aquatherm blue pipe® faser-composite pipe
SDR 7.4/11



Material: fusiolen® PP-R faser-composite

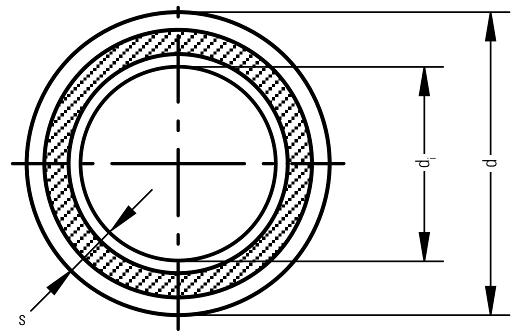
In accordance with:

- NSF-14
- CSA-B137.11
- ICC AC 122
- ICC ESR 1613
- ASTM F 2389

Appearance: Blue with light green stripe.

NSF system certification: Including fittings, connection pieces, and connection techniques.

Fields of application: Heating and cooling applications, industrial applications, compressed air.



Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	gal/ft	lb/ft
2670708	½" — 20 mm SDR 7.4	25	20	2.8	14.4	0.013	0.11
2670710	¾" — 25 mm SDR 7.4	25	25	3.5	18	0.024	0.17
2670112	1" — 32 mm SDR 11	10	32	2.9	26.2	0.043	0.19
2670114	1 ¼" — 40 mm SDR 11	10	40	3.7	32.6	0.067	0.29
2670116	1 ½ " — 50 mm SDR 11	5	50	4.6	40.8	0.105	0.45
2670118	2" — 63 mm SDR 11	5	63	5.8	51.4	0.167	0.72
2670120	2 ½" — 75 mm SDR 11	5	75	6.8	61.4	0.237	1.00
2670122	3" — 90 mm SDR 11	3	90	8.2	73.6	0.343	1.44
2670124	3 ½" — 110 mm SDR 11	2	110	10	90	0.512	2.13
2670126	4" — 125 mm SDR 11	1	125	11.4	102.2	0.661	2.77
2670130	6" — 160 mm SDR 11	1	160	14.6	130.8	1.082	4.52
2670134	8" — 200 mm SDR 11	1	200	18.2	163.6	1.692	7.04
2670138	10" — 250 mm SDR 11	1	250	22.7	204.6	2.646	10.95
2070142	12" — 315 mm SDR 11	1	315	28.6	257.8	4.201	17.26
2070144	14" — 355 mm SDR 11	1	355	33.3	290.5	5.387	21.91
2070146	16" — 400 mm SDR 11	6	400	36.3	327.6	6.787	27.82
2070148	18" — 450 mm SDR 11	6	450	40.9	368.2	8.573	35.21
	The following items are supplied in coils (non-faser)						
2010308	½" — 20 mm SDR 11	328 ft	20	1.9	16.2	0.017	0.11
2010310	¾" — 25 mm SDR 11	328 ft	25	2.3	20.4	0.026	0.16
2010312	1" — 32 mm SDR 11	164 ft	32	2.9	26.2	0.043	0.26

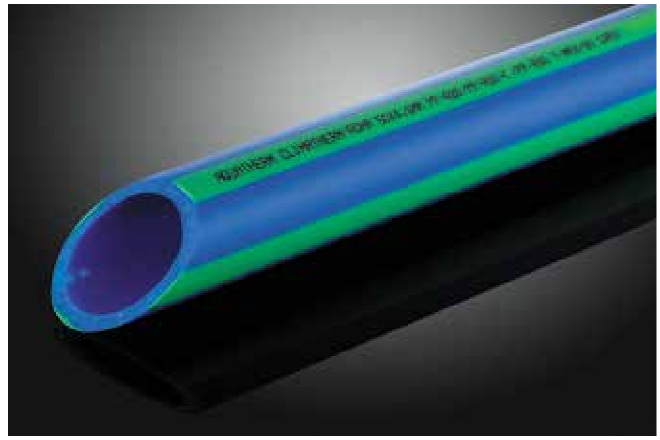
[a] ½" - 4" pipes come in standard 13 ft lengths (4 m). 6" - 14" pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.

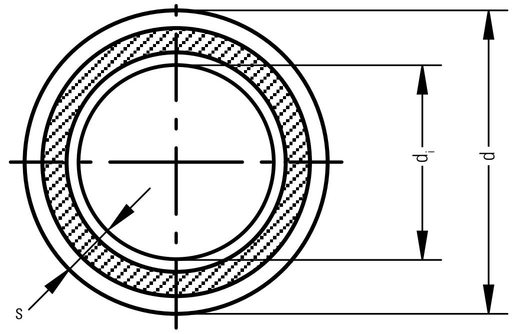
aquatherm blue pipe® faser-composite pipe SDR 17.6

Material: fusiolen® PP-R faser-composite

In accordance with:

- NSF-14
- CSA-B137.11
- ICC AC 122
- ICC ESR 1613
- ASTM F 2389





Appearance: Blue with light green stripe.

NSF system certification: Including fittings, connection pieces, and connection techniques.

Fields of application: Cooling distribution, condenser water, industrial applications, compressed air, and limited heating applications.

Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	gal/ft	lb/ft
2570130	6″ — 160 mm	6	160	9.1	141.8	1.272	2.93
2570134	8″ — 200 mm	6	200	11.4	177.2	1.986	4.57
2570138	10″ — 250 mm	6	250	14.2	221.6	3.105	7.11
2570142	12″ — 315 mm	6	315	17.9	279.2	4.930	11.25
2570144	14″ — 355 mm	6	355	20.1	314.8	6.267	14.25
2570146	16″ — 400 mm	11.8	400	22.7	354.6	7.952	18.10
2570148	18″ — 450 mm	11.8	450	25.5	399.0	10.068	22.86
2570150	20″ — 500 mm	11.8	500	28.4	443.2	12.422	28.27
2570152	22″ — 560 mm	11.8	560	31.7	496.6	15.596	35.31
2570154	24″ — 630 mm	11.8	630	35.7	558.6	19.733	44.71

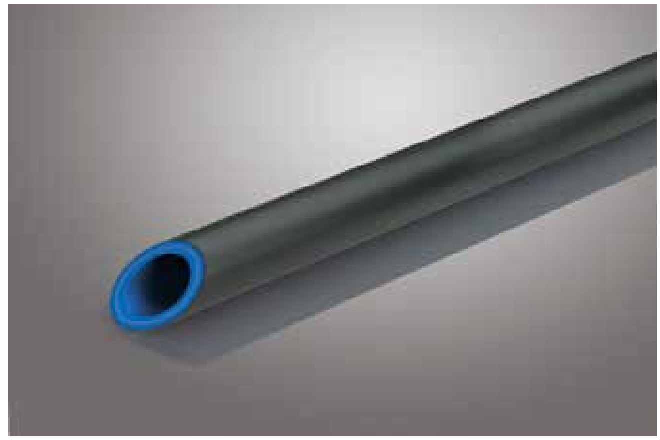
[a] Pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.

aquatherm blue pipe® UV faser-composite pipe SDR 7.4/11

Material: fusiolen® PP-R

In accordance with:

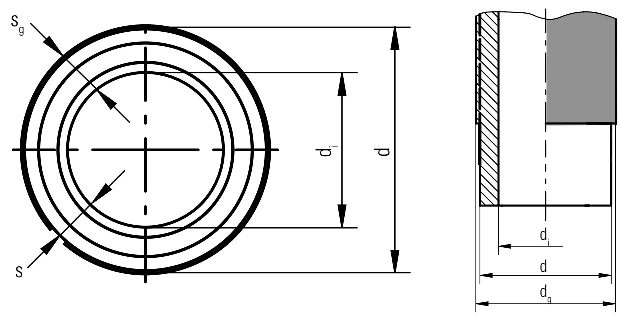
- NSF-14
- CSA-B137.11
- ICC AC 122
- ICC ESR 1613
- ASTM F 2389



Appearance: Light blue with black exterior.

NSF system certification: Including fittings, connection pieces and connection techniques.

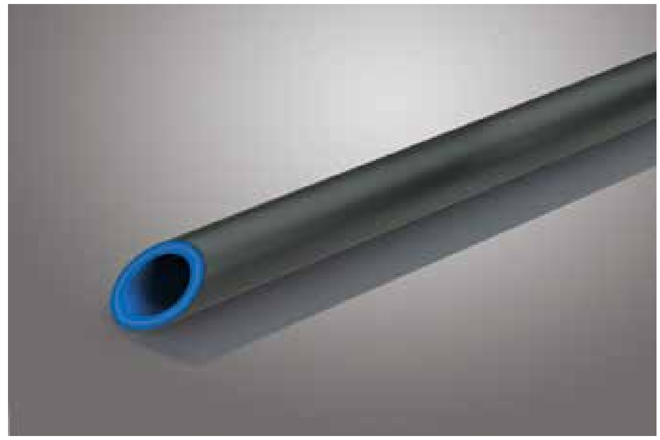
Fields of application: All the same applications as the standard aquatherm blue pipe® SDR 11 faser-composite, but for installations where the pipe is exposed to UV radiation.



Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	(d) total	(s) total	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	d_g (mm)	s_g (mm)	gal/ft	lb/ft
2670758	½" — 20 mm SDR 7.4	25	20	2.8	14.4	22	3.8	0.013	0.14
2670760	¾" — 25 mm SDR 7.4	25	25	3.5	18.0	27	4.5	0.020	0.21
2670162	1" — 32 mm SDR 11	10	32	2.9	26.2	34	3.9	0.043	0.25
2670164	1 ¼" — 40 mm SDR 11	10	40	3.7	32.6	42	4.7	0.067	0.37
2670166	1 ½" — 50 mm SDR 11	5	50	4.6	40.8	52	5.6	0.105	0.55
2670168	2" — 63 mm SDR 11	5	63	5.8	51.4	65	6.8	0.167	0.84
2670170	2 ½" — 75 mm SDR 11	5	75	6.8	61.4	77	7.8	0.238	1.14
2670172	3" — 90 mm SDR 11	3	90	8.2	73.6	92	9.2	0.342	1.66
2670174	3 ½" — 110 mm SDR 11	2	110	10.0	90.0	112	11.0	0.512	2.46
2670176	4" — 125 mm SDR 11	1	125	11.4	102.2	127	12.4	0.660	3.12
2670180	6" — 160 mm SDR 11	1	160	14.6	130.8	162	15.6	1.032	4.88
2670184	8" — 200 mm SDR 11	1	200	18.2	163.6	202	19.2	1.622	7.54
2670188	10" — 250 mm SDR 11	1	250	22.7	204.6	252	23.7	2.544	11.69

[a] ½" - 4" pipes come in standard 13 ft lengths (4 m). 6" - 14" pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.

aquatherm blue pipe® UV faser-composite pipe SDR 17.6

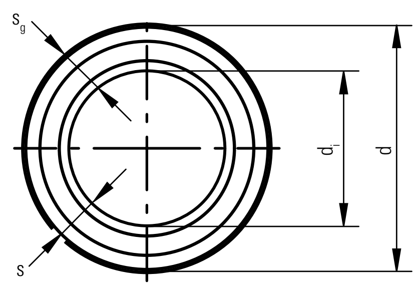


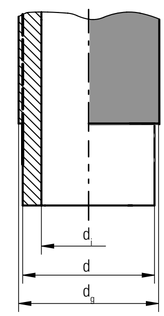
Material: fusiolen® PP-R

In accordance with:

- NSF-14
- CSA-B137.11
- ICC AC 122
- ICC ESR 1613
- ASTM F 2389

Appearance: Light blue with black exterior.





NSF system certification: Including fittings, connection pieces and connection techniques.

Fields of application: All the same applications as the standard aquatherm blue pipe® SDR 17.6 faser-composite, but for installations where the pipe is exposed to UV radiation.

Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	(d) total	(s) total	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	d_g (mm)	s_g (mm)	gal/ft	lb/ft
2570180	6″ — 160 mm	25	20	2.8	14.4	22	3.8	0.013	0.14
2570184	8″ — 200 mm	25	25	3.5	18.0	27	4.5	0.020	0.21
2570188	10″ — 250 mm	10	32	4.4	23.6	34	5.4	0.034	0.33
2570192	12″ — 315 mm	10	32	2.9	26.2	34	3.9	0.043	0.25
2570194	14″ — 355 mm	10	40	3.7	32.6	42	4.7	0.067	0.37
2570196	16″ — 400 mm	5	50	4.6	40.8	52	5.6	0.105	0.55
2570198	18″ — 450 mm	5	63	5.8	51.4	65	6.8	0.167	0.84
2570200	20″ — 500 mm	5	75	6.8	61.4	77	7.8	0.238	1.14
2570202	22″ — 560 mm	3	90	8.2	73.6	92	9.2	0.342	1.66
2570204	24″ — 630 mm	2	110	10.0	90.0	112	11.0	0.512	2.46

[a] ½″ - 4″ pipes come in standard 13 ft lengths (4 m). 6″ - 14″ pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.

aquatherm lilac pipe® SDR 7.4/11 for recycled / reclaimed water

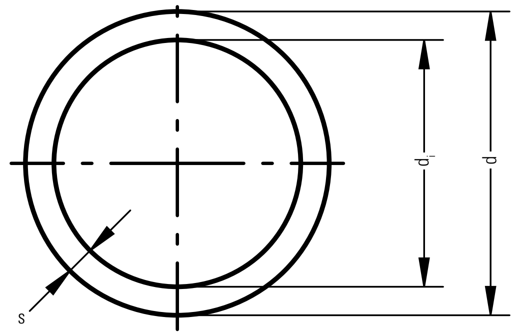
Material: fusiolen® **PP-R**

In accordance with:

- NSF-14
- CSA B 137.11

Appearance: Light purple.

Fields of application: For rainwater and reclaimed water systems, greywater supply.

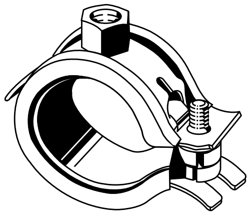


Pipe[a]			Diameter[b]	Wall thickness	Internal diameter	Water capacity	Weight[c]
Part no.	Dimension ND — OD	Packing unit	d (mm)	s (mm)	d_i (mm)	gal/ft	lb/ft
9010808	½" — 20 mm SDR 7.4	25	20	2.8	14.4	0.013	0.10
9010810	¾" — 25 mm SDR 7.4	25	25	3.5	18.0	0.020	0.16
9010212	1" — 32 mm SDR 11	10	32	2.9	26.2	0.043	0.18
9010214	1 ¼" — 40 mm SDR 11	10	40	3.7	32.6	0.067	0.28
9010216	1 ½" — 50 mm SDR 11	5	50	4.6	40.8	0.105	0.43
9010218	2" — 63 mm SDR 11	5	63	5.8	51.4	0.167	0.68
9010220	2 ½" — 75 mm SDR 11	5	75	6.8	61.4	0.238	0.95
9010222	3" — 90 mm SDR 11	3	90	8.2	73.6	0.342	1.36
9010224	3 ½" — 110 mm SDR 11	2	110	10.0	90.0	0.512	2.02
9010226	4" — 125 mm SDR 11	1	125	11.4	102.2	0.660	2.63
9010230	6" — 160 mm SDR 11	1	160	14.6	130.8	1.081	4.29
9010234	8" — 200 mm SDR 11	1	200	18.2	163.6	1.692	6.69
9010238	10" — 250 mm SDR 11	1	250	22.7	204.6	2.646	10.42

[a] ½" - 4" pipes come in standard 13 ft lengths (4 m). 6" - 14" pipes come in standard 19 ft lengths (5.8 m).
[b] To calculate exact dimensions of the pipe in imperial inches, divide the metric measurement by 25.4.
[c] To calculate the weight of the pipe in kg/m, multiply the measurement by 1.5.

Pipe clamps for aquatherm pipes

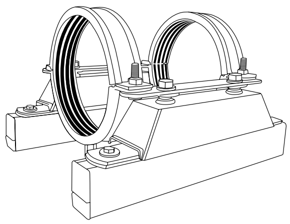
Part no.	Dimension ND — OD	[lb]
0060520	½” — 20 mm	0.11
0060525	¾” — 25 mm	0.11
0060532	1” — 32 mm	0.13
0060540	1 ¼” — 40 mm	0.15
0060550	1 ½” — 50 mm	0.17
0060563	2” — 63 mm	0.20
0060575	2 ½” — 75 mm	0.23
0060590	3” — 90 mm	0.28
0060594	3 ½” — 110 mm	0.34
0060595	4” — 125 mm	0.47
0060597	6” — 160 mm	0.75
0060650	8” — 200 mm	2.24
0060654	10” — 250 mm	2.63
0060658	12” — 315 mm	3.73
0060660	14” — 355 mm	-



Suitable for sliding and fixed point installation.

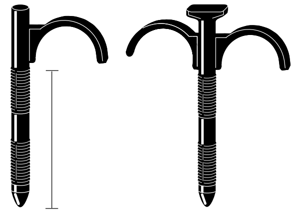
Pipe clamps for aquatherm pipe fixed point installation

Part no.	Dimension ND — OD	[lb]
0060668	6” — 160 mm	8.89
0060670	8” — 200 mm	22.26
0060674	10” — 250 mm	23.37
0060678	12” — 315 mm	-



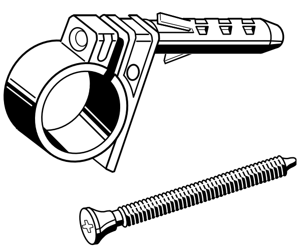
Pipe fastening strap suitable for ⅜” - 1” (16 - 32 mm) pipe

Part no.	Dimension	[lb]
0060604	Single — 1 ⅜” (45 mm)	0.01
0060606	Single — 2 ½” (75 mm)	0.02
0060608	Double — 1 ⅜” (45 mm)	0.02
0060610	Double — 2 ½” (75 mm)	0.02

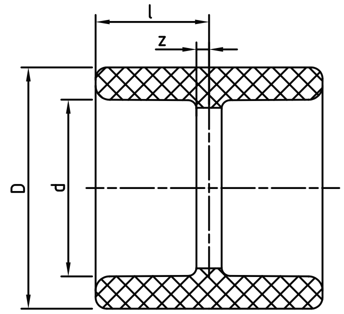


Plastic pipe clamps for aquatherm pipe

Part no.	Dimension ND — OD	[lb]
0060620	½” — 20 mm	0.02
0060625	¾” — 25 mm	0.04

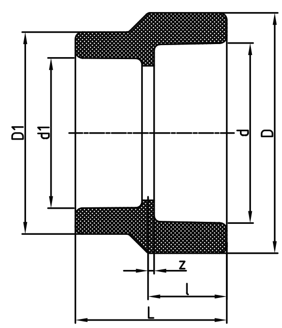


aquatherm green pipe® coupling



Part no.	Dimension ND — OD	d	l	z	D	Weight
		[in]	[in]	[in]	[in]	[lb]
0111008	½" — 20 mm	0.79	0.63	0.06	1.16	0.02
0111010	¾" — 25 mm	0.98	0.69	0.06	1.34	0.04
0111012	1" — 32 mm	1.26	0.80	0.09	1.69	0.06
0111014	1¼" — 40 mm	1.57	0.94	0.13	2.05	0.10
0111016	1½" — 50 mm	1.97	1.04	0.12	2.68	0.19
0111018	2" — 63 mm	2.48	1.19	0.11	3.31	0.28
0111020	2½" — 75 mm	2.95	1.31	0.13	3.94	0.46
0111022	3" — 90 mm	3.54	1.43	0.13	4.72	0.73
0111024	3½" — 110 mm	4.33	1.61	0.16	5.79	1.31
0111026	4" — 125 mm	4.92	1.77	0.20	6.57	1.78

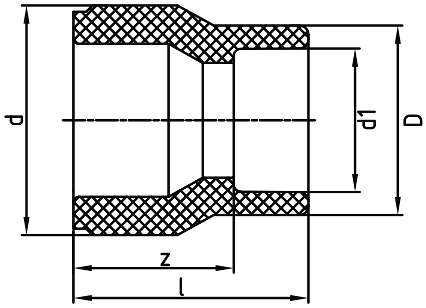
aquatherm green pipe® reducing coupling female/female



Part no.	Dimension ND — OD	d	d1	L	l	z	D	D1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0111222	1 ¼" to 1" — 40 to 32 mm	1.57	1.26	1.73	0.94	0.14	2.05	1.69	0.08
0111228	1 ½" to 1" — 50 to 32 mm	1.97	1.26	1.85	1.04	0.12	2.68	1.69	0.25
0111230	1 ½" to 1 ¼" — 50 to 40 mm	1.97	1.57	1.99	1.04	0.12	2.68	2.05	0.15
0111236	2" to 1 ¼" — 63 to 40 mm	2.48	1.57	2.13	1.20	0.12	3.31	2.05	0.23
0111238	2" to 1 ½" — 63 to 50 mm	2.48	1.97	2.20	1.18	0.10	3.31	2.68	0.26
0111240	2 ½" to 1 ½" — 75 to 50 mm	2.95	1.97	2.36	1.32	0.14	3.94	2.68	0.38
0111242	2 ½" to 2" — 75 to 63 mm	2.95	2.48	2.46	1.28	0.10	3.94	3.31	0.41
0111252	3" to 2" — 90 to 63 mm	3.54	2.48	2.62	1.44	0.14	4.72	3.31	0.61
0111253	3" to 2 ½" — 90 to 75 mm	3.54	2.95	2.72	1.42	0.12	4.72	3.94	0.34
0111257	3 ½" to 2 ½" — 110 to 75 mm	4.33	2.95	2.93	1.61	0.16	5.79	3.94	1.21
0111259	3 ½" to 3" — 110 to 90 mm	4.33	3.54	3.05	1.61	0.16	5.79	4.72	1.19
0111263	4" to 3" — 125 to 90 mm	4.92	3.54	3.27	1.81	0.24	6.57	4.72	1.65
0111265	4" to 3 ½" — 125 to 110 mm	4.92	4.33	3.43	1.81	0.24	6.57	5.79	1.67

aquatherm green pipe® bushing
(female to male for use with standard fitting)

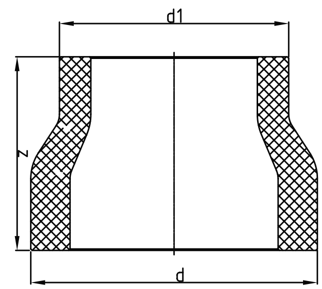
Appearance of bushing will vary by dimension. Female side is identified by a socket-fitting structure. Male side is identified with a beveled edge.



Part no.	Dimension ND — OD (M to F)	d	d1	l	z	D	Weight
		[in]	[in]	[in]	[in]	[in]	[lb]
0111112	¾" to ½" — 25 to 20 mm	0.98	0.79	1.52	0.94	1.16	0.03
0111114	1" to ½" — 32 to 20 mm	1.26	0.79	1.48	0.91	1.16	0.04
0111116	1" to ¾" — 32 to 25 mm	1.26	0.98	1.50	0.87	1.34	0.05
0111118	1 ¼" to ½" — 40 to 20 mm	1.57	0.79	1.77	1.20	1.16	0.06
0111120	1 ¼" to ¾" — 40 to 25 mm	1.57	0.98	1.97	1.34	1.34	0.08
0111122	1 ¼" to 1" — 40 to 32 mm	1.57	1.26	1.97	1.26	1.69	0.08
0111124	1 ½" to ½" — 50 to 20 mm	1.97	0.79	2.17	1.59	1.16	0.10
0111126	1 ½" to ¾" — 50 to 25 mm	1.97	0.98	2.17	1.54	1.34	0.09
0111128	1 ½" to 1" — 50 to 32 mm	1.97	1.26	2.13	1.42	1.69	0.12
0111130	1 ½" to 1 ¼" — 50 to 40 mm	1.97	1.57	2.07	1.26	2.05	0.13
0111131	2" to ½" — 63 to 20 mm	2.48	0.79	2.56	1.99	1.16	0.16
0111132	2" to ¾" — 63 to 25 mm	2.48	0.98	2.56	1.93	1.34	0.15
0111134	2" to 1" — 63 to 32 mm	2.48	1.26	2.44	1.73	1.69	0.19
0111136	2" to 1 ¼" — 63 to 40 mm	2.48	1.57	2.56	1.75	2.05	0.20
0111138	2" to 1 ½" — 63 to 50 mm	2.48	1.97	2.50	1.57	2.68	0.26
0111143	2 ½" to ½" — 75 to 20 mm	2.95	1.57	2.74	1.93	2.05	0.24
0111144	2 ½" to ¾" — 75 to 25 mm	2.95	1.97	2.48	1.56	2.68	0.24
0111145	2 ½" to 1" — 75 to 32 mm	2.95	2.48	2.80	1.71	3.31	0.29
0111139	2 ½" to 1 ¼" — 75 to 40 mm	2.95	0.79	2.58	2.01	1.36	0.29
0111140	2 ½" to 1 ½" — 75 to 50 mm	2.95	0.98	2.58	1.95	1.36	0.34
0111142	2 ½" to 2" — 75 to 63 mm	2.95	1.26	2.74	2.03	2.05	0.40
0111151	3" to 1 ½" — 90 to 50 mm	3.54	1.97	2.95	2.03	2.68	0.46
0111152	3" to 2" — 90 to 63 mm	3.54	2.48	3.07	1.99	3.31	0.54
0111153	3" to 2 ½" — 90 to 75 mm	3.54	2.95	3.21	2.03	3.94	0.64
0111155	3 ½" to 2" — 110 to 63 mm	4.33	2.48	3.39	2.30	3.31	0.77
0111157	3 ½" to 2 ½" — 110 to 75 mm	4.33	2.95	3.50	2.32	3.94	0.89
0111159	3 ½" to 3" — 110 to 90 mm	4.33	3.54	3.90	2.60	4.72	1.17
0111161	4" to 2 ½" — 125 to 75 mm	4.92	2.95	3.98	2.80	3.94	1.17
0111163	4" to 3" — 125 to 90 mm	4.92	3.54	3.90	2.60	4.72	1.17
0111165	4" to 3 ½" — 125 to 110 mm	4.92	4.33	4.41	2.95	5.79	1.81

aquatherm green pipe® butt weld reducer

SDR	Part no.	Dimension ND — OD	d	d1	z	Weight
			[in]	[in]	[in]	[lb]
	0111184	8” to 6” — 200 to 160 mm	7.87	6.30	5.31	3.46
	0111188	10” to 6” — 250 to 160 mm	9.84	6.30	6.80	6.39
	0111190	10” to 8” — 250 to 200 mm	9.84	7.87	6.89	7.08
7.4	0111192	12” to 8” — 315 to 200 mm	12.40	7.87	8.86	-
	0111194	12” to 10” — 315 to 250 mm	12.40	9.84	8.86	-
	0111196	14” to 10” — 355 to 250 mm	13.98	9.84	6.69	11.64
	0111198	14” to 12” — 355 to 315 mm	13.98	12.40	6.30	-
	0111185	8” to 6” — 200 to 160 mm	7.87	6.30	5.31	2.58
	0111189	10” to 6” — 250 to 160 mm	9.84	6.30	6.89	7.65
	0111191	10” to 8” — 250 to 200 mm	9.84	7.87	6.89	5.14
	0111193	12” to 8” — 315 to 200 mm	12.40	7.87	8.86	7.52
	0111195	12” to 10” — 315 to 250 mm	12.40	9.84	9.17	10.25
	0111197	14” to 10” — 355 to 250 mm	13.98	9.84	9.65	8.69
11	0111199	14” to 12” — 355 to 315 mm	13.98	12.40	6.30	9.58
	0111201	16” to 10” — 400 to 250 mm	15.75	9.84	10.24	-
	0111203	16” to 12” — 400 to 315 mm	15.75	12.40	10.24	-
	0111204	16” to 14” — 400 to 355 mm	15.75	13.98	10.24	-
	0111206	18” to 12” — 450 to 315 mm	17.72	12.40	9.05	-
	0111207	18” to 14” — 450 to 355 mm	17.72	13.98	9.05	-
	0111208	18” to 16” — 450 to 400 mm	17.72	15.75	9.05	-
	2511184	8” to 6” — 200 to 160 mm	7.87	6.30	5.31	2.29
	2511188	10” to 6” — 250 to 160 mm	9.84	6.30	6.80	4.55
	2511190	10” to 8” — 250 to 200 mm	9.84	7.87	6.80	4.55
	2511193	12” to 8” — 315 to 200 mm	12.40	7.87	6.80	9.30
	2511195	12” to 10” — 315 to 250 mm	12.40	9.84	8.86	10.05
	2511197	14” to 10” — 355 to 250 mm	13.98	9.84	9.65	9.10
	2511199	14” to 12” — 355 to 315 mm	13.98	12.40	6.30	10.20
	2511201	16” to 10” — 400 to 250 mm	15.75	9.84	10.24	9.88
	2511203	16” to 12” — 400 to 315 mm	15.75	12.40	10.24	10.50
	2511204	16” to 14” — 400 to 355 mm	15.75	13.98	10.24	12.68
	2511206	18” to 12” — 450 to 315 mm	17.72	12.40	9.05	11.10
	2511207	18” to 14” — 450 to 355 mm	17.72	13.98	9.05	10.34
17.6	2511208	18” to 16” — 450 to 400 mm	17.72	15.75	9.05	9.45
	2511209	20” to 12” — 500 to 315 mm	19.68	12.40	9.05	17.86
	2511210	20” to 14” — 500 to 355 mm	19.68	13.98	9.05	14.33
	2511211	20” to 16” — 500 to 400 mm	19.68	15.75	9.05	14.77
	2511212	20” to 18” — 500 to 450 mm	19.68	17.72	9.05	12.13
	2511213	22” to 16” — 560 to 400 mm	22.05	15.75	9.05	19.84
	2511214	22” to 18” — 560 to 450 mm	22.05	17.72	7.87	19.96
	2511215	22” to 20” — 560 to 500 mm	22.05	19.68	7.87	16.76
	2511216	24” to 16” — 630 to 400 mm	24.80	15.75	9.05	33.29
	2511217	24” to 18” — 630 to 450 mm	24.80	17.72	7.87	30.20
	2511218	24” to 20” — 630 to 500 mm	24.80	19.68	7.87	24.25
	2511219	24” to 22” — 630 to 560 mm	24.80	22.02	7.87	19.84

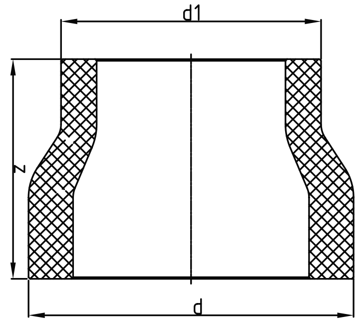


The butt weld reducer can be used with either the aquatherm green pipe® or aquatherm blue pipe® systems, but are all molded from the green fusiolen® material. The SDR of the fittings must match the SDR of the pipe.

aquatherm green pipe® reducing coupling

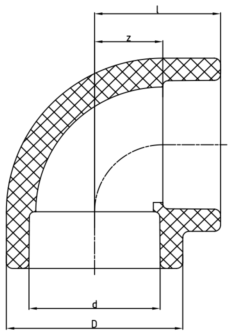
socket welded on one side, butt welded on the other

The following fittings can be used with either the **aquatherm green pipe®** or **aquatherm blue pipe®** systems, but are all molded from the green **fusiolen®** material. The SDR of the fittings must match the SDR of the pipe.



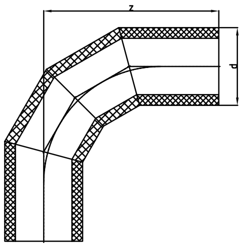
SDR	Part no.	Dimension ND — OD	d	d1	l	z	D	Weight
			[in]	[in]	[in]	[in]	[in]	[lb]
7.4	0111174	6” to 3 ½” — 160 to 110 mm	6.30	4.33	3.43	1.97	5.79	1.59
	0111176	6” to 4” — 160 to 125 mm	6.30	4.92	3.54	1.97	6.57	1.80
	0111182	8” to 4” — 200 to 125 mm	7.87	4.92	5.31	3.74	6.57	3.53
11	0111175	6” to 3 ½” — 160 to 110 mm	6.30	4.33	3.54	2.09	5.79	1.31
	0111177	6” to 4” — 160 to 125 mm	6.30	4.92	3.54	1.97	6.57	1.55
	0111183	8” to 4” — 200 to 125 mm	7.87	4.92	5.31	3.74	6.57	2.99
17.6	2511174	6” to 3 ½” — 160 to 110 mm	6.30	4.33	3.54	2.09	5.79	-
	2511176	6” to 4” — 160 to 125 mm	6.30	4.92	3.54	1.97	6.57	1.39
	2511182	8” to 4” — 200 to 125 mm	7.87	4.92	5.31	3.74	6.57	2.33

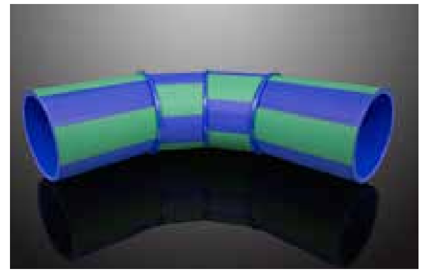
aquatherm green pipe® elbow 90° (socket)



Part no.	Dimension ND — OD	d	z	l	D	Weight
		[in]	[in]	[in]	[in]	[lb]
0112108	½” — 20 mm	0.79	0.43	1.00	1.16	0.04
0112110	¾” — 25 mm	0.98	0.53	1.16	1.34	0.05
0112112	1” — 32 mm	1.26	0.67	1.38	1.69	0.09
0112114	1 ¼” — 40 mm	1.57	0.83	1.63	2.05	0.16
0112116	1 ½” — 50 mm	1.97	1.02	1.95	2.68	0.36
0112118	2” — 63 mm	2.48	1.28	2.36	3.31	0.64
0112120	2 ½” — 75 mm	2.95	1.52	2.70	3.94	0.98
0112122	3” — 90 mm	3.54	1.81	3.11	4.72	1.64
0112124	3 ½” — 110 mm	4.33	2.20	3.66	5.79	2.83
0112126	4” — 125 mm	4.92	3.01	4.59	6.57	4.42

aquatherm green pipe® elbow 90°





SDR	Part no.	Dimension ND — OD	d [in]	z [in]	Weight [lb]
7.4	0112130[a]	6" — 160 mm	6.30	5.71	5.64
7.4	0112130L[b]	6" — 160 mm	6.30	17.46	18.44
7.4	0112134	8" — 200 mm	7.87	17.72	25.76
7.4	0112138	10" — 250 mm	9.84	24.61	57.32
7.4	0112142	12" — 315 mm	12.40	30.43	54.01
7.4	0112144	14" — 355 mm	13.98	32.79	-
11	0112131	6" — 160 mm	6.30	5.71	4.22
11	0112131LG[b]	6" — 160 mm	6.30	17.46	13.26
11	0112135	8" — 200 mm	7.87	17.72	17.95
11	0112139	10" — 250 mm	9.84	24.61	39.69
11	0112143	12" — 315 mm	12.40	30.43	83.45
11	0112145	14" — 355 mm	13.98	32.79	82.45
11	0112147[c]	16" — 400 mm	15.75	35.43	89.56
11	0112149[c]	18" — 450 mm	17.72	38.39	119.99

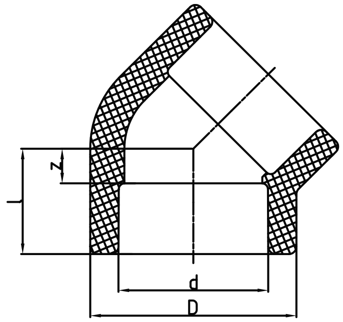
[a] Molded fitting, made from green **fusiolen**®.
[b] Molded fitting, made from green **fusiolen**® with 1-ft extension on each end.
[c] Mechanically stabilized with a faser-composite layer in the center of the pipe.

aquatherm blue pipe® elbow 90°

SDR	Part no.	Dimension ND — OD	d [in]	z [in]	Weight [lb]
11	0112131[a]	6" — 160 mm	6.30	5.71	4.22
11	0112131LB[b]	6" — 160 mm	6.30	17.46	13.26
11	2612135	8" — 200 mm	7.87	17.72	24.08
11	2612139	10" — 250 mm	9.84	21.61	46.38
11	2012143	12" — 315 mm	12.40	30.43	82.23
11	2012145	14" — 355 mm	13.98	32.79	58.75
11	2012147	16" — 400 mm	15.75	35.43	164.24
11	2012149	18" — 450 mm	17.72	38.39	176.05
17.6	2512130	6" — 160 mm	6.30	15.35	7.06
17.6	2512134	8" — 200 mm	7.87	17.72	15.99
17.6	2512138	10" — 250 mm	9.84	24.61	28.44
17.6	2512142	12" — 315 mm	12.40	30.41	52.91
17.6	2512144	14" — 355 mm	13.98	32.79	70.55
17.6	2512146	16" — 400 mm	15.75	35.43	85.07
17.6	2512148	18" — 450 mm	17.72	38.39	114.30
17.6	2512150	20" — 500 mm	19.69	43.31	155.49
17.6	2512152	22" — 560 mm	22.05	46.85	204.80
17.6	2512154	24" — 630 mm	24.80	50.98	268.26

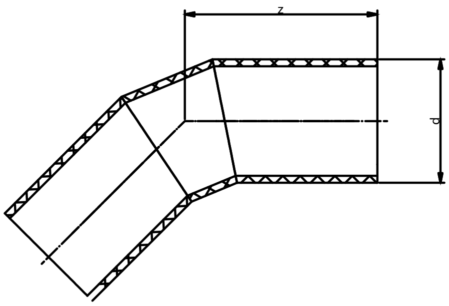
[a] Molded fitting, made from green **fusiolen**®.
[b] Molded fitting, made from green **fusiolen**® with 1-ft extension on each end.

aquatherm green pipe® **elbow 45°** (socket)



Part no.	Dimension ND — OD	d	z	l	D	Weight
		[in]	[in]	[in]	[in]	[lb]
0112508	½" -- 20 mm	0.79	0.20	0.77	1.16	0.02
0112510	¾" -- 25 mm	0.98	0.24	0.87	1.34	0.03
0112512	1" -- 32 mm	1.26	0.30	1.00	1.69	0.08
0112514	1 ¼" -- 40 mm	1.57	0.37	1.18	2.05	0.12
0112516	1 ½" -- 50 mm	1.97	0.45	1.38	2.68	0.25
0112518	2" -- 63 mm	2.48	0.55	1.63	3.31	0.49
0112520	2 ½" -- 75 mm	2.95	0.65	1.83	3.94	0.77
0112522	3" -- 90 mm	3.54	0.77	2.07	4.72	1.26
0112524	3 ½" -- 110 mm	4.33	0.93	2.38	5.79	2.25
0112526	4" -- 125 mm	4.92	1.06	2.64	6.57	2.89

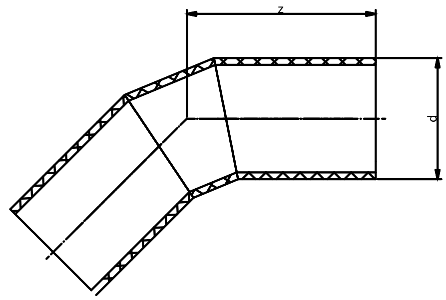
aquatherm green pipe® **elbow 45°**

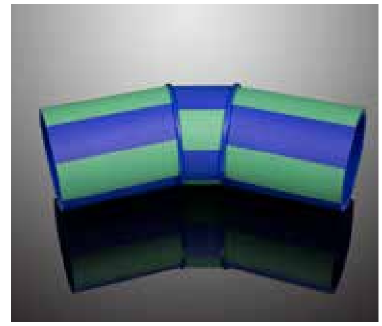


SDR	Part no.	Dimension ND — OD	d	z	Weight
			[in]	[in]	[lb]
7.4	0112530[a]	6" — 160 mm	6.30	3.74	4.14
	0112530L[b]	6" — 160 mm	6.30	15.49	16.96
	0112534	8" — 200 mm	7.87	10.79	18.02
	0112538	10" — 250 mm	9.84	16.22	28.66
	0112542	12" — 315 mm	12.40	20.35	62.63
	0112544	14" — 355 mm	13.98	20.47	79.55
11	0112531[a]	6" — 160 mm	6.30	3.74	3.04
	0112531LG[b]	6" — 160 mm	6.30	15.49	12.08
	0112535	8" — 200 mm	7.87	10.79	12.64
	0112539	10" — 250 mm	9.84	16.22	28.66
	0112543	12" — 315 mm	12.4	20.35	60.19
	0112545	14" — 355 mm	13.98	20.47	58.75
	0112547[c]	16" — 400 mm	15.75	21.57	105.49
	0112549[c]	18" — 450 mm	17.72	22.83	138.56

[a] Molded fitting, made from green **fusiolen**®.
[b] Molded fitting, made from green **fusiolen**® with 1-ft extension on each end.
[c] Mechanically stabilized with a faser-composite layer in the center of the pipe.

aquatherm blue pipe® elbow 45°

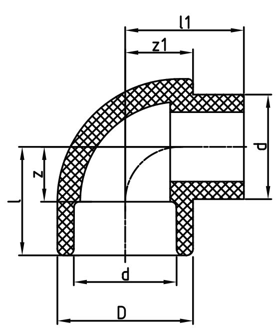




SDR	Part no.	Dimension ND — OD	d	z	Weight
			[in]	[in]	[lb]
11	0112531[a]	6" — 160 mm	6.30	3.74	3.04
	0112531LB[b]	6" — 160 mm	6.30	15.49	12.08
	2612535	8" — 200 mm	7.87	10.79	14.08
	2612539	10" — 250 mm	9.84	16.22	27.38
	2012543	12" — 315 mm	12.4	20.35	59.75
	2012545	14" — 355 mm	13.98	20.47	92.59
	2012547	16" — 400 mm	15.75	21.57	-
	2012549	18" — 450 mm	17.72	22.83	-
17.6	2512530	6" — 160 mm	6.30	9.80	5.37
	2512534	8" — 200 mm	7.87	10.79	8.57
	2512538	10" — 250 mm	9.84	16.22	20.72
	2512542	12" — 315 mm	12.40	19.60	36.05
	2512544	14" — 355 mm	13.98	20.47	51.15
	2512546	16" — 400 mm	15.75	21.47	67.90
	2512548	18" — 450 mm	17.73	22.83	87.65
	2512550	20" — 500 mm	19.69	26.18	-
	2512552	22" — 560 mm	22.05	27.48	-
	2512554	24" — 630 mm	24.80	29.17	-

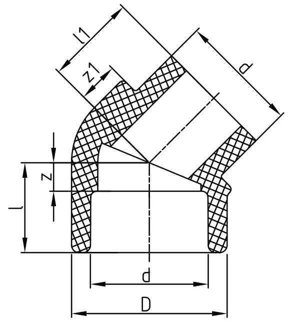
[a] Molded fitting, made from green **fusiolen**®.
[b] Molded fitting, made from green **fusiolen**® with 1-ft extension on each end.

aquatherm green pipe® street 90° female/male



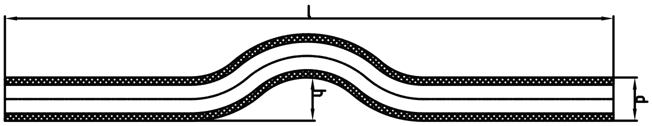
Part no.	Dimension ND — OD	d	z	l	D	l1	z1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0112308	½" — 20 mm	0.79	0.43	1.00	1.16	1.00	0.59	0.40
0112310	¾" — 25 mm	0.98	0.53	1.16	1.34	1.16	0.67	0.05
0112312	1" — 32 mm	1.26	0.67	1.38	1.69	1.54	0.85	0.10
0112314	1 ¼" — 40 mm	1.57	0.83	1.63	2.05	1.79	1.02	0.18

aquatherm green pipe® **street 45°** female/male



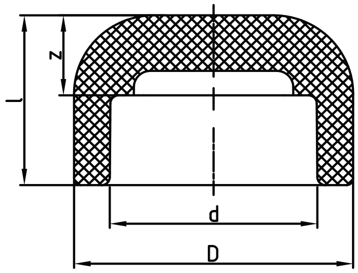
Part no.	Dimension ND — OD	d	z	l	D	l1	z1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0112708	½" — 20 mm	0.79	0.20	0.77	1.16	0.77	0.35	0.03
0112710	¾" — 25 mm	0.98	0.24	0.87	1.34	0.87	0.33	0.04
0112712	1" — 32 mm	1.26	0.30	1.00	1.69	1.12	0.45	0.08
0112714	1 ¼" — 40 mm	1.57	0.37	1.18	2.05	1.20	0.53	0.13

aquatherm green pipe® **cross-over**



Part no.	Dimension ND — OD	d	h	l	Weight
		[in]	[in]	[in]	[lb]
0116108	½" — 20 mm	0.79	0.87	13.86	0.13
0116110	¾" — 25 mm	0.98	0.98	13.86	0.20
0116112	1" — 32 mm	1.26	1.26	13.86	0.34

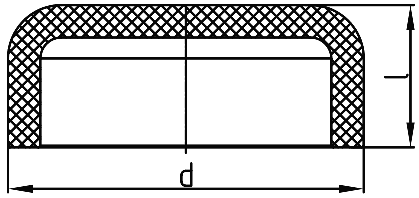
aquatherm green pipe® **end cap**



Part no.	Dimension ND — OD	d	z	l	D	Weight
		[in]	[in]	[in]	[in]	[lb]
0114108	½" — 20 mm	0.79	0.94	0.37	0.37	0.02
0114110	¾" — 25 mm	0.98	0.94	0.31	0.16	0.02
0114112	1" — 32 mm	1.26	1.24	0.53	1.69	0.04
0114114	1 ¼" — 40 mm	1.57	1.50	0.69	2.05	0.10
0114116	1 ½" — 50 mm	1.97	1.75	0.83	2.68	0.18
0114118	2" — 63 mm	2.48	2.05	0.96	3.31	0.32
0114120	2 ½" — 75 mm	2.95	2.30	1.12	3.94	0.54
0114122	3" — 90 mm	3.54	2.26	1.36	4.72	0.81
0114124	3 ½" — 110 mm	4.33	2.56	1.10	5.79	1.30
0114126	4" — 125 mm	4.92	2.76	1.18	6.57	1.90

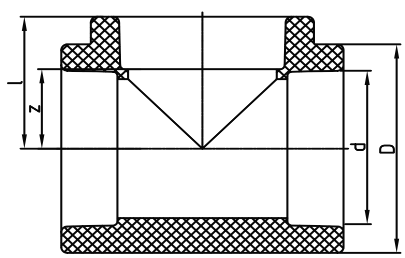
aquatherm end cap

The following fittings can be used with either the aquatherm green pipe® or aquatherm blue pipe ® systems, but are all molded from the green fusiolen® material. The SDR of the fittings must match the SDR of the pipe.



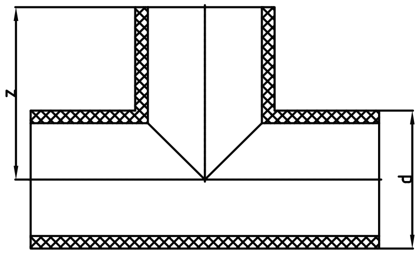
SDR	Part no.	Dimension ND — OD	d [in]	l [in]	Weight [lb]
7.4	0114130	6″ — 160 mm	6.30	2.76	2.02
	0114134	8″ — 200 mm	7.87	3.15	3.04
	0114138	10″ — 250 mm	9.84	3.54	5.58
	0114142	12″ — 315 mm	12.40	-	-
	0114144	14″ — 355 mm	13.98	-	-
11	0114131	6″ — 160 mm	6.30	2.76	1.80
	0114135	8″ — 200 mm	7.87	3.15	2.36
	0114139	10″ — 250 mm	9.84	3.54	4.39
	0114143	12″ — 315 mm	12.40	10.63	13.67
	0114145	14″ — 355 mm	13.98	2.56	20.94
	0114147	16″ — 400 mm	15.75	2.36	-
	0114149	18″ — 450 mm	17.72	2.76	-
17.6	2514130	6″ — 160 mm	6.30	2.84	1.50
	2514134	8″ — 200 mm	7.87	3.10	2.04
	2514138	10″ — 250 mm	9.84	-	4.65
	2514142	12″ — 315 mm	12.40	1.98	6.53
	2514144	14″ — 355 mm	13.98	-	8.66
	2514146	16″ — 400 mm	15.75	2.36	12.83
	2514148	18″ — 450 mm	17.72	2.76	18.78
	2514150	20″ — 500 mm	19.69	2.99	27.56
	2514152	22″ — 560 mm	22.05	3.15	35.27
	2514154	24″ —630 mm	24.80	3.54	51.81

aquatherm green pipe® tee (socket)



Part no.	Dimension ND — OD	d [in]	z [in]	l [in]	D [in]	Weight [lb]
0113108	½″ — 20 mm	0.79	0.43	1.00	1.16	0.05
0113110	¾″ — 25 mm	0.98	0.59	1.22	1.34	0.07
0113112	1″ — 32 mm	1.26	0.67	1.38	1.69	0.12
0113114	1 ¼″ — 40 mm	1.57	0.79	1.59	2.05	0.22
0113116	1 ½″ — 50 mm	1.97	1.02	1.95	2.68	0.39
0113118	2″ — 63 mm	2.48	1.28	2.36	3.31	0.82
0113120	2 ½″ — 75 mm	2.95	1.52	2.70	3.94	1.19
0113122	3″ — 90 mm	3.54	1.81	3.11	4.72	2.04
0113124	3 ½″ — 110 mm	4.33	2.20	3.66	5.79	3.55
0113126	4″ — 125 mm	4.92	3.01	4.59	6.57	5.85

aquatherm green pipe® tee



SDR	Part no.	Dimension ND — OD	d	z	Weight
			[in]	[in]	[lb]
7.4	0113130[a]	6" — 160 mm	6.30	5.71	7.88
	0113130L[b]	6" — 160 mm	6.30	17.46	27.11
	0113134	8" — 200 mm	7.87	9.84	21.66
	0113138	10" — 250 mm	9.84	14.76	48.50
	0113142	12" — 315 mm	12.40	18.11	100.20
	0113144	14" — 355 mm	13.98	18.90	143.19
11	0113131[a]	6" — 160 mm	6.30	5.71	6.15
	0113131LG[b]	6" — 160 mm	6.30	17.46	19.08
	0113135	8" — 200 mm	7.87	9.84	15.14
	0113139	10" — 250 mm	9.84	14.76	35.28
	0113143	12" — 315 mm	12.40	18.11	45.09
	0113145	14" — 355 mm	13.98	18.90	94.46
	0113147[c]	16" — 400 mm	15.75	19.69	105.50
	0113149[c]	18" — 450 mm	17.72	20.67	138.56

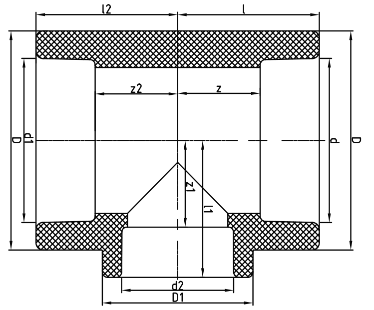
[a] Molded fitting, made from green **fusiolen**®.
[b] Molded fitting, made from green **fusiolen**® with 1-ft extension on each end.
[c] Mechanically stabilized with a faser-composite layer in the center of the pipe.

aquatherm blue pipe® tee

SDR	Part No.	Dimension ND — OD	d	z	Weight
			[in]	[in]	lb/pc
11	0113131[a]	6" — 160 mm	6.30	5.71	7.88
	0113131LB[b]	6" — 160 mm	6.30	17.46	12.40
	2613135	8" — 200 mm	7.87	9.84	15.14
	2613139	10" — 250 mm	9.84	14.76	35.27
	2013143	12" — 315 mm	12.40	18.11	45.09
	2013145	14" — 355 mm	13.98	18.90	92.59
	2013147	16" — 400 mm	15.75	19.69	130.75
	2013149	18" — 450 mm	17.76	20.67	176.05
17.6	2513130	6" — 160 mm	6.30	5.71	5.99
	2513134	8" — 200 mm	7.87	9.84	15.99
	2513138	10" — 250 mm	9.84	14.76	25.35
	2513142	12" — 315 mm	12.40	18.11	48.50
	2513144	14" — 355 mm	13.98	18.90	60.63
	2513146	16" — 400 mm	15.75	19.69	90.50
	2513148	18" — 450 mm	17.76	20.67	125.73
	2513150	20" — 500 mm	19.69	23.62	169.62
	2513152	22" — 560 mm	22.05	24.80	247.17
	2513154	24" — 630 mm	24.05	26.18	312.97

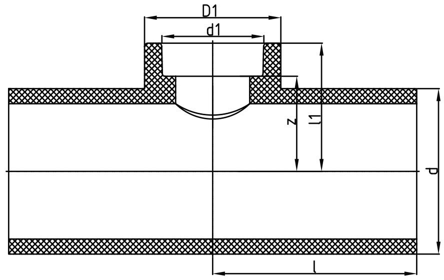
[a] Molded fitting, made from green **fusiolen**®.
[b] Molded fitting, made from green **fusiolen**® with 1-ft extension on each end.

aquatherm green pipe® reducing tee (inlet, outlet, branch)



Part no.	Dimension ND — OD	d	d1	d2	l	l1	l2	z	z1	z2	D	D1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0113511	½" x ½" x ¾" — 20 x 20 x 25 mm	0.79	0.79	0.98	1.22	1.20	1.22	0.65	0.57	0.65	1.34	1.34	0.09
0113520	¾" x ½" x ½" — 25 x 20 x 20 mm	0.98	0.79	0.79	1.22	1.20	1.22	0.59	0.63	0.65	1.34	1.34	0.08
0113522	¾" x ¾" x ½" — 25 x 25 x 20 mm	0.98	0.98	0.79	1.22	1.20	1.22	0.59	0.63	0.59	1.34	1.34	0.08
0113532	1" x ½" x ½" — 32 x 20 x 20 mm	1.26	0.79	0.79	1.44	1.46	1.44	0.74	0.89	0.88	1.69	1.69	0.17
0113534	1" x 1" x ½" — 32 x 32 x 20 mm	1.26	1.26	0.79	1.38	1.22	1.38	0.67	0.65	0.67	1.69	1.16	0.11
0113538	1" x ¾" x ¾" — 32 x 25 x 25 mm	1.26	0.98	0.98	1.38	1.36	1.38	0.67	0.73	0.59	1.69	1.69	0.15
0113540	1" x 1" x ¾" — 32 x 32 x 25 mm	1.26	1.26	0.98	1.38	1.36	1.38	0.67	0.73	0.67	1.69	1.69	0.11
0113542	1 ¼" x 1 ¼" x ½" — 40 x 40 x 20 mm	1.57	1.57	0.79	1.63	1.42	1.63	0.83	0.85	0.83	2.05	1.34	0.20
0113544	1 ¼" x 1 ¼" x ¾" — 40 x 40 x 25 mm	1.57	1.57	0.98	1.63	1.42	1.63	0.83	0.79	0.83	2.05	1.34	0.20
0113546	1 ¼" x 1 ¼" x 1" — 40 x 40 x 32 mm	1.57	1.57	1.26	1.65	1.59	1.65	0.85	0.89	0.85	2.05	2.05	0.20
0113547	1 ½" x 1 ½" x ½" — 50 x 50 x 20 mm	1.97	1.97	0.79	1.95	1.59	1.95	1.02	1.02	1.02	2.68	1.16	0.35
0113548	1 ½" x 1 ½" x ¾" — 50 x 50 x 25 mm	1.97	1.97	0.98	1.95	1.75	1.95	1.02	1.12	1.02	2.68	1.69	0.35
0113550	1 ½" x 1 ½" x 1" — 50 x 50 x 32 mm	1.97	1.97	1.26	1.95	1.75	1.95	1.02	1.04	1.02	2.68	1.69	0.35
0113551	1 ½" x 1 ½" x 1 ¼" — 50 x 50 x 40 mm	1.97	1.97	1.57	1.95	1.95	1.95	1.02	1.14	1.02	2.68	2.68	0.36
0113552	2" x 2" x ½" — 63 x 63 x 20 mm	2.48	2.48	0.79	2.36	1.91	2.36	1.28	1.34	1.28	3.31	1.34	0.74
0113554	2" x 2" x ¾" — 63 x 63 x 25 mm	2.48	2.48	0.98	2.36	1.91	2.36	1.28	1.28	1.28	3.31	1.34	0.73
0113556	2" x 2" x 1" — 63 x 63 x 32 mm	2.48	2.48	1.26	2.36	2.11	2.36	1.28	1.40	1.28	3.31	2.05	0.75
0113558	2" x 2" x 1 ¼" — 63 x 63 x 40 mm	2.48	2.48	1.57	2.36	2.11	2.36	1.28	1.30	1.28	3.31	2.05	0.73
0113560	2" x 2" x 1 ½" — 63 x 63 x 50 mm	2.48	2.48	1.97	2.36	2.36	2.36	1.28	1.44	1.28	3.31	3.31	0.89
0113561	2 ½" x 2 ½" x ½" — 75 x 75 x 20 mm	2.95	2.95	0.79	2.70	2.15	2.70	1.52	1.57	1.52	3.94	1.34	1.10
0113562	2 ½" x 2 ½" x ¾" — 75 x 75 x 25 mm	2.95	2.95	0.98	2.70	2.15	2.70	1.52	1.52	1.52	3.94	1.34	1.10
0113564	2 ½" x 2 ½" x 1" — 75 x 75 x 32 mm	2.95	2.95	1.26	2.70	2.32	2.70	1.52	1.61	1.52	3.94	2.05	1.12
0113566	2 ½" x 2 ½" x 1 ¼" — 75 x 75 x 40 mm	2.95	2.95	1.57	2.70	2.32	2.70	1.52	1.52	1.52	3.94	2.05	1.09
0113568	2 ½" x 2 ½" x 1 ½" — 75 x 75 x 50 mm	2.95	2.95	1.97	2.70	2.60	2.70	1.52	1.67	1.52	3.94	3.31	1.22
0113570	2 ½" x 2 ½" x 2" — 75 x 75 x 63 mm	2.95	2.95	2.48	2.70	2.60	2.70	1.52	1.52	1.52	3.94	3.31	1.14
0113576	3" x 3" x 1" — 90 x 90 x 32 mm	3.54	3.54	1.26	3.11	2.56	3.11	1.81	1.85	1.81	4.72	2.05	1.94
0113578	3" x 3" x 1 ¼" — 90 x 90 x 40 mm	3.54	3.54	1.57	3.11	2.56	3.11	1.81	1.75	1.81	4.72	2.05	1.92
0113580	3" x 3" x 1 ½" — 90 x 90 x 50 mm	3.54	3.54	1.97	3.11	2.95	3.11	1.81	2.03	1.81	4.72	3.31	2.00
0113582	3" x 3" x 2" — 90 x 90 x 63 mm	3.54	3.54	2.48	3.11	2.95	3.11	1.81	1.87	1.81	4.72	3.31	1.93
0113584	3" x 3" x 2 ½" — 90 x 90 x 75 mm	3.54	3.54	2.95	3.11	3.19	3.11	1.81	2.01	1.81	4.72	4.72	2.19
0113586	3 ½" x 3 ½" x 2" — 110 x 110 x 63 mm	4.33	4.33	2.48	3.66	3.44	3.66	2.20	2.36	2.20	5.79	3.94	3.45
0113588	3 ½" x 3 ½" x 2 ½" — 110 x 110 x 75 mm	4.33	4.33	2.95	3.66	3.44	3.66	2.20	2.26	2.20	5.79	3.94	3.31
0113590	3 ½" x 3 ½" x 2 ½" — 110 x 110 x 90 mm	4.33	4.33	3.54	3.66	3.50	3.66	2.20	2.20	2.20	5.79	4.72	3.38
0113592	4" x 4" x 2 ½" — 125 x 125 x 75 mm	4.92	4.92	2.95	4.59	4.19	4.59	3.01	3.01	3.01	6.57	3.94	5.34
0113594	4" x 4" x 3" — 125 x 125 x 90 mm	4.92	4.92	3.54	4.59	4.31	4.59	3.01	3.01	3.01	6.57	4.72	5.55
0113596	4" x 4" x 3 ½" — 125 x 125 x 110 mm	4.92	4.92	4.33	4.59	4.47	4.59	3.01	3.01	3.01	6.57	5.79	5.65

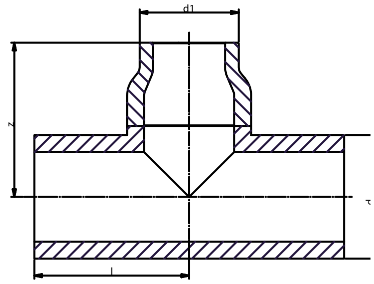
aquatherm green pipe® **reducing tee** (inlet, outlet, branch)



SDR	Part no.	Dimension ND — OD	d [in]	d1 [in]	l [in]	l1 [in]	z [in]	D [in]	Weight [lb]
7.4	0113600	6" x 6" x 2 ½" — 160 x 160 x 75 mm	6.30	2.95	9.06	4.80	11.02	3.94	9.73
	0113602	6" x 6" x 3" — 160 x 160 x 90 mm	6.30	3.54	9.06	4.92	11.02	4.27	9.95
	0113604L[a]	6" x 6" x 4" — 160 x 160 x 125 mm	6.30	4.92	21.06	8.87	7.25	6.57	-
	0113608	8" x 8" x 2 ½" — 200 x 200 x 75 mm	7.87	2.95	9.84	5.59	4.41	3.94	15.68
	0113610	8" x 8" x 3" — 200 x 200 x 90 mm	7.87	3.54	9.84	5.71	4.41	4.27	16.62
	0113612	8" x 8" x 3 ½" — 200 x 200 x 110 mm	7.87	4.33	9.84	5.87	4.41	5.79	16.15
	0113614	8" x 8" x 4" — 200 x 200 x 125 mm	7.87	4.92	9.84	6.10	4.53	6.57	16.85
	0113624	10" x 10" x 2 ½" — 250 x 250 x 75 mm	9.84	2.95	14.76	6.57	5.39	3.94	36.40
	0113626	10" x 10" x 3" — 250 x 250 x 90 mm	9.84	3.54	14.76	6.69	5.39	4.27	37.04
	0113628	10" x 10" 3 ½" — 250 x 250 x 110 mm	9.84	4.33	14.76	6.85	5.39	5.79	37.04
	0113630	10" x 10" x 4" — 250 x 250 x 125 mm	9.84	4.92	14.76	7.09	5.51	6.57	37.48
	0113904	12" x 12" x 4" — 315 x 315 x 125 mm	12.40	4.92	18.11	8.39	6.81	6.57	-
	0113916	14" x 14" x 4" — 355 x 355 x 125 mm	13.98	4.92	18.90	9.17	7.60	6.57	-
11	0113601	6" x 6" x 2 ½" — 160 x 160 x 75 mm	6.30	2.95	9.06	4.80	11.02	3.94	6.92
	0113603	6" x 6" x 3" — 160 x 160 x 90 mm	6.30	3.54	9.06	4.92	11.02	4.27	7.00
	0113605LG[a]	6" x 6" x 4" — 160 x 160 x 125 mm	6.30	4.92	21.06	8.87	7.25	6.57	-
	0113609	8" x 8" x 2 ½" — 200 x 200 x 75 mm	7.87	2.95	9.84	5.59	4.41	3.94	11.65
	0113611	8" x 8" x 3" — 200 x 200 x 90 mm	7.87	3.54	9.84	5.71	4.41	4.27	11.39
	0113613	8" x 8" x 3 ½" — 200 x 200 x 110 mm	7.87	4.33	9.84	5.87	4.41	5.79	12.46
	0113615	8" x 8" x 4" — 200 x 200 x 125 mm	7.87	4.92	9.84	6.10	4.53	6.57	26.46
	0113625	10" x 10" x 2 ½" — 250 x 250 x 75 mm	9.84	2.95	14.76	6.59	5.39	3.94	12.76
	0113627	10" x 10" x 3" — 250 x 250 x 90 mm	9.84	3.54	14.76	6.69	5.39	4.27	26.46
	0113629	10" x 10" x 3 ½" — 250 x 250 x 110 mm	9.84	4.33	14.76	6.85	5.39	5.79	28.67
	0113631	10" x 10" x 4" — 250 x 250 x 125 mm	9.84	4.92	14.76	7.09	5.51	6.57	26.46
	0113651	12" x 12" x 4" — 315 x 315 x 125 mm	12.40	4.92	18.11	8.39	6.81	6.57	55.45
	0113663	14" x 14" x 4" — 355 x 355 x 125 mm	13.98	4.92	18.90	9.17	7.60	6.57	-
	0113676[b]	16" x 16" x 4" — 400 x 400 x 125 mm	15.75	4.92	19.69	10.04	8.46	6.57	-
	0113690[b]	18" x 18" x 4" — 450 x 450 x 125 mm	17.72	4.92	20.67	11.02	9.45	6.57	-

[a] Includes 1-ft extension of aquatherm green pipe®.
[b] Mechanically stabilized with a faser-composite layer in the center of the pipe.

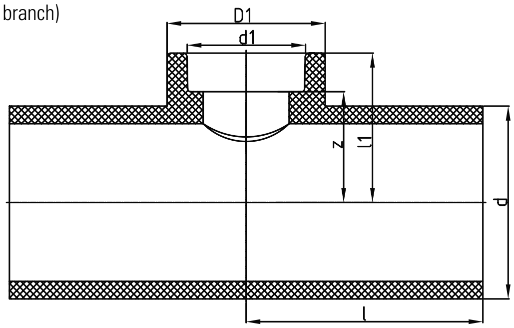
aquatherm green pipe® reducing tee (inlet, outlet, branch)

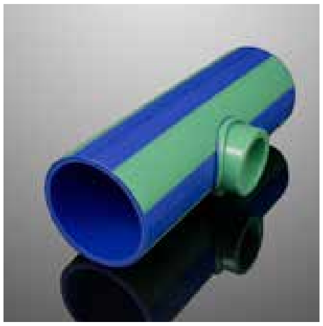


SDR	Part no.	Dimension ND — OD	d [in]	d1 [in]	l [in]	z [in]	Weight [lb]
7.4	0113618	8" x 8" x 6" — 200 x 200 x 160 mm	7.87	6.30	9.84	9.84	-
	0113634	10" x 10" x 6" — 250 x 250 x 160 mm	9.84	6.30	14.76	26.85	61.73
	0113640	10" x 10" x 8" — 250 x 250 x 200 mm	9.84	7.87	14.76	21.57	59.53
	0113906	12" x 12" x 6" — 315 x 315 x 160 mm	12.40	6.30	18.11	9.37	-
	0113908	12" x 12" x 8" — 315 x 315 x 200 mm	12.40	7.87	18.11	18.11	-
	0113910	12" x 12" x 10" — 315 x 315 x 250 mm	12.40	9.84	18.11	18.11	-
	0113918	14" x 14" x 6" — 355 x 355 x 160 mm	13.98	6.30	18.90	10.16	-
	0113920	14" x 14" x 8" — 355 x 355 x 200 mm	13.98	7.87	18.90	10.55	-
	0113922	14" x 14" x 10" — 355 x 355 x 250 mm	13.98	9.84	18.90	18.90	-
	0113924	14" x 14" x 12" — 355 x 355 x 315 mm	13.98	12.40	18.90	18.90	-
11	0113619	8" x 8" x 6" — 200 x 200 x 160 mm	7.87	6.30	9.84	9.84	17.15
	0113635	10" x 10" x 6" — 250 x 250 x 160 mm	9.84	6.30	14.76	26.85	-
	0113641	10" x 10" x 8" — 250 x 250 x 200 mm	9.84	7.87	14.76	21.57	42.99
	0113653	12" x 12" x 6" — 315 x 315 x 160 mm	12.40	6.30	18.11	9.37	40.79
	0113655	12" x 12" x 8" — 315 x 315 x 200 mm	12.40	7.87	18.11	18.11	54.79
	0113657	12" x 12" x 10" — 315 x 315 x 250 mm	12.40	9.84	18.11	18.11	64.82
	0113665	14" x 14" x 6" — 355 x 355 x 160 mm	13.98	6.30	18.90	10.16	66.69
	0113667	14" x 14" x 8" — 355 x 355 x 200 mm	13.98	7.87	18.90	10.55	-
	0113669	14" x 14" x 10" — 355 x 355 x 250 mm	13.98	9.84	18.90	18.90	-
	0113671	14" x 14" x 12" — 355 x 355 x 315 mm	13.98	12.40	18.90	13.94	-
	0113678[a]	16" x 16" x 6" — 400 x 400 x 160 mm	15.75	6.30	19.69	12.52	-
	0113680[a]	16" x 16" x 8" — 400 x 400 x 200 mm	15.75	7.87	19.69	11.02	-
	0113682[a]	16" x 16" x 10" — 400 x 400 x 250 mm	15.75	9.84	19.69	19.69	-
	0113684[a]	16" x 16" x 12" — 400 x 400 x 315 mm	15.75	12.40	19.69	19.69	-
	0113685[a]	16" x 16" x 14" — 400 x 400 x 355 mm	15.75	13.98	19.69	14.92	-
	0113692[a]	18" x 18" x 6" — 450 x 450 x 160 mm	17.72	6.30	20.67	13.50	-
	0113694[a]	18" x 18" x 8" — 450 x 450 x 200 mm	17.72	7.87	20.67	12.01	-
	0113696[a]	18" x 18" x 10" — 450 x 450 x 250 mm	17.72	9.84	20.67	12.40	-
	0113698[a]	18" x 18" x 12" — 450 x 450 x 315 mm	17.72	12.40	20.67	20.67	-
	0113699[a]	18" x 18" x 14" — 450 x 450 x 355 mm	17.72	13.98	20.67	20.67	-
	0113700[a]	18" x 18" x 16" — 450 x 450 x 400 mm	17.72	15.75	20.67	20.67	-

[a] Mechanically stabilized with a faser-composite layer in the center of the pipe.

aquatherm blue pipe® reducing tee (inlet, outlet, branch)

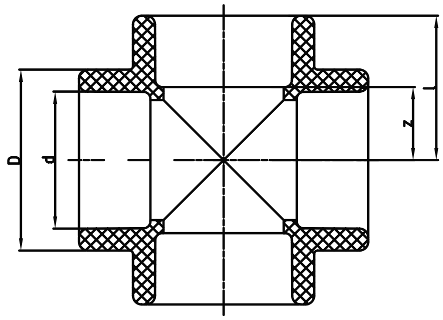




SDR	Part no.	Dimension ND — OD	d [in]	d1 [in]	l [in]	l1 [in]	z [in]	D1 [in]	Weight [lb]
11	0113601[a]	6″ x 6″ x 2 ½″ — 160 x 160 x 75 mm	6.30	2.95	9.06	4.84	11.02	3.94	6.92
	0113603[a]	6″ x 6″ x 3″ — 160 x 160 x 90 mm	6.30	3.54	9.06	4.92	11.02	4.27	7.00
	0113605LB[b]	6″ x 6″ x 4″ — 160 x 160 x 125 mm	6.30	4.92	21.06	8.87	7.25	6.57	-
	2613609	8″ x 8″ x 2 ½″ — 200 x 200 x 75 mm	7.87	2.95	9.84	5.59	4.41	3.94	-
	2613611	8″ x 8″ x 3″ — 200 x 200 x 90 mm	7.87	3.54	9.84	5.71	4.41	4.27	-
	2613613	8″ x 8″ x 3 ½″ — 200 x 200 x 110 mm	7.87	4.33	9.84	5.87	4.41	5.79	-
	2613615	8″ x 8″ x 4″ — 200 x 200 x 125 mm	7.87	4.92	9.84	6.10	4.53	6.57	-
	2613625	10″ x 10″ x 2 ½″ — 250 x 250 x 75 mm	9.84	2.95	14.76	6.57	5.39	3.94	-
	2613627	10″ x 10″ x 3″ — 250 x 250 x 90 mm	9.84	3.54	14.76	6.69	5.39	4.27	-
	2613629	10″ x 10″ x 3 ½″ — 250 x 250 x 110 mm	9.84	4.33	14.76	6.85	5.39	5.79	-
	2613631	10″ x 10″ x 4″ — 250 x 250 x 125 mm	9.84	4.92	14.76	7.09	5.51	6.57	-
	2013651	12″ x 12″ x 4″ — 315 x 315 x 125 mm	12.40	4.92	18.11	8.39	6.81	6.57	55.12
	2013663	14″ x 14″ x 4″ — 355 x 355 x 125 mm	13.98	4.92	18.90	9.17	7.60	6.57	-
	2013676	16″ x 16″ x 4″ — 400 x 400 x 125 mm	15.75	4.92	19.69	10.04	8.46	6.57	-
	2013690	18″ x 18″ x 4″ — 450 x 450 x 125 mm	17.72	4.92	20.67	11.02	9.45	6.57	-
17.6	2513600	6″ x 6″ x 2 ½″ — 160 x 160 x 75 mm	6.30	2.95	9.06	4.80	11.02	3.94	5.20
	2513602	6″ x 6″ x 3″ — 160 x 160 x 90 mm	6.30	3.54	9.06	4.92	11.02	4.27	-
	2513608	8″ x 8″ x 2 ½″ — 200 x 200 x 75 mm	7.87	2.95	9.84	5.59	4.41	3.94	-
	2513610	8″ x 8″ x 3″ — 200 x 200 x 90 mm	7.87	3.54	9.84	5.71	4.41	4.27	-
	2513612	8″ x 8″ x 3 ½″ — 200 x 200 x 110 mm	7.87	4.33	9.84	5.87	4.41	5.79	-
	2513614	8″ x 8″ x 4″ — 200 x 200 x 125 mm	7.87	4.92	9.84	6.10	4.53	6.57	-
	2513624	10″ x 10″ x 2 ½″ — 250 x 250 x 75 mm	9.84	2.95	14.76	6.57	5.39	3.94	-
	2513626	10″ x 10″ x 3″ — 250 x 250 x 90 mm	9.84	3.54	14.76	6.69	5.39	4.27	-
	2513628	10″ x 10″ 3 ½″ — 250 x 250 x 110 mm	9.84	4.33	14.76	6.85	5.39	5.79	-
	2513630	10″ x 10″ x 4″ — 250 x 250 x 125 mm	9.84	4.92	14.76	7.09	5.51	6.57	-
	2513651	12″ x 12″ x 4″ — 315 x 315 x 125 mm	12.40	4.92	18.11	8.39	6.81	6.57	-
	2513663	14″ x 14″ x 4″ — 355 x 355 x 125 mm	13.98	4.92	18.90	9.17	7.68	6.57	47.40
	2513676	16″ x 16″ x 4″ — 400 x 400 x 125 mm	15.75	4.92	19.69	10.04	8.46	6.57	-
	2513690	18″ x 18″ x 4″ — 450 x 450 x 125 mm	17.72	4.92	20.67	11.02	9.45	6.57	-
	2513804	20″ x 20″ x 4″ — 500 x 500 x 125 mm	19.69	4.92	23.62	12.01	10.43	6.57	-
	2513821	22″ x 22″ x 4″ — 560 x 560 x 125 mm	22.05	4.92	24.80	13.19	11.61	6.57	-
	2513839	24″ x 24″ x 4″ — 630 x 630 x 125 mm	24.80	4.92	26.18	14.57	12.99	6.57	-

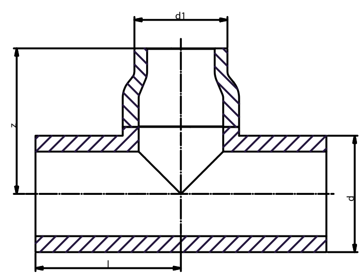
[a] Molded fitting, made from green **fusiolen**®.
[b] Molded fitting, made from green **fusiolen**® with 1-ft extension on each end.

aquatherm green pipe® cross



Part no.	Dimension ND — OD	d	z	l	D	Weight
		[in]	[in]	[in]	[in]	[lb]
0113708	½″ — 20 mm	0.79	0.45	1.02	1.16	0.06
0113710	¾″ — 25 mm	0.98	0.53	1.16	1.34	0.08
0113712	1″ — 32 mm	1.26	0.67	1.38	1.69	0.15
0113714	1 ¼″ — 40 mm	1.57	0.83	1.63	2.05	0.23

aquatherm blue pipe® reducing tee (inlet, outlet, branch)

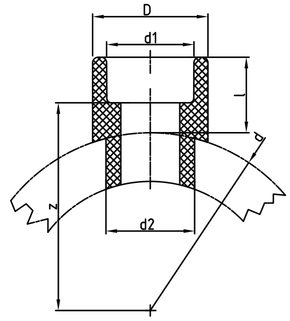


SDR	Part no.	Dimension ND — OD	d	d1	l	z	Weight
			[in]	[in]	[in]	[in]	[lb]
	2613619	8″ x 8″ x 6″ — 200 x 200 x 160 mm	7.87	6.30	9.84	9.84	-
	2613635	10″ x 10″ x 6″ — 250 x 250 x 160 mm	9.84	6.30	14.76	26.85	-
	2613641	10″ x 10″ x 8″ — 250 x 250 x 200 mm	9.84	7.87	14.76	21.57	-
	2013653	12″ x 12″ x 6″ — 315 x 315 x 160 mm	12.40	6.30	18.11	9.37	55.12
	2013655	12″ x 12″ x 8″ — 315 x 315 x 200 mm	12.40	7.87	18.11	18.11	-
	2013657	12″ x 12″ x 10″ — 315 x 315 x 250 mm	12.40	9.84	18.11	18.11	-
	2013665	14″ x 14″ x 6″ — 355 x 355 x 160 mm	13.98	6.30	18.90	10.16	-
	2013667	14″ x 14″ x 8″ — 355 x 355 x 200 mm	13.98	7.87	18.90	10.55	66.58
	2013669	14″ x 14″ x 10″ — 355 x 355 x 250 mm	13.98	9.84	18.90	18.90	88.19
	2013671	14″ x 14″ x 12″ — 355 x 355 x 315 mm	13.98	12.40	18.90	18.90	88.19
11	2013678	16″ x 16″ x 6″ — 400 x 400 x 160 mm	15.75	6.30	19.69	13.94	-
	2013680	16″ x 16″ x 8″ — 400 x 400 x 200 mm	15.75	7.87	19.69	12.52	-
	2013682	16″ x 16″ x 10″ — 400 x 400 x 250 mm	15.75	9.84	19.69	11.02	101.41
	2013684	16″ x 16″ x 12″ — 400 x 400 x 315 mm	15.75	12.40	19.69	19.69	-
	2013685	16″ x 16″ x 14″ — 400 x 400 x 355 mm	15.75	13.98	19.69	19.69	-
	2013692	18″ x 18″ x 6″ — 450 x 450 x 160 mm	17.72	6.30	20.67	14.92	-
	2013694	18″ x 18″ x 8″ — 450 x 450 x 200 mm	17.72	7.87	20.67	13.50	-
	2013696	18″ x 18″ x 10″ — 450 x 450 x 250 mm	17.72	9.84	20.67	12.01	-
	2013698	18″ x 18″ x 12″ — 450 x 450 x 315 mm	17.72	12.40	20.67	12.40	-
	2013699	18″ x 18″ x 14″ — 450 x 450 x 355 mm	17.72	13.98	20.67	20.67	-
	2013700	18″ x 18″ x 16″ — 450 x 450 x 400 mm	17.72	15.75	20.67	20.67	-

aquatherm blue pipe® reducing tee - continued (inlet, outlet, branch)

SDR	Part no.	Dimension ND — OD	d [in]	d1 [in]	l [in]	z [in]	Weight [lb]
17.6	2513618	8” x 8” x 6” — 200 x 200 x 160 mm	7.87	6.30	9.84	9.84	10.65
	2513634	10” x 10” x 6” — 250 x 250 x 160 mm	9.84	6.30	14.76	14.76	-
	2513640	10” x 10” x 8” — 250 x 250 x 200 mm	9.84	7.87	14.76	14.76	-
	2513653	12” x 12” x 6” — 315 x 315 x 160 mm	12.40	6.30	18.11	9.37	-
	2513655	12” x 12” x 8” — 315 x 315 x 200 mm	12.40	7.87	18.11	18.11	-
	2513657	12” x 12” x 10” — 315 x 315 x 250 mm	12.40	9.84	18.11	18.11	39.58
	2513665	14” x 14” x 6” — 355 x 355 x 160 mm	13.98	6.30	18.90	10.16	47.40
	2513667	14” x 14” x 8” — 355 x 355 x 200 mm	13.98	7.87	18.90	10.55	42.74
	2513669	14” x 14” x 10” — 355 x 355 x 250 mm	13.98	9.84	18.90	18.90	51.11
	2513671	14” x 14” x 12” — 355 x 355 x 315 mm	13.98	12.40	18.90	18.90	53.01
	2513678	16” x 16” x 6” — 400 x 400 x 160 mm	15.75	6.30	19.69	13.94	-
	2513680	16” x 16” x 8” — 400 x 400 x 200 mm	15.75	7.87	19.69	12.52	-
	2513682	16” x 16” x 10” — 400 x 400 x 250 mm	15.75	9.84	19.69	11.02	63.93
	2513684	16” x 16” x 12” — 400 x 400 x 315 mm	15.75	12.40	19.69	19.69	78.93
	2513685	16” x 16” x 14” — 400 x 400 x 355 mm	15.75	13.98	19.69	19.69	-
	2513692	18” x 18” x 6” — 450 x 450 x 160 mm	17.72	6.30	20.67	14.92	-
	2513694	18” x 18” x 8” — 450 x 450 x 200 mm	17.72	7.87	20.67	13.50	-
	2513696	18” x 18” x 10” — 450 x 450 x 250 mm	17.72	9.84	20.67	12.01	-
	2513698	18” x 18” x 12” — 450 x 450 x 315 mm	17.72	12.40	20.67	12.40	-
	2513699	18” x 18” x 14” — 450 x 450 x 355 mm	17.72	13.98	20.67	20.67	-
	2513700	18” x 18” x 16” — 450 x 450 x 400 mm	17.72	15.75	20.67	20.67	-
	2513806	20” x 20” x 6” — 500 x 500 x 160 mm	19.69	6.30	23.62	15.91	-
	2513808	20” x 20” x 8” — 500 x 500 x 200 mm	19.69	7.87	23.62	14.49	-
	2513810	20” x 20” x 10” — 500 x 500 x 250 mm	19.69	9.84	23.62	12.99	-
	2513812	20” x 20” x 12” — 500 x 500 x 315 mm	19.69	12.40	23.62	13.39	-
	2513813	20” x 20” x 14” — 500 x 500 x 355 mm	19.69	13.98	23.62	23.62	-
	2513814	20” x 20” x 16” — 500 x 500 x 400 mm	19.69	15.75	23.62	23.62	-
	2513815	20” x 20” x 18” — 500 x 500 x 450 mm	19.69	17.72	23.62	23.62	-
	2513823	22” x 22” x 6” — 560 x 560 x 160 mm	22.05	6.30	24.80	17.09	-
	2513825	22” x 22” x 8” — 560 x 560 x 200 mm	22.05	7.87	24.80	15.67	-
	2513827	22” x 22” x 10” — 560 x 560 x 250 mm	22.05	9.84	24.80	14.17	-
	2513829	22” x 22” x 12” — 560 x 560 x 315 mm	22.05	12.40	24.80	14.57	-
	2513830	22” x 22” x 14” — 560 x 560 x 355 mm					
	2513831	22” x 22” x 16” — 560 x 560 x 400 mm	22.05	15.75	24.80	24.80	-
	2513832	22” x 22” x 18” — 560 x 560 x 450 mm	22.05	17.72	24.80	24.80	-
	2513833	20” x 20” x 20” — 560 x 560 x 500 mm	22.05	19.69	24.80	24.80	-
	2513841	24” x 24” x 6” — 630 x 630 x 160 mm	24.80	6.30	26.18	18.66	-
	2513843	24” x 24” x 8” — 630 x 630 x 200 mm	24.80	7.87	26.18	17.24	-
	2513845	24” x 24” x 10” — 630 x 630 x 250 mm	24.80	9.84	26.18	15.75	-
	2513847	24” x 24” x 12” — 630 x 630 x 315 mm	24.80	12.40	26.18	15.95	-
	2513848	24” x 24” x 14” — 630 x 630 x 355 mm					
	2513849	24” x 24” x 16” — 630 x 630 x 400 mm	24.80	15.75	26.18	26.18	-
	2513850	24” x 24” x 18” — 630 x 630 x 450 mm	24.80	17.72	26.18	26.18	-
	2513851	24” x 24” x 20” — 630 x 630 x 500 mm	24.80	19.69	26.18	26.18	-
	2513852	24” x 24” x 22” — 630 x 630 x 560 mm	24.80	22.05	26.18	26.18	-

aquatherm green pipe® fusion outlet

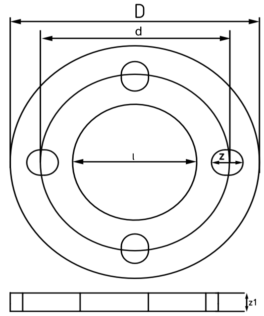


Part no.	Dimension ND — OD (pipe x outlet)	d	d1	d2	l	z	D	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0115156	1 ¼" x ½" — 40 x 20 mm	1.57	0.79	0.98	1.06	1.28	1.16	0.04
0115158	1 ¼" x ¾" — 40 x 25 mm	1.57	0.98	0.98	1.12	1.28	1.34	0.04
0115160	1 ½" x ½" — 50 x 20 mm	1.97	0.79	0.98	1.08	1.50	1.16	0.04
0115162	1 ½" x ¾" — 50 x 25 mm	1.97	0.98	0.98	1.12	1.48	1.34	0.04
0115164	2 x ½" — 63 x 20 mm	2.48	0.79	0.98	1.08	1.75	1.16	0.04
0115166	2" x ¾" — 63 x 25 mm	2.48	0.98	0.98	1.12	1.73	1.34	0.04
0115168	2" x 1" — 63 x 32 mm	2.48	1.26	1.26	1.18	1.71	1.69	0.06
0115170	2 ½" x ½" — 75 x 20 mm	2.95	0.79	0.98	1.08	1.99	1.16	0.04
0115172	2 ½" x ¾" — 75 x 25 mm	2.95	0.98	0.98	1.12	1.97	1.34	0.04
0115174	2 ½" x 1" — 75 x 32 mm	2.95	1.26	1.26	1.18	1.95	1.69	0.06
0115175	2 ½" x 1 ¼" — 75 x 40 mm	2.95	1.57	1.57	1.34	2.01	2.05	0.11
0115176	3" x ½" — 90 x 20 mm	3.54	0.79	0.98	1.08	2.28	1.16	0.04
0115178	3" x ¾" — 90 x 25 mm	3.54	0.98	0.98	1.12	2.26	1.34	0.04
0115180	3" x 1" — 90 x 32 mm	3.54	1.26	1.26	1.18	2.24	1.69	0.06
0115181	3" x 1 ¼" — 90 x 40 mm	3.54	1.57	1.57	1.34	2.30	2.05	0.11
0115182	3 ½" x ½" — 110 x 20 mm	4.33	0.79	0.98	1.08	2.68	1.16	0.04
0115184	3 ½" x ¾" — 110 x 25 mm	4.33	0.98	0.98	1.12	2.70	1.34	0.04
0115186	3 ½" x 1" — 110 x 32 mm	4.33	1.26	1.26	1.18	2.64	1.69	0.07
0115188	3 ½" x 1 ¼" — 110 x 40 mm	4.33	1.57	1.57	1.34	2.70	2.05	0.11
0115189	3 ½" x 1 ½" — 110 x 50 mm	4.33	1.97	1.97	1.34	2.58	2.68	0.20
0115190	4" x ½" — 125 x 20 mm	4.92	0.79	0.98	1.08	2.97	2.64	0.04
0115192	4" x ¾" — 125 x 25 mm	4.92	0.98	0.98	1.12	2.95	1.34	0.04
0115194	4" x 1" — 125 x 32 mm	4.92	1.26	1.26	1.18	2.93	1.69	0.06
0115196	4" x 1 ¼" — 125 x 40 mm	4.92	1.57	1.57	1.34	2.99	2.05	0.11
0115197	4" x 1 ½" — 125 x 50 mm	4.92	1.97	1.97	1.34	2.87	2.68	0.20
0115198	4" x 2" — 125 x 63 mm	4.92	2.48	2.48	1.50	2.87	3.31	0.33
0115206	6" x ½" — 160 x 20 mm	6.30	0.79	0.98	1.08	3.66	1.16	0.05
0115208	6" x ¾" — 160 x 25 mm	6.30	0.98	0.98	1.12	3.64	1.34	0.05
0115210	6" x 1" — 160 x 32 mm	6.30	1.26	1.26	1.18	3.62	1.69	0.08
0115212	6" x 1 ¼" — 160 x 40 mm	6.30	1.57	1.57	1.34	3.68	2.05	0.12
0115214	6" x 1 ½" — 160 x 50 mm	6.30	1.97	1.97	1.34	3.56	3.31	0.21
0115216	6" x 2" — 160 x 63 mm	6.30	2.48	2.48	1.50	3.56	3.31	0.25
0115218	6" x 2 ½" — 160 x 75 mm	6.30	2.95	2.95	1.65	3.62	3.94	0.50
0115220	6" x 3" — 160 x 90 mm	6.30	3.54	3.54	1.77	3.62	4.72	0.80
0115228	8 to10" x ½" — 200 to 250 x 20 mm	7.87/9.84	0.79	0.98	1.08	4.45	1.16	0.04
0115229	8 to10" x ¾" — 200 to 250 x 25 mm	7.87/9.84	0.98	0.98	1.12	4.43	1.34	0.05
0115230	8 to10" x 1" — 200 to 250 x 32 mm	7.87/9.84	1.26	1.26	1.18	4.41	1.69	0.07
0115231	8" x 1 ¼" — 200 x 40 mm	7.87	1.57	1.57	1.34	4.47	2.05	0.11

aquatherm green pipe® fusion outlet - continued

Part no.	Dimension ND — OD (pipe x outlet)	d [in]	d1 [in]	d2 [in]	l [in]	z [in]	D [in]	Weight [lb]
0115232	8" x 1 ½" — 200 x 50 mm	7.87	1.97	1.97	1.34	4.35	2.68	0.19
0115233	8" x 2" — 200 x 63 mm	7.87	2.48	2.48	1.48	4.33	3.31	0.32
0115234	8" x 2 ½" — 200 x 75 mm	7.87	2.95	2.95	1.65	4.41	3.94	0.49
0115235	8" x 3" — 200 x 90 mm	7.87	3.54	3.54	1.77	4.41	4.72	0.75
0115236	8" x 3 ½" — 200 x 110 mm	7.87	4.33	4.33	1.93	4.41	5.79	1.27
0115237	8" x 4" — 200 x 125 mm	7.87	4.92	4.92	2.17	4.53	6.57	1.92
0115251	10" x 1 ¼" — 250 x 40 mm	9.84	1.57	0.00	1.34	5.45	2.05	0.12
0115252	10" x 1 ½" — 250 x 50 mm	9.84	1.97	1.97	1.34	5.33	2.68	0.20
0115253	10" x 2" — 250 x 63 mm	9.84	2.48	2.48	1.48	5.31	3.31	0.34
0115254	10" x 2 ½" — 250 x 75 mm	9.84	2.95	2.95	1.65	5.39	3.94	0.49
0115255	10" x 3" — 250 x 90 mm	9.84	3.54	3.54	1.77	5.39	4.72	0.77
0115256	10" x 3 ½" — 250 x 110 mm	9.84	4.33	4.33	1.93	5.39	5.79	0.12
0115257	10" x 4" — 250 x 125 mm	9.84	4.92	4.92	2.17	5.51	6.57	1.81
0115260	12" to 14" x 2" — 315 to 355 x 63 mm	12.40/13.98	2.48	2.48	1.48	6.59	3.31	0.34
0115261	12" to 14" x 2 ½" — 315 to 355 x 75 mm	12.40/13.98	2.95	2.95	1.65	6.67	3.94	0.51
0115262	12" x 3" — 315 x 90 mm	12.40	3.54	3.54	1.77	6.67	4.27	0.77
0115263	12" x 3 ½" — 315 x 110 mm	12.40	4.33	4.33	1.93	6.67	5.79	1.25
0115264	12" x 4" — 315 x 125 mm	12.40	4.92	4.92	2.17	6.79	6.57	1.83
0115265	12" x 6" — 315 x 160 mm	12.40	6.30	6.30	3.15	9.35	-	1.91
0115268	14" x 3" — 355 x 90 mm	13.98	3.54	3.54	1.77	7.46	4.27	0.78
0115269	14" x 3 ½" — 355 x 110 mm	13.98	4.33	4.33	1.93	7.46	5.79	1.29
0115270	14" x 4" — 355 x 125 mm	13.98	4.92	4.92	2.17	7.58	6.57	1.77
0115271	14" x 6" — 355 x 160 mm	13.98	6.30	6.30	3.15	10.14		1.86
0115272	14" x 8" — 355 x 200 mm	13.98	7.87	7.87	3.55	9.29	7.87	3.56
0115275	16" to 20" x 2 ½" — 400 to 500 x 75 mm	15.75/17.72	2.95	2.95	1.65	4.76	3.94	0.46
0115277	16" to18" x 3 ½" — 400 to 450 x 110 mm	15.75/17.72	4.33	4.33	1.93	4.76	5.79	1.16
0115278	16" x 4" — 400 x 125 mm	15.75	4.92	4.92	2.17	8.46	6.57	1.70
0115280	16" x 6" to 10" — 400 x 160 - 250 mm	15.75	-	-	-	-	-	
0115288	16" to 20" x 3" — 400 to 500 x 90 mm	15.75/19.69	3.54	3.54	1.77	9.33	4.27	0.72
0115290	18" to 20" x 4" — 450 to 500 x 125 mm	17.72/19.69	4.92	4.92	2.17	9.45	6.57	1.71
0115292	18" x 6" to 10" — 450 x 160 to 250 mm	17.72	-	-	-	-	-	-
0115298	18" x 12" — 450 x 315 mm	17.72	-	-	-	-	-	-
0115300	16" to 24" x 2" — 400 to 630 x 63 mm	15.75/24.80	2.48	2.48	1.48	10.24	3.31	0.33
0115303	20" to 22" x 3 ½" — 500 to 560 x 110 mm	19.69/22.05	4.33	4.33	1.93	10.31	5.79	1.19
0115306	20" x 6" to 10" — 500 x 160 to 250 mm	19.69	-	-	-	-	-	-
0115312	20" x 12" — 500 x 315 mm	19.69	-	-	-	-	-	-
0115315	22" to 24" x 2 ½" — 560 to 630 x 75 mm	22.05/24.80	2.95	2.95	1.65	11.50	3.94	0.49
0115316	22" to 24" x 3" — 560 to 630 x 90 mm	22.05/24.80	3.54	3.54	1.77	11.50	4.27	0.75
0115318	22" to 24" x 4" — 560 - 630 x 125 mm	22.05/24.80	4.92	4.92	2.17	11.02	6.57	1.75
0115331	24" x 3 ½" — 630 x 110 mm	24.80	4.33	4.33	1.93	12.87	5.79	1.24
0115334	24" x 6" to 10" — 630 x 160 to 250 mm	24.80	-	-	-	-	-	-
0115340	24" x 12" — 630 x 315 mm	24.80	-	-	-	-	-	-

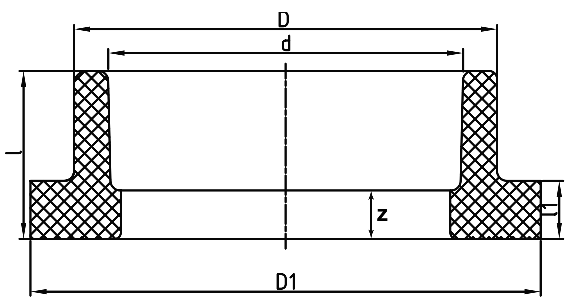
aquatherm flange ring



Part no.	Dimension ND — OD	No. of bolt holes	d	l	z	D	z1	Weight
			[in]	[in]	[in]	[in]	[in]	[lb]
3315712	1" — 32 mm	4	3.38	1.63	0.56	4.25	0.50	1.53
3315714	1 ¼" — 40 mm	4	3.94	2.00	0.69	5.56	0.50	2.73
3315716	1 ½" — 50 mm	4	4.31	2.44	0.69	5.94	0.50	3.03
3315718	2" — 63 mm	4	4.94	3.06	0.69	6.56	0.50	3.53
3315720	2 ½" — 75 mm	4	5.69	3.63	0.81	7.31	0.50	4.19
3315722	3" — 90 mm	8	6.31	4.31	0.69	7.94	0.63	5.45
3315724	3 ½" — 110 mm	8	7.06	5.25	0.69	8.69	0.63	6.21
3315726	4" — 125 mm	8	7.06	5.25	0.69	9.00	0.63	6.78
3315730	6" — 160 mm	8	9.50	7.00	0.88	11.00	0.69	10.15
3315734	8" — 200 mm	8	11.75	9.25	0.88	13.50	0.69	13.70
3315738	10" — 250 mm	12	13.75	11.31	0.88	16.00	0.81	21.35
3315742	12" — 315 mm	12	17.00	13.38	1.25	19.00	1.25	46.95
3315744	14" — 355 mm	12	18.75	14.81	1.38	21.00	1.38	45.35
3315746	16" — 400 mm	16	21.25	16.88	1.38	23.50	1.44	77.95
3315748	18" — 450 mm	16	25.00	20.315	0.630	27.52	43.00	119.10
3315750	20" — 500 mm	20	-	-	-	-	-	111.65
3315752	22" — 560 mm	20	-	-	-	-	-	137.20
3315754	24" — 630 mm	20	29.49	25.35	0.69	32.05	1.89	150.40

For flange bolt torque and size, refer to appendix A.

aquatherm green pipe® flange adapter
(socket welded, gasket not included)



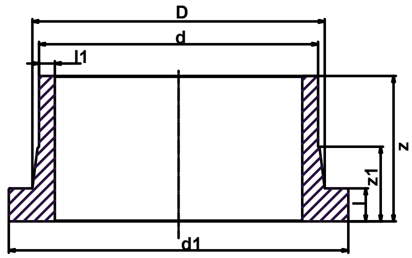
Part no.	Dimension ND — OD	d	l	z	D	D1	l1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0115512	1" — 32 mm	1.26	1.38	0.67	1.61	2.68	0.43	0.12
0115514	1 ¼" — 40 mm	1.57	1.44	0.65	1.97	3.07	0.49	0.16
0115516	1 ½" — 50 mm	1.97	1.56	0.63	2.40	3.46	0.47	0.21
0115518	2" — 63 mm	2.48	1.71	0.63	2.99	4.02	0.61	0.29
0115520	2 ½" — 75 mm	2.95	1.81	0.63	3.54	4.80	0.63	0.42
0115522	3" — 90 mm	3.54	1.97	0.67	4.25	5.43	0.67	0.57
0115524	3 ½" — 110 mm	4.33	2.19	0.73	5.16	6.22	0.73	0.73
0115526[a]	4" — 125 mm	4.92	7.95	0.52	4.92	6.22	0.53	2.93
0115527	4" — 125 mm	4.92	2.48	0.91	6.50	7.40	0.79	1.60

[a] Part no. 0115526 must be paired with a coupling (part no. 0111026, sold separately).

aquatherm green pipe® flange adapter

(butt welded, gasket not included)

If the flange adapter is being used to connect to a butterfly valve, select the appropriate part from the "Part no. for butterfly valve" column to ensure flange adapter compatibility. The dimensional data does not apply to the butterfly valve compatible flange adapters. Contact Aquatherm for the dimensional data.

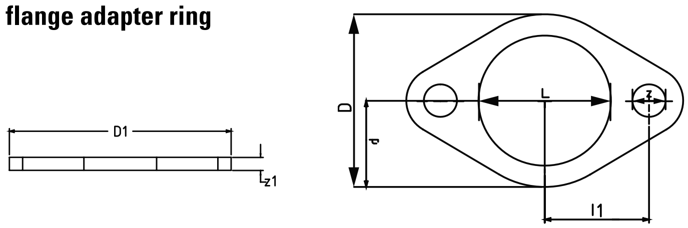


SDR	Part no.	Part no. for butterfly valve	Dimension ND — OD	d [in]	l [in]	z [in]	D [in]	D1 [in]	l1 [in]	z1 [in]	Weight [lb]
7.4	0115530	0115530BV	6" — 160 mm	6.30	0.98	3.66	6.89	8.35	0.86	2.09	2.56
	0115530L[a]	0115530LBV[a]	6" — 160 mm	6.30	0.98	15.41	6.89	8.35	0.86	2.09	8.97
	0115534	0115534BV	8" — 200 mm	7.87	1.26	5.12	9.13	10.55	1.08	2.83	5.05
	0115538	0115538BV	10" — 250 mm	9.84	1.38	5.12	11.22	12.60	1.35	2.95	7.27
	0115542	0115542BV	12" — 315 mm	12.40	1.38	6.69	13.11	14.57	1.13	3.54	-
	0115544	0115544BV	14" — 355 mm	13.98	1.65	7.28	14.57	17.01	1.27	3.74	-
11	0115531	0115531BV	6" — 160 mm	6.30	0.98	3.66	6.89	8.35	0.57	2.09	2.11
	0115531LB[b]	0115531LBBV[b]	6" — 160 mm	6.30	0.98	15.41	6.89	8.35	0.57	2.09	6.63
	0115531LG[a]	0115531LGBV[a]	6" — 160 mm	6.30	0.98	15.41	6.89	8.35	0.57	2.09	6.42
	0115535	0115535BV	8" — 200 mm	7.87	1.26	5.12	9.13	10.55	0.72	2.83	4.31
	0115539	0115539BV	10" — 250 mm	9.84	1.38	5.12	11.22	12.60	0.89	2.95	5.99
	0115543	0115543BV	12" — 315 mm	12.40	1.38	6.69	13.11	14.57	1.13	3.54	12.46
	0115545	0115545BV	14" — 355 mm	13.98	1.65	7.28	14.57	17.01	1.27	3.74	19.84
	0115547	0115547BV	16" — 400 mm	15.75	1.30	7.83	16.73	19.06	0.89	3.50	-
	0115549	0115549BV	18" — 450 mm	17.72	1.81	5.51	16.73	23.07	1.01	2.99	-
17.6	2515530	2515530BV	6" — 160 mm	6.30	0.98	3.66	6.89	8.35	0.36	2.09	1.809
	2515534	2515534BV	8" — 200 mm	7.87	1.26	5.12	9.13	10.55	0.45	2.83	-
	2515538	2515538BV	10" — 250 mm	9.84	1.38	5.12	11.22	12.60	0.56	2.95	6.03
	2515542	2515542BV	12" — 315 mm	12.40	1.38	6.69	13.11	14.57	0.70	3.54	9.92
	2515544	2515544BV	14" — 355 mm	13.98	1.65	7.28	14.57	17.01	0.79	3.74	14.33
	2515546	2515546BV	16" — 400 mm	15.75	1.30	7.83	16.73	19.06	0.89	3.50	18.74
	2515548	2515548BV	18" — 450 mm	17.72	1.81	5.51	20.16	23.07	1.01	2.99	26.46
	2515550	2515550BV	20" — 500 mm	19.69	1.85	5.51	20.67	23.03	1.12	2.91	21.11
	2515552	2515552BV	22" — 560 mm	22.05	1.97	5.55	24.09	26.97	1.25	3.19	30.42
	2515554	2515554BV	24" — 630 mm	24.80	1.97	5.59	25.20	27.09	1.41	3.23	27.78

[a] Includes 1-ft extension of aquatherm green pipe®.
[b] Includes 1-ft extension of aquatherm blue pipe®.

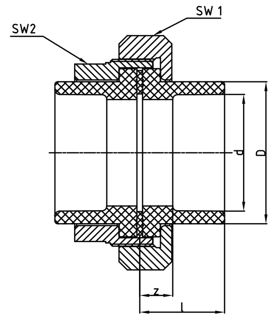
aquatherm green pipe® pump flange adapter ring

American bolt pattern



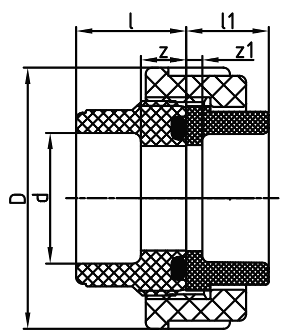
Part no.	Dimension ND — OD	d [in]	L [in]	z [in]	D [in]	l1 [in]	D1 [in]	z1 [in]	Weight [lb]
5515712	1" — 32 mm pump flange ring - blue (used with part no. 0115512)	1.33	1.75	0.50	2.66	1.58	4.18	0.25	0.36
5515713	1 ¼" — 40 mm pump flange ring (used with part no. 0115514)	1.33	2.00	0.50	2.66	1.58	4.18	0.25	0.30
5515714	1 ¼" — 40 mm pump flange ring (used with part no. 0115514, fitted Grundfos model UP4375)	1.50	2.00	0.50	3.00	1.75	4.80	0.25	0.43

aquatherm green pipe® union with brass nut



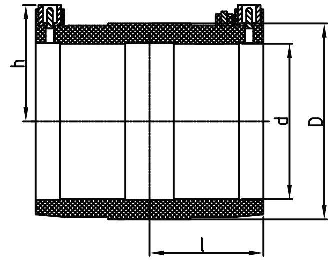
Part no.	Dimension ND — OD	d	l	z	D	SW1	SW2	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0115812	1" — 32 mm	1.26	1.44	0.73	1.61	2.56	1.97	1.06
0115814	1 ¼" — 40 mm	1.57	1.50	0.69	1.97	3.15	2.36	1.86
0115816	1 ½" — 50 mm	1.97	1.61	0.69	2.40	3.39	2.76	1.81
0115818	2" — 63 mm	2.48	1.77	0.69	2.99	4.25	3.74	3.30
0115820	2 ½" — 75 mm	2.95	1.87	0.69	3.54	5.12	4.13	4.41

aquatherm green pipe® union with PP-R nut



Part no.	Dimension ND — OD	d	l	z	l1	z1	D	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0115838	½" — 20 mm	0.79	1.02	0.47	0.79	0.22	1.81	0.08
0115840	¾" — 25 mm	0.98	1.10	0.47	0.83	0.20	2.20	0.13
0115842	1" — 32 mm	1.26	1.26	0.47	0.91	0.20	2.60	0.20
0115844	1 ¼" — 40 mm	1.57	1.50	0.55	1.00	0.20	3.11	0.30
0115846	1 ½" — 50 mm	1.97	1.77	0.63	1.12	0.20	3.43	0.38
0115848	2" — 63 mm	2.48	2.19	0.79	1.28	0.20	4.21	0.53
0115850	2 ½" — 75 mm	2.89	1.97	1.02	1.43	0.20	5.08	1.20

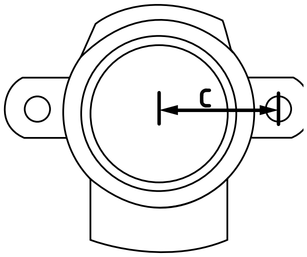
aquatherm green pipe® electrofusion coupling

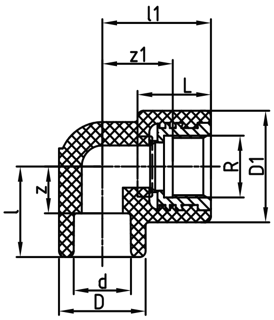


Part no.	Dimension ND — OD	d	l	l1	D	Weight
		[in]	[in]	[in]	[in]	[lb]
0117208	½” — 20 mm	0.79	1.38	1.42	1.24	0.11
0117210	¾” — 25 mm	0.98	1.54	1.52	1.44	0.13
0117212	1” — 32 mm	1.26	1.57	1.67	1.77	0.17
0117214	1 ¼” — 40 mm	1.57	1.81	1.85	2.13	0.23
0117216	1 ½” — 50 mm	1.97	2.03	2.05	2.56	0.31
0117218	2” — 63 mm	2.48	2.32	2.28	3.21	0.53
0117220	2 ½” — 75 mm	2.95	2.56	2.54	3.78	0.77
0117222	3” — 90 mm	3.54	2.85	2.83	4.47	1.11
0117224	3 ½” — 110 mm	4.33	3.15	3.25	5.47	1.89
0117226	4” — 125 mm	4.92	3.39	3.54	6.14	2.42
0117230[a]	6” — 160 mm	6.30	3.66	4.31	7.76	3.87
0117234[a]	8” — 200 mm	7.87	4.13	5.28	9.57	7.99
0117238[a]	10” — 250 mm	9.84	4.92	6.69	12.40	15.75

[a] Cannot be used in conjunction with UV pipe.

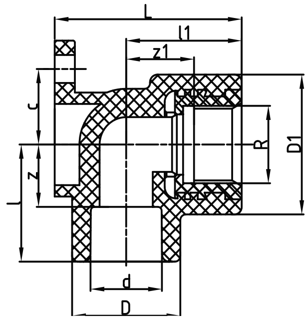
aquatherm green pipe® wing back 90° elbow





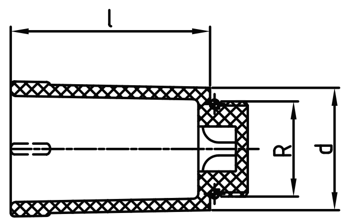
Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension	d	R	l	z	D	l1	z1	D1	L	c	Weight
				[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0120158	920158	0620158	20 mm x ½” F	0.79	0.50	1.18	0.61	1.16	1.46	0.94	1.46	0.98	2.32	0.42

aquatherm green pipe® **back plate elbow** threaded



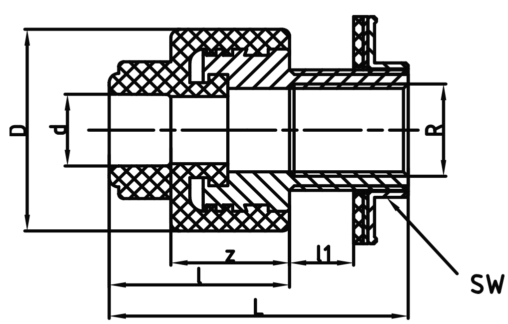
Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d	R	l	z	D	l1	z1	D1	L	c	Weight
				[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0120108	920108	0620108	(½" — 20 mm) x ½" F	0.79	0.50	1.22	0.65	1.16	1.24	0.73	1.46	2.01	0.79	0.08
0120110	920110	0620110	(½" — 20 mm) x ¾" F	0.79	0.75	1.46	0.89	1.34	1.46	0.94	1.73	2.13	0.98	0.23
0120112	920112	0620112	(¾" — 25 mm) x ¾" F	0.98	0.75	1.46	0.83	1.34	1.46	0.94	1.73	2.13	0.98	0.23
0120113	920113	0620113	(¾" — 25 mm) x ½" F	0.98	0.50	1.32	0.69	1.34	1.22	0.73	1.46	2.09	0.79	0.18

aquatherm green pipe® **ISO plug for pressure tests** with gasket



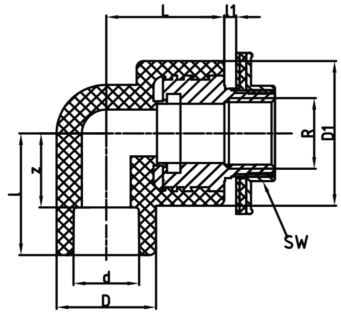
Part no.	Dimension	d	R	l	Weight
		[in]	[in]	[in]	[lb]
0050708	½" M	1.10	0.50	2.19	0.05
0050710	¾" M	1.34	0.75	2.19	0.06

aquatherm green pipe® **ISO transition piece** with counter nut, gasket and tension washer



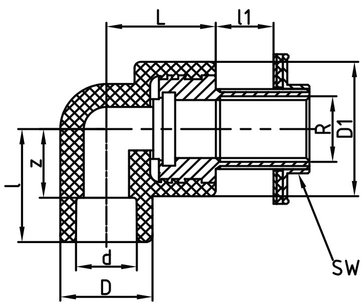
Part no.	Dimension	d	R	l	z	D	l1	L	SW	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0120204	20 mm x ½" F x ¾" M	0.79	0.50	1.57	1.00	1.71	0.53	2.56	1.14	0.45

aquatherm green pipe® **ISO transition elbow** with counter nut, gasket and tension washer



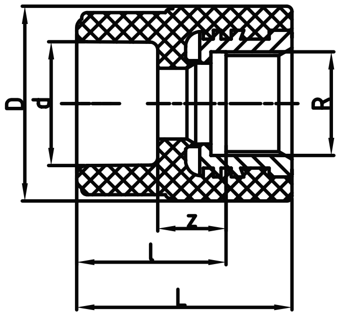
Part no.	Dimension	d	R	l	z	D	l1	L	D1	SW	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0120208	20 mm x ½" F x ¾" M	0.79	0.50	1.46	0.89	1.16	0.14	1.38	1.73	1.14	0.34
0120209	25 mm x ½" F x ¾" M	0.98	0.50	1.46	0.83	1.34	0.14	1.46	1.73	1.14	0.45

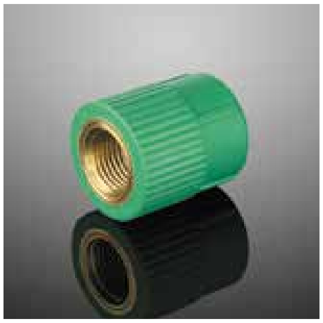
aquatherm green pipe® **ISO transition elbow** for dry construction



Part no.	Dimension (ND — OD)	d	R	l	z	D	l1	L	D1	SW	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0120210	20 mm x ½" F x ¾" M	0.79	0.50	1.46	0.89	1.16	0.73	1.38	1.73	1.14	0.49

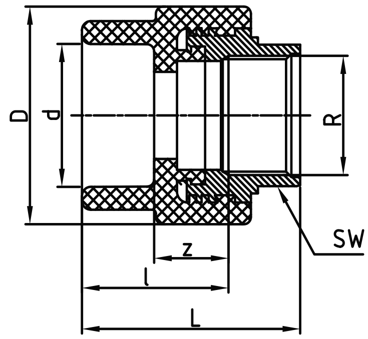
aquatherm green pipe® **transition piece** round





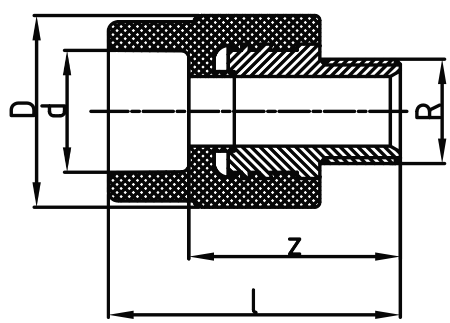
Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part No. (NPT)	Dimension PP-R (ND — OD) x thread	d	R	l	z	D	L	Weight
				[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0121008	921008	0621008	(½" — 20 mm) x ½" F	0.79	0.50	1.10	0.53	1.16	1.61	0.14
0121010	921010	0621010	(½" — 20 mm) x ¾" F	0.79	0.75	1.08	0.51	1.34	1.59	0.20
0121011	921011	0621011	(¾" — 25 mm) x ½" F	0.98	0.50	1.16	0.53	1.34	1.67	0.14
0121012	921012	0621012	(¾" — 25 mm) x ¾" F	0.98	0.75	1.08	0.45	1.34	1.59	0.19
0121013	921013	0621013	(1" — 32 mm) x ¾" F	1.26	0.75	1.20	0.49	1.69	1.71	0.20

aquatherm green pipe® **NPT transition piece** with hex-shaped threaded transition



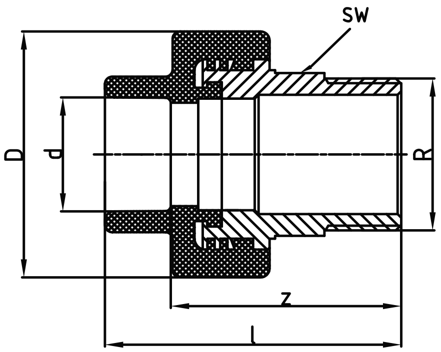
Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d [in]	R [in]	l [in]	z [in]	D [in]	L [in]	SW [in]	Weight [lb]
0121108	-	0621108	(½" — 20 mm) x ½" F	0.79	0.50	1.28	0.71	1.52	1.99	0.94	0.19
0121110	-	0621110	(½" — 20 mm) x ¾" F	0.79	0.75	1.06	0.49	1.71	1.97	1.22	0.25
0121111	-	0621111	(¾" — 25 mm) x ½" F	0.98	0.50	1.34	0.71	1.52	2.05	0.94	0.20
0121112	-	0621112	(¾" — 25 mm) x ¾" F	0.98	0.75	1.06	0.43	1.71	1.97	1.22	0.24
0121113	-	0621113	(1" — 32 mm) x ¾" F	1.26	0.75	1.18	0.47	1.71	2.09	1.22	0.25
	(NPT)										
0121114	1121114	0621114	(1" — 32 mm) x 1" F	1.26	0.75	1.48	0.77	2.36	2.34	1.54	0.53
0121115	1121115	0621115	(1 ¼" — 40 mm) x 1" F	1.57	1.00	1.57	0.77	2.36	2.44	1.54	0.54
0121116	1121116	0621116	(1 ¼" — 40 mm) x 1 ¼" F	1.57	1.25	1.65	0.85	2.91	2.56	1.97	0.85
0121117	1121117	0621117	(1 ½" — 50 mm) x 1 ¼" F	1.97	1.25	1.77	0.85	2.91	2.68	1.97	0.89
0121118	1121118	0621118	(1 ½" — 50 mm) x 1 ½" F	1.97	1.50	1.77	0.85	3.37	2.64	2.17	0.94
0121119	1121119	0621119	(2" — 63 mm) x 1 ½" F	2.48	1.50	2.03	0.94	3.31	2.89	2.17	0.97
0121120	-	0621120	(2" — 63 mm) x 2" F	2.48	2.00	1.97	0.89	3.98	2.99	2.64	1.30
0121122	-	0621122	(2 ½" — 75 mm) x 2" F	2.95	2.00	2.01	0.83	3.94	3.03	2.64	1.35

aquatherm green pipe® **transition piece** round (male)



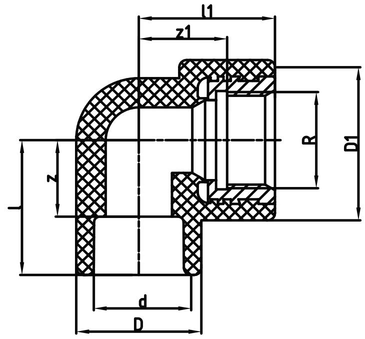
Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d [in]	R [in]	l [in]	z [in]	D [in]	Weight [lb]
0121208	921208	0621208	(½" — 20 mm) x ½" M	0.79	1/2"	2.22	1.65	1.52	0.21
0121210	921210	0621210	(½" — 20 mm) x ¾" M	0.79	3/4"	2.26	1.69	1.52	0.24
0121211	921211	0621211	(¾" — 25 mm) x ½" M	0.98	1/2"	2.28	1.65	1.52	0.22
0121212	921212	0621212	(¾" — 25 mm) x ¾" M	0.98	3/4"	2.26	1.63	1.52	0.24
0121213	921213	0621213	(1" — 32 mm) x ¾" M	1.26	3/4"	2.34	1.63	1.69	0.25

aquatherm green pipe® **NPT transition piece** hex-shaped threaded transition



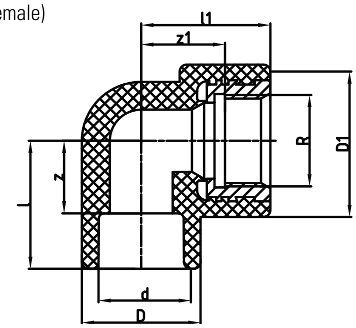
Lead-free brass part no. (NPT)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d [in]	R [in]	l [in]	z [in]	D [in]	SW [in]	Weight [lb]
0121308	0621308	(½" — 20 mm) x ½" M	0.79	0.50	2.62	2.05	1.52	0.87	0.23
0121310	0621310	(½" — 20 mm) x ¾"M	0.79	0.75	2.66	2.09	1.52	0.94	0.28
0121312	0621312	(¾" — 25 mm) x ¾" M	0.98	0.75	2.66	2.03	1.52	0.94	0.23
0121314	0621314	(1" — 32 mm) x 1" M	1.26	1.00	3.09	2.38	2.09	1.26	0.48
0121316	0621316	(1" — 32 mm) x 1 ¼" M	1.26	1.25	3.19	2.48	2.68	1.61	0.71
0121317	0621317	(1 ¼" — 40 mm) x 1" M	1.57	1.00	3.19	2.38	2.05	1.26	0.49
0121318	0621318	(1 ¼" — 40 mm) x 1 ¼" M	1.57	1.25	3.33	2.52	2.68	1.61	0.72
0121319	0621319	(1 ½" — 50 mm) x 1 ¼" M	1.97	1.25	3.37	2.44	2.68	1.61	0.78
0121320	0621320	(1 ½" — 50 mm) x 1 ½" M	1.97	1.50	3.48	2.56	2.91	1.81	0.95
0121321	0621321	(2" — 63 mm) x 1 ½" M	2.48	1.50	3.90	2.81	2.85	1.81	1.03
0121322	0621322	(2" — 63 mm) x 2" M	2.48	2.00	4.04	2.95	3.31	1.97	1.50
0121323	0621323	(2 ½" — 75 mm) x 2" M	2.95	2.00	4.09	2.91	3.31	1.97	1.61
0121324	0621324	(2 ½" — 75 mm) x 2 ½" M	2.95	2.50	4.13	2.95	3.94	2.56	2.14
0121325	0621325	(3" — 90 mm) x 3" M	3.54	3.00	4.96	3.66	4.72	3.35	2.90
0121327	-	(3 ½" — 110 mm) x 4" M	4.33	4.00	5.83	4.37	5.79	4.13	5.95

aquatherm green pipe® **transition elbow**



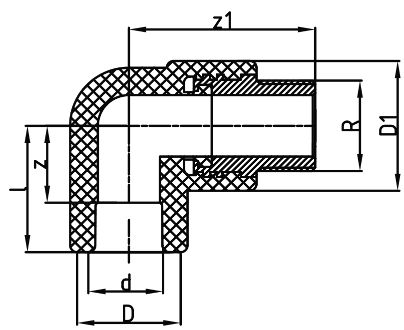
Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d [in]	R [in]	l [in]	z [in]	D [in]	l1 [in]	z1 [in]	D1 [in]	Weight [lb]
0123008	923008	0623008	(½" — 20 mm) x ¾" F	0.79	0.75	1.46	0.89	1.34	1.46	0.94	2.32	0.23
0123010	923010	0623010	(½" — 20 mm) x ½" F	0.79	0.50	1.24	0.67	1.16	1.46	0.94	1.97	0.16
0123012	923012	0623012	(¾" — 25 mm) x ¾" F	0.98	0.75	1.46	0.83	1.34	1.46	0.94	2.32	0.22
0123014	923014	0623014	(¾" — 25 mm) x ½" F	0.98	0.50	1.34	0.71	1.34	1.46	0.94	2.07	0.16
0123016	923016	0623016	(1" — 32 mm) x ¾" F	1.26	0.75	1.08	0.37	1.69	2.01	1.50	1.95	0.23
	(NPT)											
0123018	1123018	0623018	(1" — 32 mm) x 1" F	1.26	1.00	1.26	0.55	1.69	2.62	1.91	2.45	0.55

aquatherm green pipe® NPT transition street elbow (male/female)



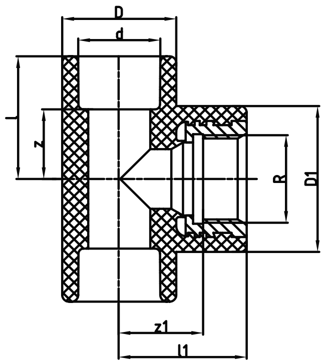
Lead-free brass part no. (NPT)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d [in]	R [in]	l [in]	z [in]	D [in]	l1 [in]	z1 [in]	D1 [in]	Weight [lb]
0123208	0623208	(½" — 20 mm) x ½" F	0.79	0.50	1.32	0.73	1.16	1.46	0.94	1.46	0.17

aquatherm green pipe® transition elbow (male)



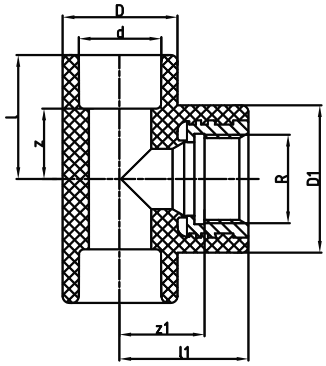
Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d [in]	R [in]	l [in]	z [in]	D [in]	z1 [in]	D1 [in]	Weight [lb]
0123506	923506	0623506	(½" — 20 mm) x ½" M	0.79	0.50	1.24	0.67	1.16	2.09	1.46	0.24
0123508	923508	0623508	(½" — 20 mm) x ¾" M	0.79	0.75	1.46	0.89	1.34	2.13	1.50	0.28
0123510	923510	0623510	(¾" — 25 mm) x ¾" M	0.98	0.75	1.46	0.83	1.34	2.13	1.50	0.23
0123512	923512	0623512	(1" — 32 mm) x ¾" M	1.26	0.75	1.08	0.37	1.69	2.68	1.50	0.25
0123514	-	0623514	(1" — 32 mm) x 1" M	1.26	1.00	1.22	0.51	1.69	3.37	2.05	0.51

aquatherm green pipe® **transition tee** (female)



Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension PP-R (ND — OD) x thread	d	R	l	z	D	l1	z1	D1	Weight
				[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0125006	925006	0625006	(½" — 20 mm) x (½" — 20 mm) x ½" F	0.79	0.50	1.24	0.67	1.16	1.46	0.94	1.46	0.19
0125008	925008	0625008	(½" — 20 mm) x (½" — 20 mm) x ¾" F	0.79	0.75	1.46	0.89	1.34	1.50	0.98	1.73	0.27
0125010	925010	0625010	(¾" — 25 mm) x (¾" — 25 mm) x ½" F	0.98	0.50	1.34	0.71	1.34	1.50	0.98	1.46	0.20
0125012	925012	0625012	(¾" — 25 mm) x (¾" — 25 mm) x ¾" F	0.98	0.75	1.46	0.83	1.34	1.50	0.98	1.73	0.20
0125014	925014	0625014	(1" — 32 mm) x (1" — 32 mm) x ¾" F	1.26	0.75	1.08	0.37	1.69	2.01	1.50	1.73	0.25
	(NPT)											
0125016	1125016	0625016	(1" — 32 mm) x (1" — 32 mm) x 1" F	1.26	1.00	1.22	0.53	1.69	2.64	1.93	2.36	0.56
0125022	-	0625022	(1 ½" — 50 mm) x (1 ½" — 50 mm) x 1" F	1.97	1.00	1.95	1.02	2.68	2.50	1.71	2.68	0.82

aquatherm green pipe® **NPT transition tee** (male)



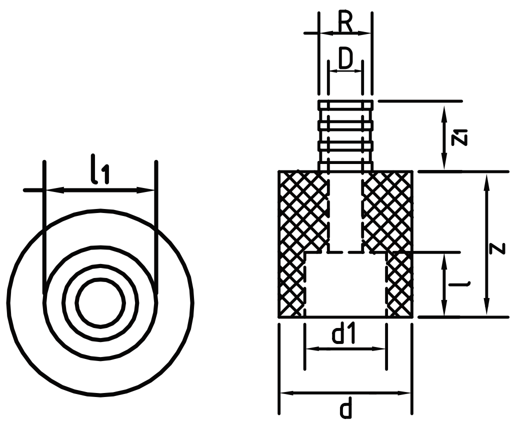
Lead-free brass part no. (NPT)	Zero-lead brass part no. (NPT)	Dimension ND — OD	d	R	l	z	D	z1	D1	Weight
			[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0125506	0625506	(½" — 20 mm) x ½" M x (½" — 20 mm)	0.79	0.50	1.24	0.67	1.16	2.09	1.46	0.23

aquatherm green pipe® transition to compression fitting (PP-R to brass)

Part no.	Dimension ND — OD	Weight
		[lb]
0099013	½" (20 mm) PP-R to ½" Compression	0.214

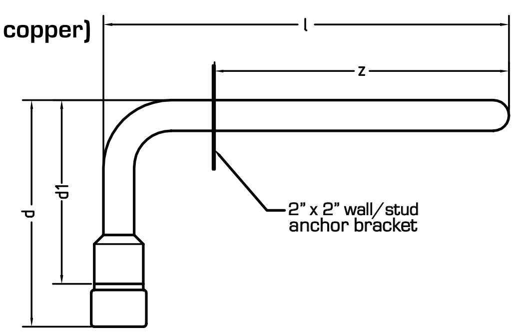
aquatherm green pipe® PEX adapter

built to ASTM F1807 standard



Part no.	Dimension ND — OD	d	R	l	z	D	l1	z1	d1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0099840	½" — 20 mm	1.125	0.5	0.625	1.25	0.25	0.75	0.625	0.75	-
0099841	¾" — 25 mm	1.375	0.625	0.625	1.375	0.5	1.00	0.625	0.875	-
0099842	1" — 32 mm	1.75	0.875	0.875	1.625	0.625	1.25	0.75	1.25	-

aquatherm green pipe® Stub out (PP-R to copper)

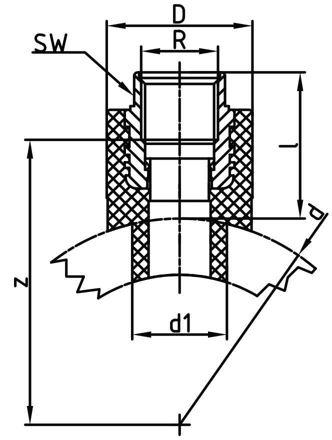


Part no.	Dimension ND — OD	d	d1	l	z	Weight
		[in]	[in]	[in]	[in]	[lb]
630P248E	½" — 20 mm	4.625	3.75	8.25	6	-
630P368E	¾" — 25 mm	7.5	6.625	8.5	6	-
630P41110	1" — 32 mm	12.25	11.25	10.5	7.5	-

These fittings are combination of a custom Aquatherm PP-R socket with a gasket and copper stub added by Sioux Chief Manufacturing. The fused PP-R portion is covered under Aquatherm's warranty. The copper portion and gasket are covered under a warranty from Sioux Chief.

aquatherm green pipe® NPT fusion outlet

with hex shaped female thread, weld-in surface and weld-in socket for fusion with the inner wall of the pipe

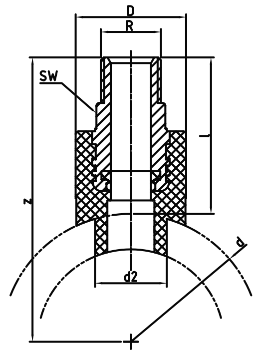


Lead-free brass part no. (NPT)	Stainless steel part no. (ISO)	Zero-lead brass part no. (NPT)	Dimension pipe x outlet (ND-OD) x thread	d [in]	d1 [in]	R [in]	l [in]	z [in]	D [in]	SW [in]	Weight [lb]
0128214	928214	0628214	1 ¼" x ¾" — 40 x 25 mm x ½" F	1.57	0.98	0.50	1.54	1.61	1.52	0.94	0.19
0128216	928216	0628216	1 ½" x ¾" — 50 x 25 mm x ½" F	1.97	0.98	0.50	1.54	1.81	1.52	0.94	0.20
0128218	928218	0628218	2" x ¾" — 63 x 25 mm x ½" F	2.48	0.98	0.50	1.54	2.07	1.52	0.94	0.20
0128220	928220	0628220	2 ½" x ¾" — 75 x 25 mm x ½" F	2.95	0.98	0.50	1.54	2.30	1.52	0.94	0.18
0128222	928222	0628222	3" x ¾" — 90 x 25 mm x ½" F	3.54	0.98	0.50	1.54	2.60	1.52	0.94	0.20
0128224	928224	0628224	3 ½" x ¾" — 110 x 25 mm x ½" F	4.33	0.98	0.50	1.54	2.99	1.52	0.94	0.20
0128226	928226	0628226	4" x ¾" — 125 x 25 mm x ½" F	4.92	0.98	0.50	1.54	3.29	1.52	0.94	0.20
0128230	928230	0628230	6" x ¾" — 160 x 25 mm x ½" F	6.30	0.98	0.50	1.54	3.98	1.52	0.94	0.20
0128232	928232	0628232	8 to 10" x ¾" —200 to 250 x 25 mm x ½" F	7.87	0.98	0.50	1.54	-	1.52	0.94	0.20
0128234	928234	0628234	1 ¼" x ¾" — 40 x 25 mm x ¾" F	1.57	0.98	0.50	1.54	1.42	1.71	1.22	0.24
0128236	928236	0628236	1 ½" x ¾" — 50 x 25 mm x ¾" F	1.97	0.98	0.50	1.54	1.61	1.71	1.22	0.24
0128238	928238	0628238	2" x ¾" — 63 x 25 mm x ¾" F	2.48	0.98	0.50	1.54	1.87	1.71	1.22	0.24
0128240	928240	0628240	2 ½" x ¾" — 75 x 25 mm x ¾" F	2.95	0.98	0.50	1.54	2.11	1.71	1.22	0.24
0128242	928242	0628242	3" x ¾" — 90 x 25 mm x ¾" F	3.54	0.98	0.50	1.54	2.40	1.71	1.22	0.24
0128244	928244	0628244	3 ½" x ¾" — 110 x 25 mm x ¾" F	4.33	0.98	0.50	1.54	2.80	1.71	1.22	0.24
0128246	928246	0628246	4" x ¾" — 125 x 25 mm x ¾" F	4.92	0.98	0.50	1.54	3.09	1.71	1.22	0.25
0128250	928250	0628250	6" x ¾" — 160 x 25 mm x ¾" F	6.30	0.98	0.50	1.54	3.78	1.71	1.22	0.25
0128254	928254	0628254	8 to 10" x ¾"—200 to 250 x 25 mm x ¾" F	7.87	0.98	0.50	1.54	-	1.71	1.22	0.25
	(NPT)										
0128260	1128260	0628260	2 ½" x 1" — 75 x 32 mm x 1" F	2.95	1.26	1.00	1.69	2.30	2.36	1.54	0.50
0128262	1128262	0628262	3" x 1" — 90 x 32 mm x 1" F	3.54	1.26	1.00	1.69	2.60	2.36	1.54	0.50
0128264	1128264	0628264	3 ½" x 1" — 110 x 32 mm x 1" F	4.33	1.26	1.00	1.69	2.99	2.36	1.54	0.50
0128266	1128266	0628266	4" x 1" — 125 x 32 mm x 1" F	4.92	1.26	1.00	1.69	3.29	2.36	1.54	0.05
0128270	1128270	0628270	6" x 1" — 160 x 32 mm x 1" F	6.30	1.26	1.00	1.69	3.98	2.36	1.54	0.50
0128274	1128274	0628274	8 to 10" x 1" – 200 to 250 x 32 mm x 1" F	7.87	1.26	1.00	1.69	4.76	2.36	1.54	0.54

The necessary heads for the fusion of aquatherm green pipe® fusion outlets are listed on page 5.48 (part no. 0050614 - 0050640).

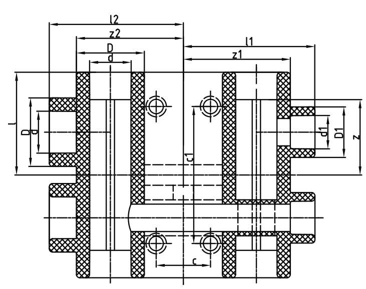
aquatherm green pipe® NPT fusion outlet

with hex shaped male thread, weld-in surface and weld-in socket
for fusion with the inner wall of the pipe



Lead-free brass part no. (NPT)	Zero-lead brass part no. (NPT)	Dimension pipe x outlet (ND-OD) x thread	d [in]	d2 [in]	l [in]	z [in]	D [in]	R [in]	SW [in]	Weight [lb]
0128314	0628314	1 " x ¾" — 40 x 25 mm x ½" M	1.57	0.98	2.17	2.95	1.52	0.50	0.83	0.19
0128316	0628316	1 ½" x ¾" — 50 x 25 mm x ½" M	1.97	0.98	2.17	3.15	1.52	0.50	0.83	0.20
0128318	0628318	2" x ¾" — 63 x 25 mm x ½" M	2.48	0.98	2.17	3.41	1.52	0.50	0.83	0.20
0128320	0628320	2 ½" x ¾" — 75 x 25 mm x ½" M	2.95	0.98	2.17	3.64	1.52	0.50	0.83	0.21
0128322	0628322	3" x ¾" — 90 x 25 mm x ½" M	3.54	0.98	2.17	3.94	1.52	0.50	0.83	0.20
0128324	0628324	3 ½" x ¾" — 110 x 25 mm x ½" M	4.33	0.98	2.17	4.33	1.52	0.50	0.83	0.20
0128326	0628326	4" x ¾" — 125 x 25 mm x ½" M	4.92	0.98	2.17	4.63	1.52	0.50	0.83	0.20
0128330	0628330	6" x ¾" — 160 x 25 mm x ½" M	6.30	0.98	2.17	5.31	1.52	0.50	0.83	0.20
0128334	0628334	1 " x ¾" — 40 x 25 mm x ¾" M	1.57	0.98	2.20	2.99	1.71	0.75	0.94	0.24
0128336	0628336	1 ½" x ¾" — 50 x 25 mm x ¾" M	1.97	0.98	2.20	3.19	1.71	0.75	0.94	0.24
0128338	0628338	2" x ¾" — 63 x 25 mm x ¾" M	2.48	0.98	2.20	3.44	1.71	0.75	0.94	0.24
0128340	0628340	2 ½" x ¾" — 75 x 25 mm x ¾" M	2.95	0.98	2.20	3.68	1.71	0.75	0.94	0.24
0128342	0628342	3" x ¾" — 90 x 25 mm x ¾" M	3.54	0.98	2.20	3.98	1.71	0.75	0.94	0.24
0128344	0628344	3 ½" x ¾" — 110 x 25 mm x ¾" M	4.33	0.98	2.20	4.37	1.71	0.75	0.94	0.24
0128346	0628346	4" x ¾" — 125 x 25 mm x ¾" M	4.92	0.98	2.20	4.67	1.71	0.75	0.94	0.25
0128350	0628350	6" x ¾" — 160 x 25 mm x ¾" M	6.30	0.98	2.20	5.35	1.71	0.75	0.94	0.25

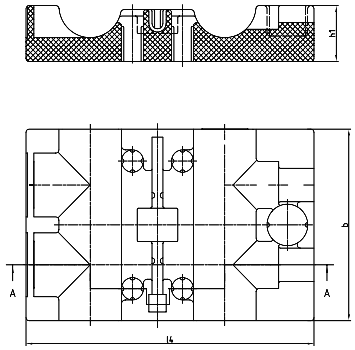
aquatherm green pipe® distribution block plumbing including 1 plug and 2 fasteners



Part no.	Dimension ND — OD	d [in]	l [in]	z [in]	D [in]	d1 [in]	l1 [in]	z1 [in]	D1 [in]	l2 [in]	z2 [in]	c [in]	c1 [in]	cl [in]	l3 [in]	h [in]	Weight [lb]
0130115	¾" x ½" — 25 x 20 mm	0.98	2.36	1.73	1.57	0.79	3.05	2.48	1.16	3.11	2.48	1.26	3.15	3.94	1.42	2.01	0.61

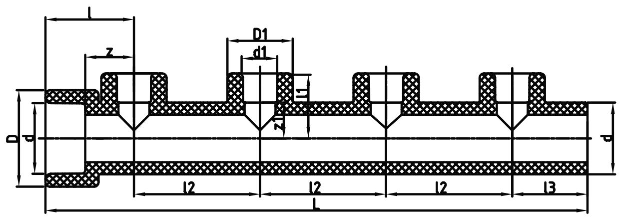
Material: fusiolen® **PP-R**
Passage: 25 mm (socket) / 2 branches: 20 mm (sockets).

aquatherm green pipe® distribution block plumbing with insulation block (3" x 3" — 70 x 70 mm)




Part no.	Dimension ND — OD	l4	b	h1	Weight
		[in]	[in]	[in]	[lb]
0130130	¾" x ½" — 25 x 20 mm	7.24	4.72	1.38	0.70

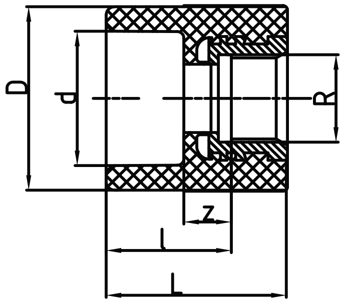
aquatherm green pipe® distribution pipe (246 mm long, with four branch connections)




Part no.	Dimension ND — OD	d	d1	l	z	D	l1	z1	D1	l2	l3	L	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0130604	1" x ½" — 32 x 20 mm	1.26	0.79	1.57	0.87	1.69	1.14	0.57	1.16	2.24	1.42	9.65	0.30

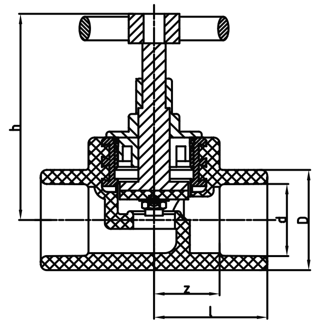
The distribution pipe can be shortened or supplemented by fusion with further distribution pipes as needed.

aquatherm green pipe® distributor end piece with female thread **NPT**
to empty or aerate the distribution pipe



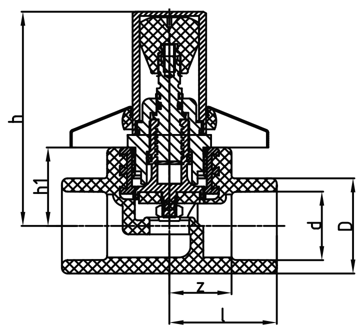

Part no.	Dimension (ND — OD) x thread	d	l	z	D	L	R	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0130804	(1" — 32 mm) x ½" F	1.26	1.14	0.43	1.69	1.65	0.50	0.17

aquatherm green pipe® screw-down stop globe valve
for surface installation



Part no.	Dimension ND — OD	d	l	z	D	h	Weight
		[in]	[in]	[in]	[in]	[in]	[lb]
0140808	½" — 20 mm	0.79	1.38	0.81	1.56	2.76	0.36
0140810	¾" — 25 mm	0.98	1.50	0.87	1.34	2.76	0.38
0140812	1" — 32 mm	1.26	1.93	1.22	1.69	3.41	0.69
0140814	1 ¼" — 40 mm	1.57	2.36	1.56	2.05	3.96	1.29

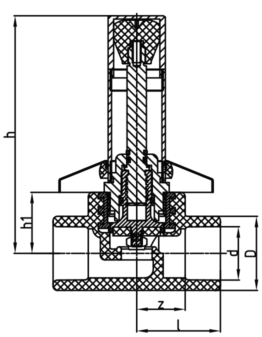
aquatherm green pipe® concealed valve
chromium-plated, tamper proof, short design



Part no.	Dimension ND — OD	d	l	z	D	h	h1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0140868	½" — 20 mm	0.79	1.38	0.81	1.16	2.81	1.10	0.57
0140870	¾" — 25 mm	0.98	1.50	0.87	1.34	2.81	1.10	0.64
0140872	1" — 32 mm	1.26	1.93	1.22	1.69	3.25	1.34	0.83

Part no. 0140868 - 0140870 suitable for construction depths up to 1".
Part no. 0140872 suitable for construction depths up to 1 ⅛".

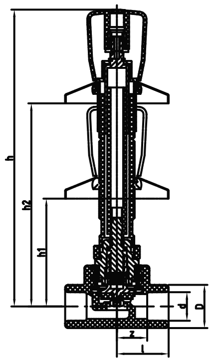
aquatherm green pipe® concealed valve chromium-plated, tamper proof



Part no.	Dimension ND — OD	d	l	z	D	h	h1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0140888	½" — 20 mm	0.79	1.38	0.81	1.16	4.29	1.10	0.75
0140890	¾" — 25 mm	0.98	1.50	0.87	1.34	4.29	1.10	0.77
0140892	1" — 32 mm	1.26	1.93	1.22	1.69	4.53	1.34	0.95

Suitable for construction depths up to 2 ⅓".

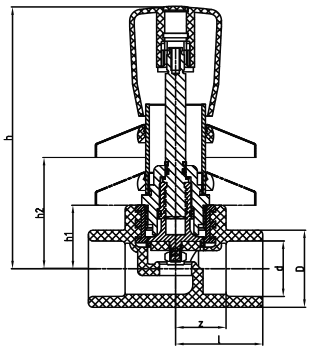
aquatherm green pipe® **concealed valve** chromium-plated



Part no.	Dimension ND — OD	d	l	z	D	h	h1	h2	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0140878	½" — 20 mm	0.79	1.38	0.81	1.16	8.39	5.79	2.32	0.79
0140880	¾" — 25 mm	0.98	1.50	0.87	1.34	8.39	5.79	2.32	0.81
0140882	1" — 32 mm	1.26	1.93	1.22	1.69	8.62	6.02	2.56	1.00

Suitable for construction depths from 2 ⅛" - 4".

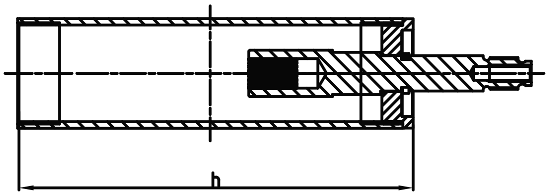
aquatherm green pipe® **concealed valve** chromium-plated



Part no.	Dimension ND — OD	d	l	z	D	h	h1	h2	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0140858	½" — 20 mm	0.79	1.38	0.81	1.16	4.57	1.10	2.32	0.70
0140860	¾" — 25 mm	0.98	1.50	0.87	1.34	4.57	1.10	2.32	0.73
0140862	1" — 32 mm	1.26	1.93	1.22	1.69	4.76	1.34	2.32	0.92

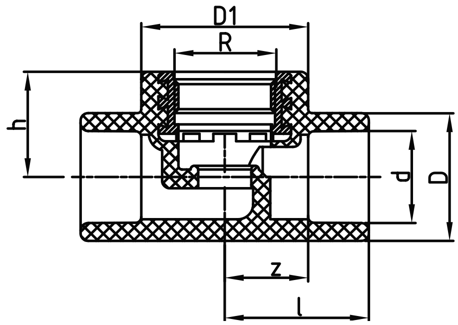
Extension for aquatherm green pipe® **concealed valve**

chromium-plated for part no. 0040858 - 0040862



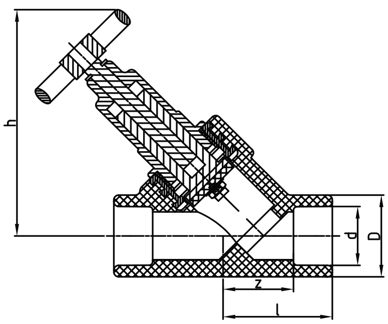
Part no.	Dimension	h	Weight
		[in]	[lb]
0040900	3.2" extension (92 mm)	3.62	0.33
0040902	4.25" extension (132 mm)	5.20	0.46

aquatherm green pipe® **stop valve body ISO**



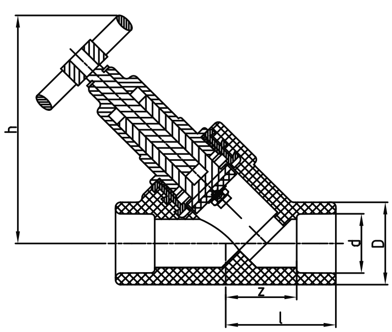
Part no.	Dimension PP-R (ND — OD) x thread	d	l	z	D	h	D1	R	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0040908	(½" — 20 mm) x ¾" F	0.79	1.38	0.79	1.16	1.10	1.73	0.75	0.21
0040910	(¾" — 25 mm) x ¾" F	0.98	1.50	0.87	1.34	1.10	1.73	0.75	0.22
0040912	(1" — 32 mm) x 1" F	1.26	1.93	1.22	1.69	1.34	2.05	1.00	0.32
0040914	(1 ¼" — 40 mm) x 1 ¼" F	1.57	2.36	1.56	2.05	1.61		1.25	0.69

aquatherm green pipe® **inclined valve** without drain



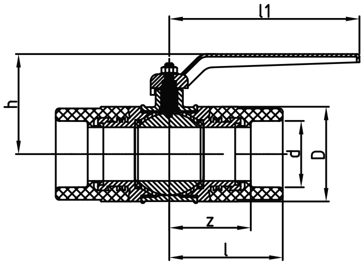
Part no.	Dimension ND — OD	d	l	z	D	h	Weight
		[in]	[in]	[in]	[in]	[in]	[lb]
0041108	½" — 20 mm	0.79	1.77	1.20	1.34	3.76	0.65
0041110	¾" — 25 mm	0.98	1.77	1.14	1.34	3.76	0.62
0041112	1" — 32 mm	1.26	2.20	1.50	1.69	4.39	0.93
0041114	1 ¼" — 40 mm	1.57	2.56	1.75	2.05	5.31	1.84

aquatherm green pipe® **inclined check valve** without drain



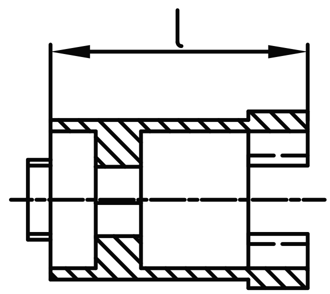
Part no.	Dimension ND — OD	d	l	z	D	h	Weight
		[in]	[in]	[in]	[in]	[in]	[lb]
0041208	½" — 20 mm	0.79	1.77	1.20	1.34	3.76	0.65
0041210	¾" — 25 mm	0.98	1.77	1.14	1.34	3.76	0.64
0041212	1" — 32 mm	1.26	2.20	1.50	1.69	4.39	0.95
0041214	1 ¼" — 40 mm	1.57	2.56	1.75	2.05	5.31	1.85

aquatherm green pipe® **ball valve** without drain



Part no.	Dimension ND — OD	d	l	z	D	h	l1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0041308	½" — 20 mm	0.79	2.17	1.59	1.26	2.60	3.35	0.62
0041310	¾" — 25 mm	0.98	2.17	1.54	1.61	2.87	3.35	0.83
0041312	1" — 32 mm	1.26	2.50	1.79	1.85	3.23	4.25	1.31
0041314	1 ¼" — 40 mm	1.57	2.85	2.05	2.28	3.66	4.25	2.28
0041316	1 ½" — 50 mm	1.97	3.29	2.36	2.78	4.49	5.51	2.95
0041318	2" — 63 mm	2.48	4.04	2.95	3.43	5.20	5.51	5.63

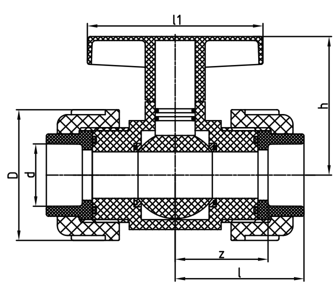
Extension for aquatherm green pipe® ball valve



Part no.	Dimension ND — OD x length	l	Weight
		[in]	[lb]
0041378	½" to ¾" — 20 to 25 mm x 35 mm	1.38	0.27
0041382	1" to 1 ¼" — 32 to 40 mm x 35 mm	1.38	0.27
0041386	1 ½" to 2" — 50 - 63 mm x 46 mm	1.81	0.60

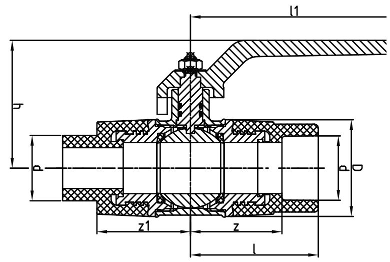
Part no. 0041378 suitable for part no. 0041308 / 0041310.
Part no. 0041382 suitable for part no. 0041312 / 0041314.
Part no. 0041386 suitable for part no. 0041316 / 0041318.

aquatherm green pipe® **ball valve** polypropylene



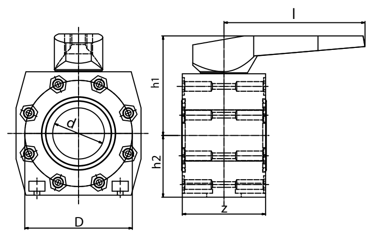
Part no.	Dimension ND — OD	d	l	z	D	h	L2	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0041488	½" — 20 mm	0.79	2.03	1.46	1.81	2.01	2.68	0.26
0041490	¾" — 25 mm	0.98	2.30	1.67	2.20	2.40	3.07	0.41
0041492	1" — 32 mm	1.26	2.48	1.77	2.60	2.76	3.46	0.61
0041494	1 ¼" — 40 mm	1.57	2.83	2.03	3.11	3.19	3.86	0.96
0041496	1 ½" — 50 mm	1.97	2.99	2.07	3.43	3.54	4.25	1.21
0041498	2" — 63 mm	2.48	3.56	2.48	4.21	4.33	4.65	2.03
0041400	2 ½" — 75 mm	2.95	9.84	5.71	7.32	7.32	15.35	5.77

aquatherm green pipe® ball valve (male/female)



Part no.	Dimension ND — OD	d	l	z	D	z1	h	l1	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0078000	(1" — 32 mm) M/F	1.26	2.48	1.77	1.87	1.83	3.07	4.25	1.27

aquatherm green pipe® ball valve polypropylene (European flange ring)

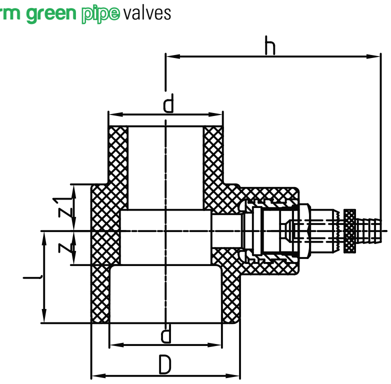


Part no.	Dimension ND — OD	d	l	z	D	h1	h2	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0041602	3" — 90 mm	3.03	8.27	4.88	6.30	5.91	3.66	9.20
0041604[a]	3 ½" to 4" — 110 to 125 mm	3.70	10.24	5.71	7.09	6.50	4.06	12.37
0041607	6" — 160 mm	5.31	12.20	8.07	9.45	8.27	5.37	12.38

[a] For a 4" connection, use part no. 0115526 and part no. 3315724. For a 3 ½" connection, use part no. 0115524 and part no. 3315724.

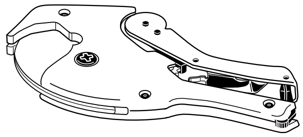
Note: Screws and washers not included in delivery. Use hexagon screw M16 x 60 mm for part no. 41602/41604, M16 x 80 mm for part no. 41607, and flat washer M16.

aquatherm green pipe® draining branch to weld in aquatherm green pipe valves



Part no.	Dimension ND — OD	d	l	z	D	z1	h	Weight
		[in]	[in]	[in]	[in]	[in]	[in]	[lb]
0041408	½" — 20 mm	0.79	0.45	1.02	1.34	0.65	2.64	0.22
0041410	¾" — 25 mm	0.98	0.39	1.02	1.34	0.65	2.64	0.21
0041412	1" — 32 mm	1.26	0.55	1.26	1.69	0.67	2.78	0.26
0041414	1 ¼" — 40 mm	1.57	0.47	1.28	2.05	0.65	3.01	0.31
0041416	1 ½" — 50 mm	1.97	0.61	1.54	2.68	0.67	3.30	0.45
0041418	2" — 63 mm	2.48	0.65	1.73	3.31	0.65	3.66	0.64

aquatherm pipe cutter



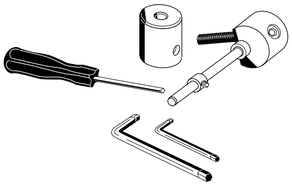
Part no.	Dimension	Weight [lb]
0050104	(⅜″ - 1 ¼″) — (16 - 40 mm)	1.31

Note: Intended for use with PP-R pipe and fittings only.

aquatherm temperature protective gloves for welding head changing

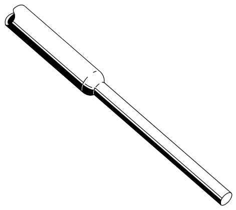
Part no.	Dimension
0050195	-

aquatherm repair set to close pipe holes up to 0.4 in (repair stick part no. 0060600)



Part no.	Dimension	Weight [lb]
0050307	¼″ — 7 mm	0.37
0050311	7⁄16″ — 11 mm	0.37

aquatherm green pipe® repair plug

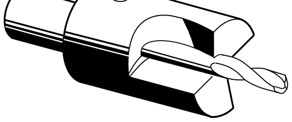


Part no.	Dimension OD for each end	Weight [lb]
0060600	7⁄16″ x ¼″ — 11 x 7 mm	0.02

Material: **fusiolen® PP-R** to close pipe holes up to 0.4 in.

Tool: aquatherm repair set (part no. 0050307 & 0050311).

aquatherm drill bit for the mounting of weld in fusion outlets

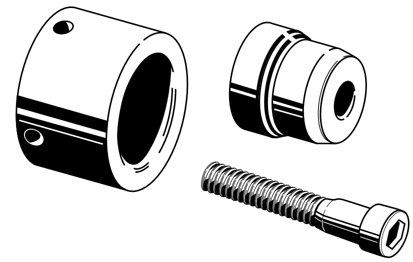


Part no.	Dimension	Weight [lb]
0050940	½″ & ¾″ — 20 & 25 mm (for pipes 1 ¼″ - 6″ — 40 - 160 mm)	0.31
0050941	½″ & ¾″ — 20 & 25 mm (for pipes 2″ - 10″ — 63 - 160 mm)	0.35
0050942	1″ — 32 mm	0.46
0050944	1 ¼″ — 40 mm	0.63
0050946	1 ½″ — 50 mm	0.70
0050948	2″ — 63 mm	1.00
0050950[a]	2 ½″ — 75 mm	3.12
0050952[a]	3″ — 90 mm	3.56
0050954[a]	3 ½″ — 110 mm	4.80
0050956[a]	4″ — 125 mm	4.42
0050958[a]	6″ — 160 mm	8.81
0050960[a]	8″ — 200 mm	-

[a] Must be used in fixed drilling machine. Morse taper shank.

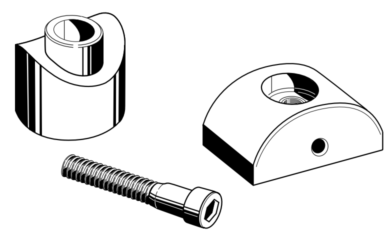
aquatherm welding heads

Part no.	Dimension	Weight [lb]
0050206	⅜" — 16 mm	0.24
0050208	½" — 20 mm	0.25
0050210	¾" — 25 mm	0.31
0050212	1" — 32 mm	0.46
0050214	1 ¼" — 40 mm	0.68
0050216	1 ½" — 50 mm	1.00
0050218	2" — 63 mm	1.50
0050220	2 ½" — 75 mm	2.02
0050222	3" — 90 mm	3.12
0050224	3 ½" — 110 mm	5.40
0050226	4" — 125 mm	7.33



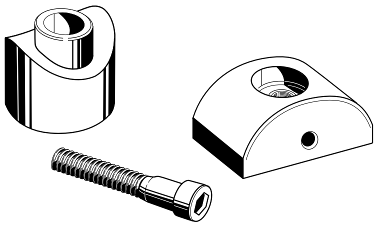
aquatherm fusion outlet welding heads

Part no.	Dimension	Weight [lb]
0050614	1 ¼" x ½" & ¾" — 40 x 20 & 25 mm	0.41
0050616	1 ½" x ½" & ¾" — 50 x 20 & 25 mm	0.49
0050619	2" x ½" & ¾" — 63 x 20 & 25 mm	0.53
0050620	2" x 1" — 63 x 32 mm	0.54
0050623	2 ½" x ½" & ¾" — 75 x 20 & 25 mm	0.56
0050624	2 ½" x 1" — 75 x 32 mm	0.57
0050625	2 ½" x 1 ¼" — 75 x 40 mm	0.99
0050627	3" x ½" & ¾" — 90 x 20 & 25 mm	0.59
0050628	3" x 1" — 90 x 32 mm	0.60
0050629	3" x 1 ¼" — 90 x 40 mm	1.02
0050631	3 ½" x ½" & ¾" — 110 x 20 & 25 mm	0.61
0050632	3 ½" x 1" — 110 x 32 mm	0.63
0050634	3 ½" x 1 ¼" — 110 x 40 mm	1.06
0050635	3 ½" x 1 ½" — 110 x 50 mm	1.72
0050636	4" x ½" & ¾" — 125 x 20 & 25 mm	0.64
0050638	4" x 1" — 125 x 32 mm	0.66
0050640	4" x 1 ¼" — 125 x 40 mm	1.12
0050642	4" x 1 ½" — 125 x 50 mm	1.75
0050644	4" x 2" — 125 x 63 mm	2.69
0050648	6" x ½" & ¾" — 160 x 20 & 25 mm	0.71
0050650	6" x 1" — 160 x 32 mm	0.74
0050652	6" x 1 ¼" — 160 x 40 mm	1.20
0050654	6" x 1 ½" — 160 x 50 mm	1.85
0050656	6" x 2" — 160 x 63 mm	2.82
0050657	6" x 2 ½" — 160 x 75 mm	-
0050658	6" x 3" — 160 x 90 mm	-
0050660	8" x ½" & ¾" — 200 x 20 & 25 mm	0.44
0050662	8" x 1" — 200 x 32 mm	0.51
0050664	8" x 1 ¼" — 200 x 40 mm	0.89
0050666	8" x 1 ½" — 200 x 50 mm	1.42



aquatherm fusion outlet welding heads (continued)

Part no.	Dimension	Weight [lb]
0050667	8” x 2 ½” — 200 x 75 mm	3.98
0050668	8” x 2” — 200 x 63 mm	2.30
0050669	8” x 3” — 200 x 90 mm	5.53
0050670	8” x 3 ½” — 200 x 110 mm	-
0050671	8” x 4” — 200 x 125 mm	-
0050672	10” x ½” & ¾” — 250 x 20 & 25 mm	0.45
0050674	10” x 1” — 250 x 32 mm	0.51
0050676	10” x 1 ¼” — 250 x 40 mm	0.89
0050678	10” x 1 ½” — 250 x 50 mm	1.46
0050680	10” x 2” — 250 x 63 mm	2.35
0050682	10” x 2 ½” — 250 x 75 mm	4.01
0050684	10” x 3” — 250 x 90 mm	5.66
0050686	10” x 3 ½” — 250 x 110 mm	8.05
0050688	10” x 4” — 250 x 125 mm	13.16
0050690	12” x 2” — 315 x 63 mm	2.41
0050692	12” x 2 ½” — 315 x 75 mm	4.22
0050694	12” x 3” — 315 x 90 mm	7.11
0050696	12” x 3 ½” — 315 x 110 mm	10.55
0050698	12” x 4” — 315 x 125 mm	13.23
0050699	12” x 6” — 315 x 160 mm	18.96
0050712	14”x 2” — 355 x 63 mm	-
0050714	14” x 2 ½” — 355 x 75 mm	-
0050716	14” x 3” — 355 x 90 mm	-
0050718	14” x 3 ½” — 355 x 110 mm	-
0050720	14” x 4” — 355 x 125 mm	-
0050722	14” x 6” — 355 x 160 mm	-
0050724	14” x 8” — 355 x 200 mm	-
0050726	16” - 24” x 2” — 400-630 x 63 mm	-
0050728	16” - 20” x 2 ½” — 400-500 x 75 mm	-
0050730	22” - 24” x 2 ½” — 560-630 x 75 mm	-
0050732	16” - 20” x 3” — 400-500 x 90 mm	-
0050734	22” - 24” x 3” — 560-630 x 90 mm	-
0050736	16” - 18” x 3 ½” — 400-450 x 110 mm	-
0050738	20” - 22” x 3 ½” — 500-560 x 110 mm	-
0050740	24” x 3 ½” — 630 x 110 mm	-
0050742	16” x 4” — 400 x 125 mm	-
0050744	18” - ½” x 4” — 450-500 x 125 mm	-
0050746	22” - 24” x 4” — 560-630 x 125 mm	-



Glossary

Aquatherm Green Pipe

A polypropylene pressure piping system designed for potable and food-grade applications. It is identified by its green color and joined using heat fusion. Hot water pipes have a faser-composite layer as well as dark green stripes, while cold water pipes have light blue stripes and no faser-composite layer.

Butt welding

A heat fusion connection where the face of one pipe is fused directly to the face of another pipe. Fittings are sized to be even with the pipe walls and are joined the same way. This process is only used on sizes above 4 inches.

Aquatherm Blue Pipe®

Formerly know as Climatherm, **aquatherm blue pipe®** is a polypropylene pressure piping system designed for non-potable applications such as heating and cooling, chemical transport, compressed air, etc. **aquatherm blue pipe®** is blue, has a faser-composite layer and thick green stripes, and is also joined using heat fusion.

Extrusion

The process by which Aquatherm's pipes are manufactured. The **fusiolen®** material is shaped and pushed from the extrusion machine in three layers and cooled in long tanks, forming the uniquely designed Aquatherm pipes.

Faser-composite

A patented mixture of **fusiolen®** **PP-R** and fiberglass, specially engineered to increase structural strength and reduce linear expansion.

Fusiolen PP-R

The basic material used in all of Aquatherm's polypropylene piping systems. This resin is produced exclusively by Aquatherm using only the purest raw polypropylene.

Fusion outlet

A special fitting designed to fuse directly onto the side of a pipe. These fittings were once called saddles but have been renamed to distinguish them from less reliable mechanical fittings.

Heat fusion (or heat welding)

The process of simultaneously heating two similar plastics and allowing them to cool together under pressure. This process forms a seamless bond between the materials.

Aquatherm Lilac Pipe

A special formulation of the Aquatherm piping systems engineered for use in rainwater and reclaimed water. This system is distinguished by the purple color of the pipe.

Linear (thermal) expansion

The growth in a pipe that occurs when hot water is run through the system. Contraction can also occur under cold temperatures.

Mold injection

The process through which Aquatherm's fittings are manufactured. Heated **fusiolen®** is pressed into molds and cooled under high pressure, creating strong fittings with no mechanical weaknesses.

Polypropylene random (PP-R)

A unique formulation of the thermoplastic polymer used to create all the Aquatherm pipe and fittings. Random lengths of polypropylene molecules ensure chemical uniformity throughout the connection.

Socket fusion

A heat fusion connection using welding heads and special fittings. The inside of the fitting is fused to the outside of the pipe, forming a quick and simple leak-proof connection. This process is only used on sizes from 4 inches and smaller.

Transition, flange

A flange connection using a polypropylene flange, a steel flange ring, and a gasket that can be attached to a same-size flange of any other piping material.

Transition, threaded

A special fitting with a brass or stainless steel insert mold injected into the polypropylene. The insert is threaded for use with any other type of threaded connection.

Welding heads

Teflon-coated molds designed to match specific sizes of pipe and fittings. The welding heads are engineered for direct contact with the pipe and fittings and generally contain one male side and one female side in order to heat both sides of a connection at the same time.

Welding iron

An electronic heating device with a large, flat heating surface. This surface is designed to heat the welding heads to the proper welding temperature and should never be in direct contact with the material

Glossary

being welded.

Welding jig

A portable clamping system that assists with moving the pipe and fitting during the fusion process.

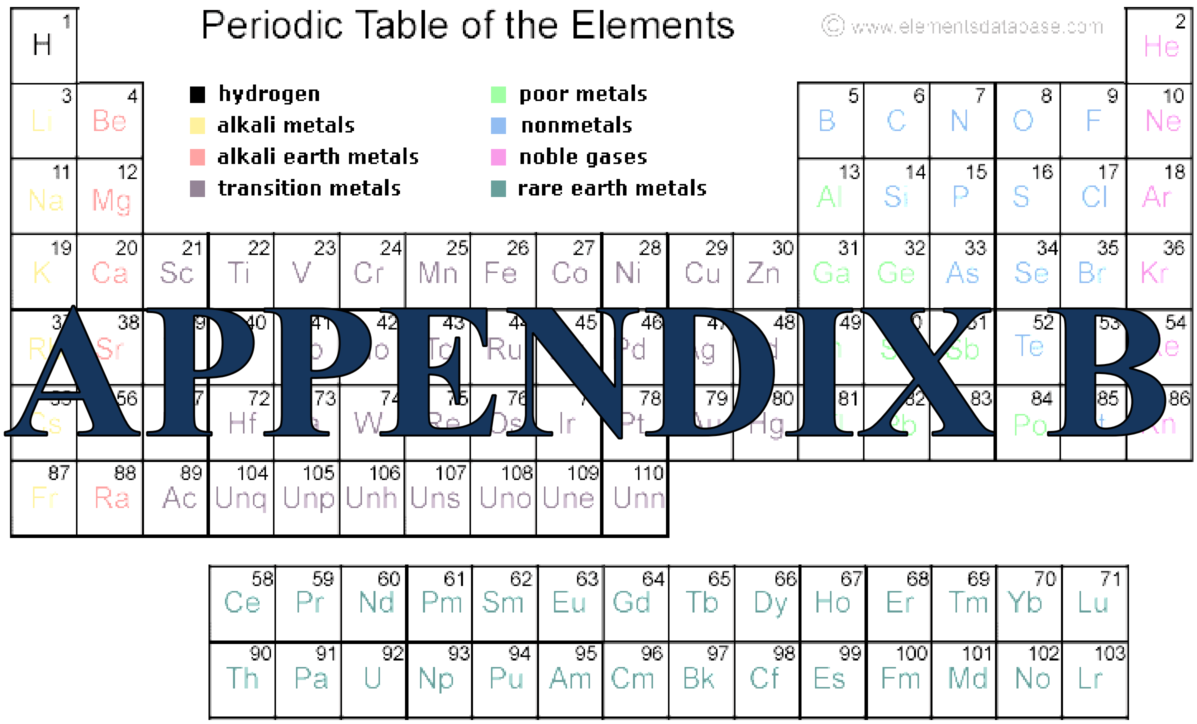
Appendix A

Aquatherm flange bolt torque and size

Nominal pipe size	Torque		Bolts		
	N-m	ft-lb	Number	Diameter	Washers
½″ (20mm)	10	14	4	½	Yes
¾″ (25mm)	15	20	4	½	Yes
1″ (32mm)	15	20	4	½	Yes
1 ¼″ (40mm)	20	27	4	½	Yes
1 ½″ (50 mm)	30	41	4	½	Yes
2″ (63mm)	35	47	4	⅝	Yes
2 ½″ (75mm)	40	54	4	⅝	Yes
3″ (90mm)	40	54	8	⅝	Yes
3 ½″ (110mm)	50	68	8	⅝	Yes
4″ (125mm)	50	68	8	⅝	Yes
6″ (160mm)	60	81	8	¾	Yes
8″ (200mm)	75	102	8	¾	Yes
10″ (250mm)	95	129	12	⅞	Yes
12″ (315 mm)	100	136	12	⅞	Yes
14″ (355 mm)	100	136	12	1	Yes
16″ (400 mm)	100	136	16	1	Yes
18″ (450 mm)	100	136	16	1 ⅛	Yes
20″ (500 mm)	100	136	20	1 ⅛	Yes
22″ (560 mm)	100	136	20	1 ⅛	Yes
24″ (630 mm)	100	136	20	1 ⅛	Yes

Index

APPENDIX B



Periodic Table of the Elements
© www.elementsdatabase.com
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

Pump Reduction Calculations

$$P_L = \frac{452}{d_i^{4.87}} \left(\frac{Q}{C}\right)^{1.85}$$

* specification 22 10 16 require pressure loss to be less than 14 PSI; 1" → 13 GPM flowrate

P_L = pressure loss
Q = flow rate
d_i = inside diameter of pipe (in)
C = flow coefficient
(150 for PP-R)

(aquatherm)

$$P_L = \frac{452}{(1.03)^{4.87}} \left(\frac{13\ \text{GPM}}{150}\right)^{1.85}$$

P_L = 33.68 psi / 100 LF
or
0.042 psi / ft

Using Chart XX from Appendix

Type 'L' Copper 1" P_L = 0.05 psi / ft

Climatherm 1" P_L = $\boxed{0.042 \text{ psi/ft}}$ ← Reduced pressure loss from using Aquatherm

---

Head Losses

Head Loss per L.FT. of pipe : $HL = 2.31 (P_L)$

(copper) $H_L = 2.31\ (0.05\ \text{psi}/\text{ft}) = 0.116$
(aqua) $H_L = 2.31\ (0.042\text{psi}/\text{ft}) = 0.098$

Flow Velocities

$$V = 0.4804 \left(\frac{Q}{d_i^2}\right) = 0.4804 \left(\frac{13\ \text{GPM}}{(1.03)^2}\right) = 5\ \text{ft/sec}$$ (both copper and aquatherm)

Q = flow rate
d_i = inside diam. of pipe

Affinity Laws

Pumps come in an infinite number of designs and sizes.
Need to be able to modify:

- speed of impeller
- diameter of impeller

For Fixed speed -

H_n = new head loss (aquatherm)

H_o = old head loss (copper)

$\frac{W_n}{W_o}$ = power output reduction (%)

$$\frac{H_n}{H_o} = \left(\frac{D_n}{D_o}\right)^2$$

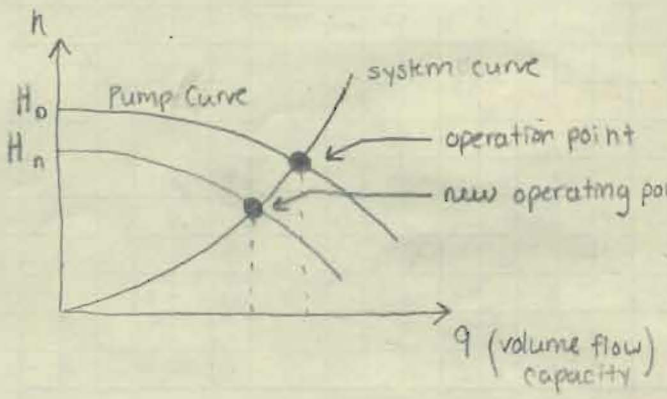
$$\sqrt[3]{\frac{\dot{W}_n}{W_o}} = \sqrt[3]{\left(\frac{D_n}{D_o}\right)^3}$$

$$\frac{D_n}{D_o} = \sqrt[3]{\frac{W_n}{W_o}}$$

$$\frac{H_n}{H_o} = \left(\frac{\dot{W}_n}{W_o}\right)^{2/3}$$

$$\frac{3}{2}\left(\frac{0.098}{0.116}\right) = \frac{\dot{W}_n}{W_o} = 0.76$$

$\boxed{\text{22\% reduction in power}}$



Quotation

QUOTE DATE	QUOTE NUMBER
03/16/14	S014424863

QUOTED BY:
130 PENSTAN STATE COLLEGE
2640 CAROLEAN IND DR
STATE COLLEGE PA 16801
814-237-3220 Fax 484-398-6350

Printed : 10:50:24 27 MAR 2014

130 PENSTAN STATE COLLEGE
2640 CAROLEAN IND DR
STATE COLLEGE PA 16801
814-237-3220 Fax 484-398-6350

QUOTE TO:
CONTRACTOR CASH OR CC ONLY
2640 CAROLEAN IND
STATE COLLEGE, PA 16801

SHIP TO:
CONTRACTOR CASH OR CC ONLY
2640 CAROLEAN IND
STATE COLLEGE, PA 16801

QUOTED FOR	CUSTOMER PURCHASE ORDER NUMBER	CUSTOMER RELEASE NUMBER	SALESPERSON
	AUBREY P.S.U.		House -

WRITER	SHIP VIA	TERMS	EXPIRATION DATE	FREIGHT ALLOWED
Doug Tressler	PK PICK UP NOW	CASH	04/30/14	No

QUOTE QTY	OUR PART#	DESCRIPTION	Net Prc	Ext Prc
		***********************************		
		BASEMENT P-100A		
		***********************************		
1ea	3779	4 CXCXC WROT COP TEE	155.821/ea	155.82
1ea	3693	4 CXC WROT COP 90 ELBOW	84.800/ea	84.80
1ea	65606	4X21/2 CXC WROT COP RED CPLG	63.009/ea	63.01
1ea	65655	21/2X21/2X1/2 CXCXC WROT COP TEE	54.059/ea	54.06
1ea	3782	4X4X1 CXCXC WROT COP TEE	102.756/ea	102.76
1ea	3613	4X2 FTGXC WROT COP FTG REDUCER	57.135/ea	57.13
1ea	3604	2X1 FTGXC WROT COP FTG REDUCER	12.003/ea	12.00
2ea	3687	1 CXC WROT COP 90 ELBOW	3.374/ea	6.75
1ea	3729	1 CXCXC WROT COP TEE	7.794/ea	7.79
2ea	1293877	CONBRACO 77FLF24A01 4 FORGED BRASS SWEAT 600 FP BALL VLV LEAD FREE	539.813/ea	1079.63
1ea	1190805	NIBCO S585-80-LF 1 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	33.075/ea	33.08
1ea	1190803	NIBCO S585-80-LF 1/2 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	15.563/ea	15.56
		***********************************		
		BASEMENT P-100B		
		***********************************		
1ea	65655	21/2X21/2X1/2 CXCXC WROT COP TEE	42.650/ea	42.65
6ea	3683	1/2 CXC WROT COP 90 ELBOW	0.633/ea	3.80
4ea	3768	21/2 CXCXC WROT COP TEE	46.640/ea	186.56
2ea	3579	21/2X11/2 CXC WROT COP RED CPLG	27.793/ea	55.59
2ea	3601	11/2X1/2 FTGXC WROT COP FTG REDUCER	6.049/ea	12.10
1ea	1111328	CELLO 21/2X3/4 CXC REDUCER ******	27.793/ea	27.79
4ea	3691	21/2 CXC WROT COP 90 ELBOW	28.697/ea	114.79
4ea	1176068	LV 105-519 S15 2-1/2 CXC BRNZ WYE ******	159.191/ea	636.76

***** Continued on Next Page *****

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QUOTED BY:
130 PENSTAN STATE COLLEGE
2640 CAROLEAN IND DR
STATE COLLEGE PA 16801
814-237-3220 Fax 484-398-6350

Printed : 10:50:24 27 MAR 2014

130 PENSTAN STATE COLLEGE
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814-237-3220 Fax 484-398-6350

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CONTRACTOR CASH OR CC ONLY
2640 CAROLEAN IND
STATE COLLEGE, PA 16801

SHIP TO:
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STATE COLLEGE, PA 16801

QUOTED FOR	CUSTOMER PURCHASE ORDER NUMBER	CUSTOMER RELEASE NUMBER	SALESPERSON
	AUBREY P.S.U.		House -

WRITER	SHIP VIA	TERMS	EXPIRATION DATE	FREIGHT ALLOWED
Doug Tressler	PK PICK UP NOW	CASH	04/30/14	No

QUOTE QTY	OUR PART#	DESCRIPTION	Net Prc	Ext Prc
3ea	1194947	NIBCO SFP600A-LF 21/2 CXC BRASS 400CWP 2PC FP LEAD FREE BALL VLV W/ CP BALL BRASS STEM PTFE SEAT & LEVER HDL	149.815/ea	449.44
1ea	1190803	NIBCO S585-80-LF 1/2 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	15.563/ea	15.56
1ea	1190804	NIBCO S585-80-LF 3/4 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	25.778/ea	25.78
		***********************************		
		FIRST FLOOR PLAN P-101A		
		***********************************		
4ea	3683	1/2 CXC WROT COP 90 ELBOW	0.633/ea	2.53
20ea	3685	3/4 CXC WROT COP 90 ELBOW	1.418/ea	28.36
5ea	3693	4 CXC WROT COP 90 ELBOW	92.282/ea	461.41
4ea	3691	21/2 CXC WROT COP 90 ELBOW	29.182/ea	116.73
9ea	75022	4 CXCXC CAST COP DWV WYE	194.326/ea	1748.94
6ea	3586	4X2 CXC WROT COP RED CPLG	66.821/ea	400.92
6ea	3606	2X1/2 FTGXC WROT COP FTG REDUCER	12.744/ea	76.46
1ea	65676	4X3X3 CXCXC WROT COP TEE	160.140/ea	160.14
1ea	3585	4X3 CXC WROT COP RED CPLG	61.097/ea	61.10
1ea	3575	2X3/4 CXC WROT COP RED CPLG	11.902/ea	11.90
4ea	3768	21/2 CXCXC WROT COP TEE	46.640/ea	186.56
3ea	3725	3/4 CXCXC WROT COP TEE	2.602/ea	7.81
3ea	3730	1X1X3/4 CXCXC WROT COP TEE	7.092/ea	21.28
1ea	3560	1X3/4 CXC WROT COP RED CPLG	2.630/ea	2.63
1ea	3731	1X1X1/2 CXCXC WROT COP TEE	6.649/ea	6.65
5ea	1194947	NIBCO SFP600A-LF 21/2 CXC BRASS 400CWP 2PC FP LEAD FREE BALL VLV W/ CP BALL BRASS STEM PTFE SEAT & LEVER HDL	182.309/ea	911.54
2ea	1190803	NIBCO S585-80-LF 1/2 BRNZ 2PC FULL	15.563/ea	31.13

***** Continued on Next Page *****

Quotation

QUOTE DATE	QUOTE NUMBER
03/16/14	S014424863

130 PENSTAN STATE COLLEGE
2640 CAROLEAN IND DR
STATE COLLEGE PA 16801
814-237-3220 Fax 484-398-6350

QUOTED BY:
130 PENSTAN STATE COLLEGE
2640 CAROLEAN IND DR
STATE COLLEGE PA 16801
814-237-3220 Fax 484-398-6350

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QUOTE TO:
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2640 CAROLEAN IND
STATE COLLEGE, PA 16801

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STATE COLLEGE, PA 16801

QUOTED FOR	CUSTOMER PURCHASE ORDER NUMBER	CUSTOMER RELEASE NUMBER	SALESPERSON
	AUBREY P.S.U.		House -

WRITER	SHIP VIA	TERMS	EXPIRATION DATE	FREIGHT ALLOWED
Doug Tressler	PK PICK UP NOW	CASH	04/30/14	No

QUOTE QTY	OUR PART#	DESCRIPTION	Net Prc	Ext Prc
		PORT SWT BALL VLV LEAD FREE		
6ea	1190804	NIBCO S585-80-LF 3/4 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	25.778/ea	154.67
2ea	1293877	CONBRACO 77FLF24A01 4 FORGED BRASS SWEAT 600 FP BALL VLV LEAD FREE	539.813/ea	1079.63
		**********************************		
		FIRST FLOOR PLAN P-101B		
		**********************************		
1ea	3560	1X3/4 CXC WROT COP RED CPLG	2.776/ea	2.78
16ea	3685	3/4 CXC WROT COP 90 ELBOW	1.418/ea	22.69
6ea	3683	1/2 CXC WROT COP 90 ELBOW	0.633/ea	3.80
1ea	3557	3/4X1/2 CXC WROT COP RED CPLG	1.733/ea	1.73
1ea	65655	21/2X21/2X1/2 CXCXC WROT COP TEE	59.624/ea	59.62
1ea	1106433	2 CXC WROT COP DWV WYE	28.154/ea	28.15
1ea	1190805	NIBCO S585-80-LF 1 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	37.566/ea	37.57
1ea	1190804	NIBCO S585-80-LF 3/4 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	25.778/ea	25.78
2ea	1190803	NIBCO S585-80-LF 1/2 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	15.563/ea	31.13
		**********************************		
		SECOND FLOOR PLAN P-102A		
		**********************************		
4ea	3692	3 CXC WROT COP 90 ELBOW	36.053/ea	144.21
1ea	3774	3 CXCXC WROT COP TEE	73.379/ea	73.38
1ea	128479	3X1 CXC CAST COP RED CPLG	95.015/ea	95.01
1ea	3581	3X21/2 CXC WROT COP RED CPLG	29.776/ea	29.78
1ea	3778	3X3X3/4 CXCXC WROT COP TEE	61.722/ea	61.72
3ea	3685	3/4 CXC WROT COP 90 ELBOW	1.418/ea	4.25
1ea	65664	3X3X1/2 CXCXC WROT COP TEE	61.722/ea	61.72
2ea	3683	1/2 CXC WROT COP 90 ELBOW	0.633/ea	1.27

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814-237-3220 Fax 484-398-6350

QUOTED BY:	PAGE NO
130 PENSTAN STATE COLLEGE 2640 CAROLEAN IND DR STATE COLLEGE PA 16801 814-237-3220 Fax 484-398-6350	

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	AUBREY P.S.U.		House -

WRITER	SHIP VIA	TERMS	EXPIRATION DATE	FREIGHT ALLOWED
Doug Tressler	PK PICK UP NOW	CASH	04/30/14	No

QUOTE QTY	OUR PART#	DESCRIPTION	Net Prc	Ext Prc
1ea	1293877	CONBRACO 77FLF24A01 4 FORGED BRASS SWEAT 600 FP BALL VLV LEAD FREE	539.813/ea	539.81
1ea	1190805	NIBCO S585-80-LF 1 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	37.566/ea	37.57
1ea	1190804	NIBCO S585-80-LF 3/4 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	29.278/ea	29.28
1ea	1190803	NIBCO S585-80-LF 1/2 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	17.677/ea	17.68
		***********************************		
		SECOND FLOOR PLAN P-102B		
		***********************************		
1ea	65655	21/2X21/2X1/2 CXCXC WROT COP TEE	59.624/ea	59.62
3ea	3691	21/2 CXC WROT COP 90 ELBOW	29.182/ea	87.55
10ea	3685	3/4 CXC WROT COP 90 ELBOW	1.418/ea	14.18
2ea	3579	21/2X11/2 CXC WROT COP RED CPLG	28.250/ea	56.50
2ea	3600	11/2X3/4 FTGXC WROT COP FTG REDUCER	6.151/ea	12.30
4ea	1106433	2 CXC WROT COP DWV WYE	28.154/ea	112.62
2ea	1194947	NIBCO SFP600A-LF 21/2 CXC BRASS 400CWP 2PC FP LEAD FREE BALL VLV W/ CP BALL BRASS STEM PTFE SEAT & LEVER HDL	182.309/ea	364.62
		***********************************		
		PENTHOUSE PLAN P-103A		
		***********************************		
1ea	3774	3 CXCXC WROT COP TEE	73.379/ea	73.38
3ea	3692	3 CXC WROT COP 90 ELBOW	36.662/ea	109.99
1ea	3582	3X2 CXC WROT COP RED CPLG	29.166/ea	29.17
4ea	3690	2 CXC WROT COP 90 ELBOW	15.033/ea	60.13
1ea	3755	2 CXCXC WROT COP TEE	25.775/ea	25.78
1ea	3575	2X3/4 CXC WROT COP RED CPLG	11.902/ea	11.90
2ea	3685	3/4 CXC WROT COP 90 ELBOW	1.418/ea	2.84

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WRITER	SHIP VIA	TERMS	EXPIRATION DATE	FREIGHT ALLOWED
Doug Tressler	PK PICK UP NOW	CASH	04/30/14	No

QUOTE QTY	OUR PART#	DESCRIPTION	Net Prc	Ext Prc
2ea	1190808	NIBCO S585-80-LF 2 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	159.100/ea	318.20
2ea	1190804	NIBCO S585-80-LF 3/4 BRNZ 2PC FULL PORT SWT BALL VLV LEAD FREE	29.278/ea	58.56
		***********************************		
		BASEMENT P-100A		
		***********************************		
85ft	2273	4X20 L HARD COPPER TUBE	29.818/ft	2534.54
160ft	2270	21/2X20 L HARD COPPER TUBE	13.451/ft	2152.10
40ft	2266	1X20 L HARD COPPER TUBE	2.837/ft	113.46
10ft	2264	1/2X20 L HARD COPPER TUBE	1.122/ft	11.22
		***********************************		
		BASEMENT P-100B		
		***********************************		
80ft	2270	21/2X20 L HARD COPPER TUBE	13.451/ft	1076.05
125ft	2265	3/4X20 L HARD COPPER TUBE	1.801/ft	225.08
55ft	2264	1/2X20 L HARD COPPER TUBE	1.122/ft	61.73
		***********************************		
		FIRST FLOOR PLAN P101A		
		***********************************		
60ft	2273	4X20 L HARD COPPER TUBE	29.818/ft	1789.09
110ft	2270	21/2X20 L HARD COPPER TUBE	13.451/ft	1479.57
25ft	2269	2X20 L HARD COPPER TUBE	7.761/ft	194.03
210ft	2266	1X20 L HARD COPPER TUBE	2.837/ft	595.67
35ft	2264	1/2X20 L HARD COPPER TUBE	1.122/ft	39.28
465ft	2265	3/4X20 L HARD COPPER TUBE	1.801/ft	837.30
		***********************************		
		FIRST FLOOR PLAN P-101B		
		***********************************		
35ft	2270	21/2X20 L HARD COPPER TUBE	13.451/ft	470.77
75ft	2266	1X20 L HARD COPPER TUBE	2.837/ft	212.74

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Quotation

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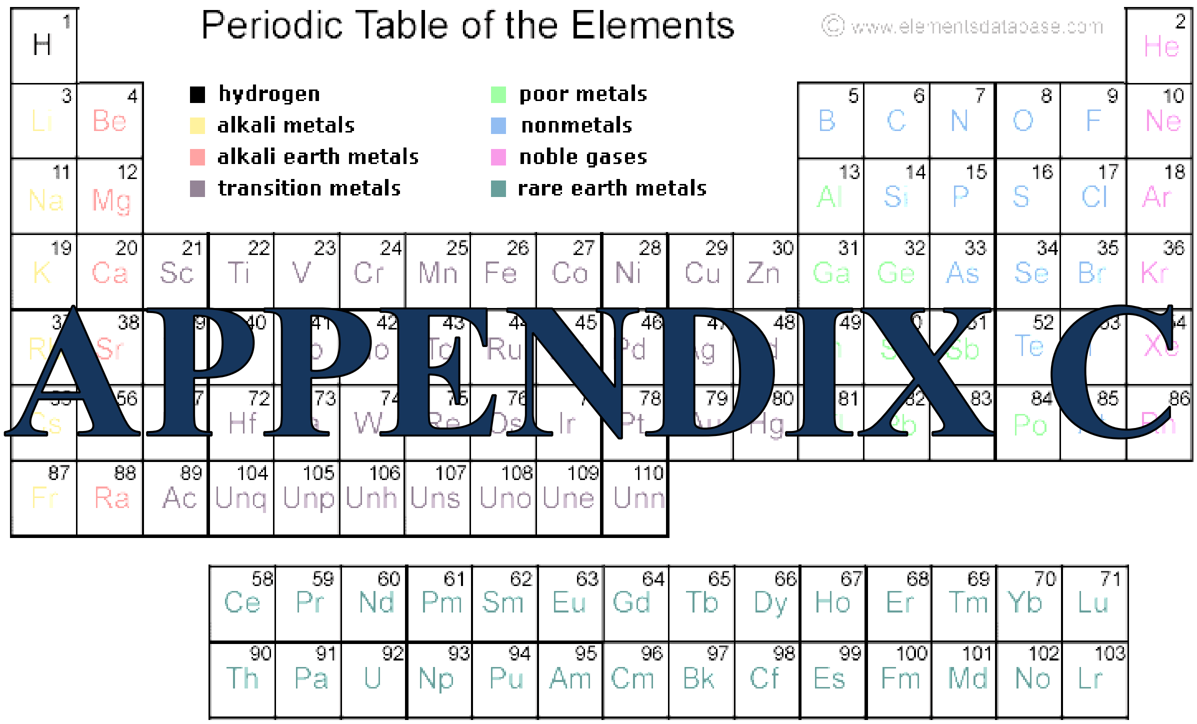
	AUBREY P.S.U.		House -

WRITER	SHIP VIA	TERMS	EXPIRATION DATE	FREIGHT ALLOWED
Doug Tressler	PK PICK UP NOW	CASH	04/30/14	No

QUOTE QTY	OUR PART#	DESCRIPTION	Net Prc	Ext Prc
110ft	2264	1/2X20 L HARD COPPER TUBE	1.122/ft	123.45
190ft	2265	3/4X20 L HARD COPPER TUBE	1.801/ft	342.12
		**********************************		
		SECONG FLOOR PLAN P-102A		
		**********************************		
260ft	2271	3X20 L HARD COPPER TUBE	17.450/ft	4537.00
20ft	2266	1X20 L HARD COPPER TUBE	2.837/ft	56.73
10ft	2264	1/2X20 L HARD COPPER TUBE	1.122/ft	11.22
25ft	2265	3/4X20 L HARD COPPER TUBE	1.801/ft	45.02
		**********************************		
		SECONG FLOOR PLAN P-102B		
		**********************************		
165ft	2270	21/2X20 L HARD COPPER TUBE	13.451/ft	2219.36
75ft	2265	3/4X20 L HARD COPPER TUBE	1.801/ft	135.05
25ft	2264	1/2X20 L HARD COPPER TUBE	1.122/ft	28.06
		**********************************		
		PENTHOUSE PLAN P-103A		
		**********************************		
45ft	2271	3X20 L HARD COPPER TUBE	17.450/ft	785.25
190ft	2269	2X20 L HARD COPPER TUBE	7.761/ft	1474.65
40ft	2265	3/4X20 L HARD COPPER TUBE	1.801/ft	72.03
		**********************************		
		PENTHOUSE PLAN P-103B		
		**********************************		
75ft	2269	2X20 L HARD COPPER TUBE	7.761/ft	582.10
		TAXES NOT INCLUDED		

Subtotal	**33624.54**
Bid Total	**33624.54**

APPENDIX C


Periodic Table of the Elements
© www.elementsdatabase.com
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
87 Fr
88 Ra
89 Ac
104 Unq
105 Unp
106 Unh
107 Uns
108 Uno
109 Une
110 Unn
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr

Provide lasting pipe performance

aquatherm

Aquatherm helps dry up industrial laundry facility's leak woes

Project Information

Project	Products Used	Location / Date
Tri-State Health Care Laundry, Supply and Process Water Retrofit	Aquatherm Greenpipe® Climatherm®	Covington, KY Summer 2008

Aquatherm Advantages

- PP-R's lighter weight made installation from a scissor lift easier
- 4-inch joint connections took only 3-4 minutes vs. 15 with steel
- Ownership liked the corrosion resistance and 10-year warranty

The Challenge

Aggressive process water had consistently rusted through the existing Schedule 80 steel

The Solution

Corrosion- and rust-proof, Aquatherm held up so well over a 3-year period the facility is using it on their main line

Located in the Cincinnati suburb of Covington, KY, Tri-State Health Care Laundry provides its services to several facilities in Ohio, Kentucky and Indiana. Featuring 52-foot-long washing machines and 12-foot-tall dryers with 8-foot tumblers, the facility manages to churn out crisply washed linens, uniforms, and other laundered items on a massive basis.

In keeping with the largesse of the process, the facility also has a tremendous amount of piping – well over 1,500 linear feet. Coursing through all that piping is an enormous amount of process water – almost 1 million gallons a month. Of course the water, detergents, and other chemicals are extremely corrosive.

In fact, the existing Schedule 80 galvanized steel piping was rusting from the inside out. The problems were so severe that for an hour once a week the facility had to flush the pipe by letting a ¾-inch line run full bore to flush the system in an effort to reduce the corrosion. In the summer of 2008, Tri-State decided to repair some pipe sections that had lost the battle with the caustic process water.

Correcting the Corrosion Conundrum

The two sections of leaking 4-inch pipe ran along Tri-State's ceiling about 30 feet off the facility floor. At the street, the water enters the piping at roughly 110 psi and in the building it runs at ambient temperature and about 80 psi.

Located in nearby Elsmere, KY, MarkCo, Inc. Plumbing and Building Services, has been providing Tri-State with backflow testing for roughly the last decade and ongoing plumbing maintenance and support for the last six years. MarkCo's foreman, Gary Kentley presented an innovative solution to the corrosion conundrum.

While a traditional solution such as roll grooved pipe was briefly considered, installing that type of pipe from a scissor lift was going to be exceedingly difficult. Kentley had been introduced to Aquatherm's polypropylene-random (PP-R) piping by Zak Schultz with the local Aquatherm representative, StreamKey Engineered Plumbing and Waste Water Solutions (Cincinnati). Kentley immediately identified the Tri-State repair as a perfect application for Aquatherm.

"The first reason that Aquatherm made sense for this job was that it is so much lighter than steel. Three joints were necessary to put the run of pipe in, and it would have been six joints if we had used galvanized steel because of its weight," Kentley said. However, since the galvanized steel had already experienced serious corrosion problems, Aquatherm was selected.

Aquatherm, which is manufactured in Germany, is extremely durable and leak- and corrosion-resistant and has been proven globally for nearly 40 years, but is relatively new to North America.

The heat fusion process used to join Aquatherm pipe bonds both sides of a joint into a single, homogenous material without the use of flames, chemicals, or mechanical connections. Once fused, pipes and fittings have the same physical properties, thus eliminating systematic weaknesses that can be caused by introducing different materials into the joint in other types of piping systems.

Additionally, Aquatherm provides a 10-year warranty on pipe and fittings with a product liability valued at 9 million Euros for personal injury and 4.5 million Euros for property damage per event, to Aquatherm-trained and certified installers.

No More Flushing

Tri-State's facility manager Steve Johnson wasn't concerned about what piping material would be used for the repair; he simply wanted the line repaired so that they didn't have to keep flushing it and so that it didn't leak. "The facility manager basically told me, if it's faster and cheaper – do it," Kentley recalled.

> "The first reason that Aquatherm made sense for this job was that it is so much lighter than steel."
>
> -Gary Kentley, Foreman of MarkCo Inc.

StreamKey's Schultz trained the MarkCo employees on the fusion welding technique. However, since they had used polypropylene for acid waste piping the Tri-State installers were already familiar with fusion welding and the training went quickly.

4-inch Aquatherm Climatherm SDR-11, which is designed specifically for industrial, HVAC, and compressed air applications, replaced the steel. Made from over 98.5% PP-R, Climatherm, is particularly well suited for these applications because of the material's natural insulation properties: an R-value of 1 or more, depending on pipe size and SDR.

The first repair was a 21-foot section that was accessed via a scissor lift. Tri-State installers cut out the existing sections and replaced them with Climatherm using Aquatherm flanges, couplings, transitions, and also some steel flanges.

After seeing PP-R perform so well for three years, Tri-State installed it for its six-inch main line.

The soft water main runs from the three water softeners in the boiler room to the tunnel washers at the back of the facility. It is a run of approximately 400 feet.

MarkCo did as much prefabrication of the joints on the ground as possible, fusing the flanges and the first piece of pipe and its coupling, then welding it into place via the scissor lift. The second repair was a 30-foot section in a corner of the facility and was done via ladders and an access through a cinder block wall.

There was one joint involving a 90-degree fitting that was buried in the wall, which made the repair a bit challenging. Getting the Aquatherm 4-inch welding jig into proper position was difficult. "We used flanges on both ends, and it was a bit short, so we had to move all the hangers, and then there was still a small gap between them so we had to massage it by hand to get it close enough to fuse," Kentley said. "However, the installation went smoothly considering it was a new product and a retrofit," he added.

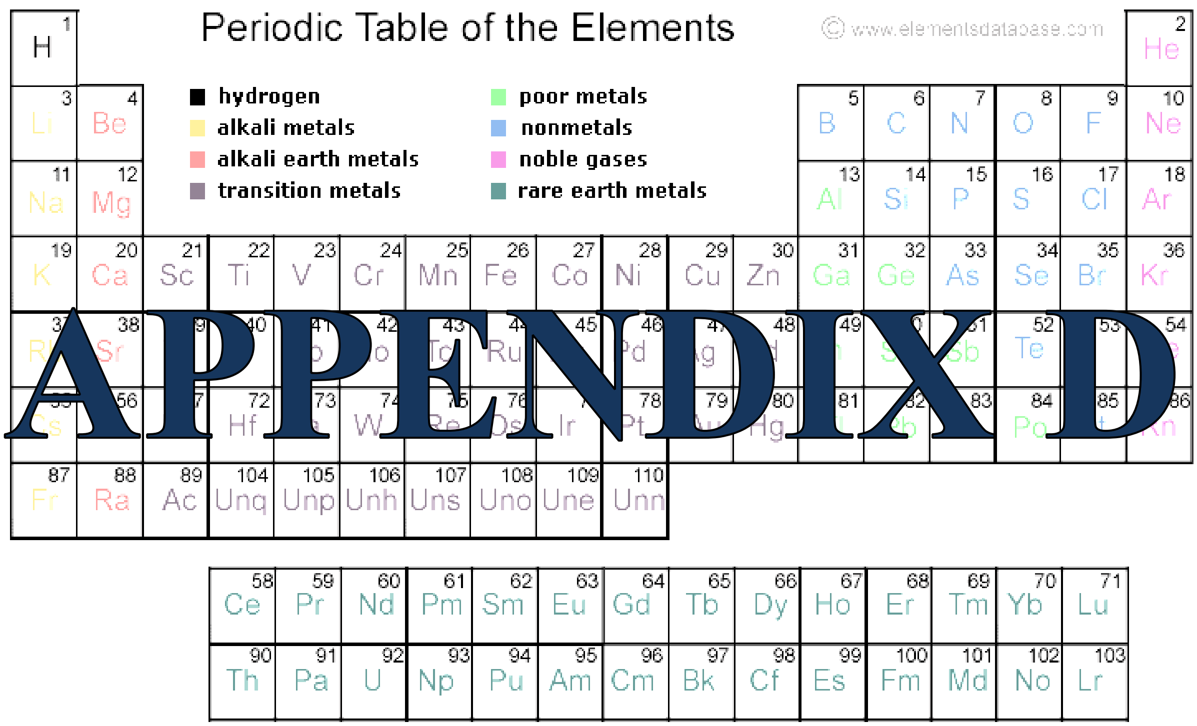
No Leaks, No Drips, No Worries

Throughout the repairs, there were no leaks at all, and Kentley explained that the 4-inch joints were typically completed in only 3-4 minutes, whereas it would have been 15 minutes per joint for steel. This considerable labor savings added up, Kentley said. "Price-wise Aquatherm was comparable to steel, or maybe a bit cheaper, but labor-wise, it was a whole lot cheaper. We look to use it wherever we can now."

More than a year later, the repairs are holding up perfectly, and Tri-State now has a go-to piping option. In fact, Aquahterm was also used on the facility's six inch main line in summer 2011.

A version of this article appeared in the October 2011 issue of PME *magazine. Click here http://digital.bnpmedia.com/publication/?i=81160 and go to page 24 to view it.*

APPENDIX D



Periodic Table of the Elements
© www.elementsdatabase.com
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

March 13, 2014

Aubrey Fulton
Penn State University
Via email

Dear Aubrey

It was a pleasure speaking with you earlier about your warehouse project in North Carolina. Mahaffey Fabric Structures is the premier supplier of temporary and semi-permanent structures in North America and the Caribbean. Since 1924, we have developed fabric structure solutions for clients such as Nissan, Entergy, GE, Mercedes-Benz, Exxon and Sporting Events such as the Super Bowl and Honda Grand Prix. Mahaffey has the inventory and personnel to meet your project needs.

For your project, you requested our 10M x 10M Mega Structure, with a snow load rating of 30lbs. and Wind rated at 130 MPH. wind gusts, All based on its advanced engineering design. The Structure utilizes aluminum trusses covered with a heavy-duty PVC coated fabric. This design features special tracks in which the fabric is placed and tensioned to provide a complete weatherproof environment. The result provides not only a clean aesthetic look, but it is fully engineered in accordance with IBC 2006 and ASCE 7-05.

To complete the structure, Mahaffey can provide accessories including doors, heaters, exhaust fans, lighting, and electrical distribution. For your structure I proposed a 2 piece fabric wall system that will be used for personnel doors and slide fabric doors at either gable ends for forklift and construction material access. In addition, we will install (8) Metal Halide Exhibit Lights approx. 6 amps (400 watts) of power lighting capacity. Mahaffey would rely upon you to provide the electrical distribution, per the specifications. For insulation and temperature control Mahaffey can provide you with Insulated Hard Sides & R-19 Rated Roof Panels to help maintain a specific temperature. I have put together 2 options for you project.

Option #1 is fabric walls no added options.
Option # 2 fully equipped with all the added options.
PLEASE NOTE: roof insulation is NOT included in this Bid.

Mahaffey provides our customers a turnkey service using dedicated, non-union crews who travel nationwide installing and dismantling structures. These personnel employ safe and efficient work practices, which allow us to offer firm-fixed pricing. Our installation / dismantle charge includes all necessary trucking, labor, and heavy equipment such as forklifts or cranes .This eliminates the worry of unbudgeted charges and costly overruns.

LOCATION:	Greensboro NC
INSTALLATION:	TBD - 2014
DISMANTLE:	TBD - 2014

Proposed Structure Options:

Option 1: Standard
33' x 33 'x 10' (10 m x 10 m) – 252 or 300 mm profile
10' Uprights with a 14' Peak Height
Fabric Personnel Door
Fabric Slide Doors
Fabric Sidewalls

First month Lease with Transportation and Installation:	$ 5,000.00
2nd month through 6th month @ $ 2,500 per month:	$ 12,500.00
Total cost for 6 month lease:	$ 17,500.00

Option 2: Fully Equipped & 10' Uprights
33 x 33 'x 10' (10 m x 10 m) – 300 mm profile structure
10' Uprights with a 14' Peak Height
1 - Metal Personnel Door
2 – 400 Watt Exhibit Lights
1 – Roll-Up Metal Doors (14' x 14')
1- Gable Exhaust Fans
8- Bays of Hard sides with two walls for office space.

First month Lease with Transportation and Installation:	$ 9, 500.00
2nd month through 6th month @ $4,665 per month:	$23,325.00
Total cost for 6 month lease:	$32,827.00

**Taxes and permitting not included.*

Note(s): Proposal includes all non-union labor and equipment for installation. Pricing assumes anchoring into an unobstructed, level surface with semi-truck access within 50' of work site. Applicable taxes, permits, and fuel surcharges are not included. This proposal is valid 30 days and is subject to equipment availability at the time the Lease Agreement is signed.

I've included some photos from similar projects that we've completed across the country. Any additional pictures or CAD drawings are available upon your request. Installation of each structure will be approximately four days.

Please review the information provided. If you have any questions or need additional information, please do not hesitate to contact me. The next stage of the process is to schedule a site inspection with you and your team, or we can immediately reserve your equipment with a Lease Agreement. I will call you in a few days to discuss which way you'd like to proceed.

Best regards,

Mark H Huels

Mark H Huels
Director of Special events
Project Manager


MAHAFFEY
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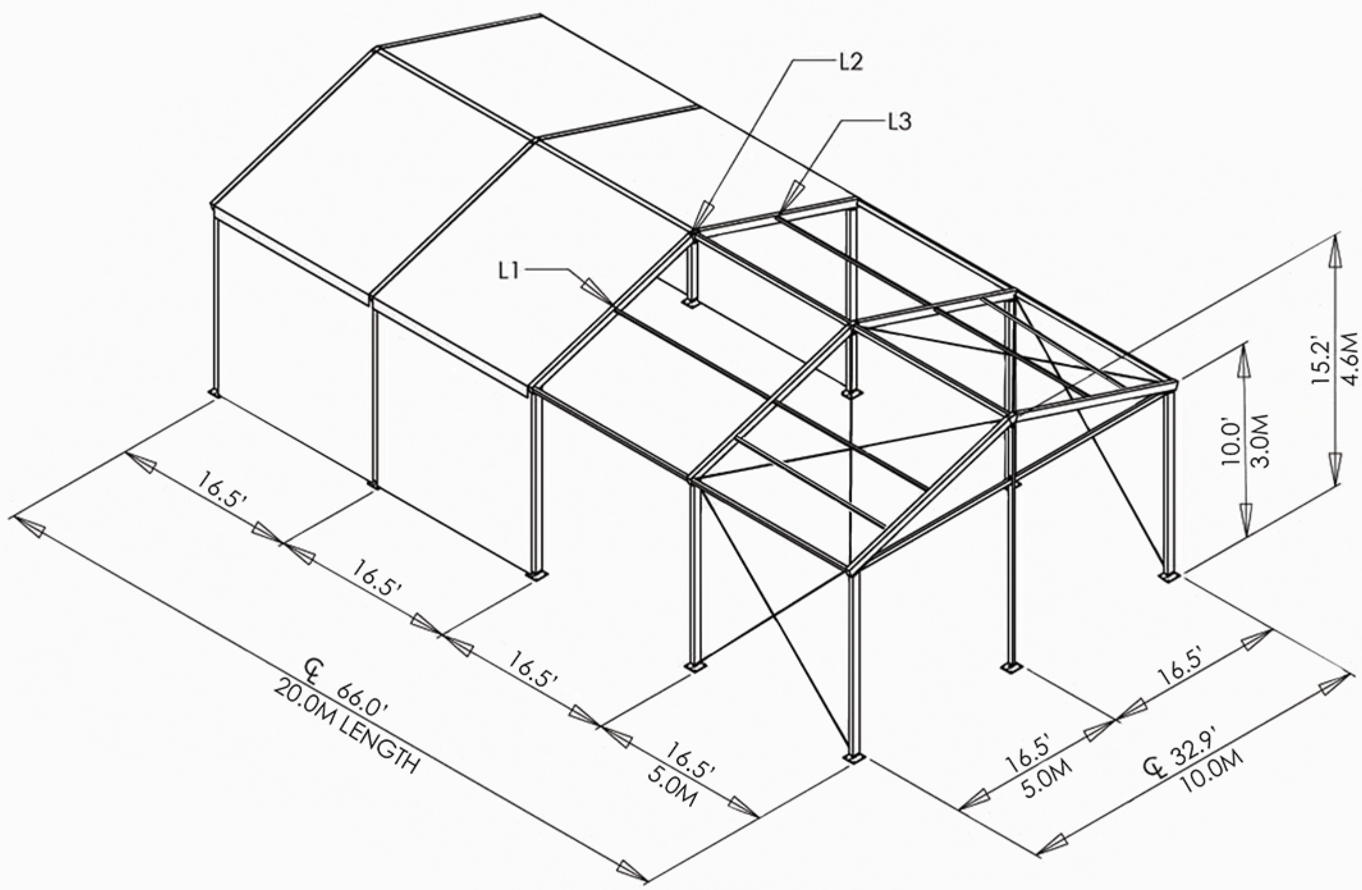
NO WEL PERMITTED

10m MegaStructure



Specifications:

Width: 10m (32.9')

Eave Height: 3m (10.0')

Ridge Height: 4.6m (15.2')

Frame Spacing: 5m (16.5')

Installation: 7,500 sq ft daily per crew (est.)

Wind Rating: 90 mph Class C*

Snow Load: 30 lbs per sq ft*

Dead Loads: 250 lbs Left Center (L1)
500 lbs Ridge (L2), 250 lbs Right Center (L3)

Engineering Information:

All Mahaffey MegaStructure clearspan structures are evaluated in accordance with applicable U.S. building codes and the International Building Code (IBC). The specifications outlined in the American National Standards Institute / American Society of Civil Engineers (ANSI / ASCE) 7-05: "Minimum Design Loads for Buildings and Other Structures."
* Wind rating and snow load are site-specific.

Fabric Information:

16oz. - 22oz. industrial vinyl-coated fabric. Complies with the California Fire Marshall Code, equal to or exceeding the standard issued by the National Fire Protection Association (NFPA 701).

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4161 Delp Street, Memphis, TN 38118 • 800.245.8368

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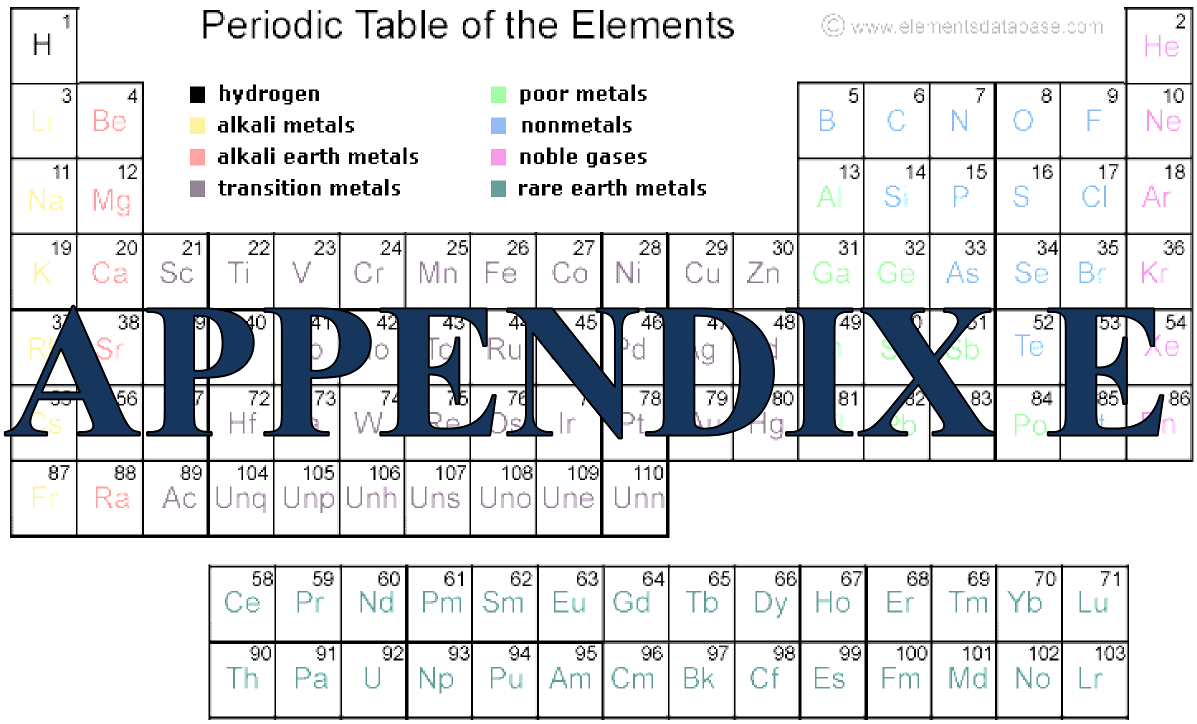
APPENDIXE



Periodic Table of the Elements
© www.elementsdatabase.com
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

SECTION 13 60 16
CLEANROOM PROTOCOL

PART 1 - GENERAL

1.1 SUMMARY

A. This Section describes the requirements for maintaining Clean Zone conditions during construction:
   1. Additional Clean Zone General Requirements are specified in Section 13 60 13.

B. Special cleanroom cleaning specified in this section shall be provided in addition to cleaning specified elsewhere.

C. Clean all materials, systems components, and equipment for placement into cleanroom areas. Maintain clean environmental conditions during construction. All procedures shall be on-going and continuous throughout the course of the Project.

D. Cleanroom areas are identified on the Drawings and include all environmentally controlled areas with mechanical air circulation/filter bank arrangements designed to reduce airborne particulate levels.

E. Types of provisions include specific requirements for:
   1. On-going cleaning procedures.
   2. Pre-cleaning of tools and equipment.
   3. "Dedicated" equipment handling devices and tools.
   4. Cutting, patching, sawing, drilling, grinding.
   5. Final clean-up.

F. Cleanroom areas shall include rooms and associated spaces identified in the Schedule of Required Classifications in Section 13 60 19.

1.2 RELATED WORK

A. Refer to other Sections for the following.
   1. Section 01 50 13, General Clean Zone Construction Procedures.
   2. Section 13 60 13, Special Clean Zone Requirements:
      a. Cleanroom Contractor and Clean Zone Director requirements.
      b. Clean Zone Boundaries defined.
      c. Clean Zone Construction Stages defined (Protocol Levels).
      d. Cleanroom areas' Clean Classes defined.
      e. Definitions.

B. Requirements for fabrication and installation of cleanroom process and mechanical service, including high purity systems, are provided in Mechanical Specification Divisions.

1.3 QUALITY ASSURANCE

A. Provide a Cleanroom Cleaning Supervisor to supervise cleaning procedures, and shall provide competent technicians to conduct the work.

B. Cleanroom cleaning supervisor shall have a minimum of 3 years experience, devoted exclusively to cleaning of cleanroom facilities.

C. Cleaning products shall be compatible with surface to be cleaned, and shall cause no damage to adjacent materials.

D. Maintain, during the entire course of construction, an on-going and continuous housekeeping program designed to facilitate final certification of the cleanliness of the various cleanroom spaces defined by the documents:

1. Actual daily procedures for continued cleaning and maintenance shall be established by Contractor.
2. Procedures shall be communicated to all tradesmen involved, and noticeably posted.
3. Cleanroom cleaning supervisor shall have the responsibility of assuring that construction is free of trapped dirt and debris through regular and thorough inspection of the work.
4. Cleaning products used inside of cleanroom areas shall be only products specifically designed for use within cleanrooms, and approved for use in the Clean Zone by the Owner and Architect.

1.4 SUBMITTALS

A. Project information:
   1. Cleanroom Contractor's detailed construction protocol program, including clean-build requirements for each stage and each discipline, and control and enforcement measures.
   2. Qualifications and references for proposed Cleanroom Cleaning Supervisor.
   3. Product data for cleaning materials and program of cleaning procedures.

PART 2 - PRODUCTS

2.1 CLEANING MATERIALS

A. Wipe-down fabric:
   1. Lint-free “Anticon 100” or “Texwipe Alphawipe” woven cleanroom wipers.

B. Wipe-down liquid:
   1. EKC "Lab Clean".
   2. "Floor Clean".
   3. "Glass Clean".
   4. Allied Chemical “WRS-200”.
   5. “Texclean 100”.
   6. “TechniPure”.

PART 3 - EXECUTION

3.1 INITIAL CLEANROOM AREA PREPARATION

A. At the first available time following completion of interior cleanroom enclosure, entire area shall be cleaned as follows:
   1. All dirt and debris, etc. shall be removed from the cleanroom areas.
   2. The entire interior of the work area, including structural steel, ductwork, piping, return air chase area, walls and floor areas, shall be cleaned to remove all dust and particulate matter likely to cause contamination of the cleanroom.
   3. All areas shall be prepainted, including structural steel, ductwork, piping, return air chase area, walls and floor, after thorough cleaning and before installation of any cleanroom material or equipment.

3.2 GENERAL CLEANROOM CLEANING

A. HEPA vacuum spaces which will be concealed by subsequent construction as the work progresses.

B. Clean dirt and dust from structural members, decking and components before proceeding with other construction.

C. Operate recirculating fan units, without HEPA filters installed, for at least 24 hours continuously before final cleaning.

D. Remove construction debris promptly.

E. Shovels, brooms, dustpans, mops and buckets may be used during Stage 1 cleaning:

1. Minimize need for brooms and sweeping tools during Stage 2 cleaning, and primarily use wet mopping and vacuum cleaning for floor cleaning.
2. Where surfactants are needed, use only non-ionic type.

F. Beginning during Stage 2 cleaning, provide positive pressurization to prevent infiltration of contamination from surrounding areas:
1. During welding, grinding and other construction operations requiring additional measures to remove contaminates, provide negative pressure ducted smoke removal fans.

G. Use 99.99 percent HEPA filtered vacuum cleaner during Stage 3 and later cleaning:
1. Output filter shall be tested at least weekly with a particle counter to assure minimum ISO 14644 Class 5 performance.

H. The following materials shall not be used in cleanroom construction:
1. Masking tape.
2. Duct tape.
3. Lubricants, pastes and fluxes containing ionic contaminants.
4. Freons, aerosols and spray products.
5. Salt, soap and other materials containing sodium, potassium or other heavy metals.
6. Any kind of wood.
7. Silicone based sealants, except those approved for the Project.

I. Cleanroom Contractor and each subcontractor performing work shall be responsible for cleaning their own tools, cleaning their construction materials, and removing their construction debris:
1. Contractor and each subcontractor provide at least one cleaning person for every ten or less of their workers on the job.

3.3 BASIC CLEANROOM PROTOCOL

A. On-going installation and cleaning procedures: Institute procedures for the fabrication and placement of specified materials which will preclude the entrapment of construction soils, refuse, dust and other debris in the finished work:
1. Ensure that each installer shall carefully inspect the substrate over which succeeding work is to be installed and shall perform such cleaning activities as required to maintain "clean conditions".
2. Cleaning activities shall include daily broom cleaning of exposed floor surfaces and wipe down or vacuuming, as appropriate, of other substrates.
3. Additionally, the following procedures shall be followed, beginning with the first installation of filter modules:
   a. Work operations scheduled within the cleanroom involving processes likely to create dusting shall be carried out within a remote fabrication area:
      1) Demountable wall panels, ceiling materials, and like constructions shall be removed to this dedicated area for cutting, drilling, sanding, grinding and similar operations.
   b. Operations of similar nature, where removal to remote fabrication area is not possible shall be carried out under the following guidelines:
      1) Only those tools, fixtures, test equipment required for current workloads will be kept in the cleanroom area.
      2) Work shall be sheltered from other areas of the cleanroom by the erection of polyethylene vapor barriers surrounding immediate work area.
      3) Air circulating systems shall be "shut-down".
      4) Any and all ceiling gel to be protected from any contamination.
      5) Filter banks at ceiling shall be covered with polyethylene.
      6) Tools shall be equipped with auxiliary HEPA vacuum for continual removal of dust before release to the air.
      7) Wiping and general vacuum procedures shall be employed to insure final construction will be free of trapped debris and particulate contaminants.

4. Maintain a complete set of tools, ladders and material handling devices for use only within the confines of cleanroom areas:
    a. Equipment shall remain in the cleanroom during construction to avoid unnecessary transfer of contamination.
5. No smoking or chewing of any tobacco products, or eating shall take place within cleanroom areas at any time.
6. Materials and equipment entering cleanroom area shall be solvent wiped and HEPA vacuumed to remove loose particles.
7. Visitors: Permission for visitors to enter cleanroom areas will be strongly discouraged and held to an absolute minimum:
    a. No one will be permitted to enter the cleanroom areas without first receiving training on cleanroom protocol.
    b. Training shall be conducted by the Cleanroom Contractor, with visitors undergoing the entire cleanup process and donning a full set of dust-preventive clothing furnished by the Cleanroom Contractor.
    c. Access to and from the cleanroom areas shall be only through one designated door that serves as both entrance and exit.
    d. "Sign In" and "Sign Out" log shall be maintained at the single point of access.
    e. Log shall register visitor's name, company represented, time "In", time "Out" and purpose of entry, i.e. work, construction observation, visitor, etc.
8. Beginning with first continuous operation of air filtration system and initial stages of process piping fit-up and process equipment installation, the following procedures shall be implemented in addition to general installation procedures with cleanrooms:
    a. Pre-cleaning of tools and equipment.
    b. Dedicated tools.
    c. Gowning.
9. Procedures shall be approved by the Cleanroom Director.

B. Pre-cleaning procedures: All items shall be unwrapped, unboxed or uncrated before moving to preparation area:
1. All exposed surfaces shall be thoroughly cleaned of all dirt, grease, oil lint and other contaminants by wiping with sterile, nonshedding, lint-free cloths, then HEPA vacuumed prior to transfer onto dedicated material handling devices for carrying into cleanroom.
2. No raw material to be installed or brought into cleanroom area.
3. Portable test equipment, jigs, fixtures, parts and subassemblies that cannot be normally cleaned due to size, material composition, or critical finishes shall be thoroughly HEPA vacuumed:
    a. All wheels and other tire surfaces on portable equipment shall be covered with cleanroom tape:
        1) Duct tape is not an approved tape material.
    b. Entry of these materials into a cleanroom area shall be accomplished through an equipment airlock.
4. All assembly tools used in the cleanroom shall be cleaned daily:
    a. Tool cleaning shall be accomplished at the beginning of the work shift.
    b. Each cleanroom worker shall clean tools and bench area to insure cleanliness.
    c. Workers shall continually inspect and clean their work-in-progress in accordance with the technical instructions for that item.
5. Workers, inspectors and visitors shall remove lint, dust and loose dirt from clothing and shoes, prior to initiating gowning procedure and entry into cleanroom as follows:
    a. Topcoats, raincoats, overshoes, umbrellas, lunches, street shoes, and other such personal articles will be removed and covered with plastic film or other lint-free, nondust generating materials, and placed in an outer cloak room.
    b. Personnel working in cleanroom areas will use liquid soap and lukewarm water to wash hands thoroughly to remove dust, cigarette ashes, loose skin flakes, loose hair, skin oils and cosmetics:
        1) After washing, dry surfaces with a hot air blower or lint-free cloth.

2) Cosmetics will not be worn or carried into a cleanroom at any time.

c. Special contamination preventive clothing furnished by Contractor shall be worn by all personnel.

6. Procedures shall be approved by the Clean Zone Director (Section 13 60 13, Special Clean Zone Requirements).

C. Contaminants: No smoking materials, hygiene sprays, cosmetics, paints, lubricants, exhaust-producing equipment or similar contaminants shall be allowed to enter either the preparation area or any cleanroom area:

1. Personnel leaving the cleanroom for any reason will remove smocks and all other dust preventive clothing and leave these garments in the clean personnel change room.
2. Upon re-entry into the change room, the entire clean-up procedure will be carefully and completely repeated.
3. Snacking and eating is absolutely forbidden in cleanrooms and in areas provided for clean-up of personnel or material preparatory to entering the cleanroom.
4. No edibles, including candy, chewing gum, or soft drinks, and no personal articles shall be taken into the cleanroom except as otherwise indicated.
5. If considered necessary, personnel may be permitted to keep billfolds, valuables such as keys, coins, knives and watches, and personal articles such as handkerchiefs, tissues and combs on their person, but these items shall be kept in pockets under dust preventive clothing and shall not be removed in the cleanroom.
6. Jewelry, such as necklaces, lockets, earrings, bracelets, and large rings shall not be worn in the cleanroom:
   a. Small rings, such as wedding bands, may be permitted if they present no work hazard.
   b. Pins and brooches may be permitted provided they are covered and remain covered by dust preventive clothing.
7. Personal clothing that tend to produce lint, such as angora sweaters or linty stockings, shall not be worn in the cleanroom areas.
8. Abrasives such as steel wool, emery cloth and sandpaper shall not be permitted in the cleanroom areas:
   a. Corrosive materials and cleaning solvents are prohibited except those specifically authorized for use in the cleanroom area.
9. Ordinary paper pads, notebooks, manuals and writing paper of any description shall not be permitted:
   a. Ordinary writing pencils, pens, erasers, crayons and chalk shall not be permitted.
   b. Notes and records shall be kept on lint-free paper or plastic sheet, using ball point pens or other suitable nondust generating materials.
   c. Drawings, specifications and other instructions shall be covered with plastic film or other lint-free, nondust generating material.
10. Dedicated Items: Maintain a complete set of tools, ladders, and material handling devices for use only within the confines of cleanroom areas:
    a. Equipment shall remain in the cleanroom to avoid transfer of contamination.
    b. Material Handling Devices: Provide hand trucks, dollies and other rolling devices that are equipped with non-lubricated bearings for use within the cleanroom:
       1) Wheels and tire surfaces shall be covered with cleanroom tape.
11. Gowning: All personnel shall wear cleanroom gowns while within the confines of the cleanroom:
    a. Gowns and gowning procedures shall be approved by the Clean Zone Director, Owner and Architect.

D. Function of the building shall be considered during entire course of construction, with particular regard to on-going cleaning procedures to be employed:

1. Walls, floors, ceilings, and air handling equipment shall be cleaned prior to conducting tests.
2. Sheet vinyl floors in cleanroom areas shall be cleaned as specified by the manufacturer but shall not be waxed.

3. Cleaning shall be performed by HEPA vacuuming, and wiping with knitted cleanroom wiper or cleanroom sponge with deionized wiper and approved cleanroom cleaner.
4. Exercise due care and consideration for cleanliness of entire facility.
5. Specific cleaning procedures shall be carried out as directed by the Cleanroom Cleaning Supervisor, and as approved by the Clean Zone Director.

3.4 FINAL CLEANROOM CLEANING

A. Prior to certification, perform following final cleaning:
   1. Clean cleanroom areas as follows, with the vacuuming and wiping down of ceiling surfaces first, walls second, and floors last.
   2. Vacuum light fixtures inside and out, HEPA filter protective grids, ceiling channels and angles, automatic fire sprinklers, trim and escutcheons, and ceiling tiles and panels, using a portable or central vacuum system with discharge to the building exterior.
   3. Vacuum wall surfaces, including furnishings, doors, hardware, and other wall attachments and accessories.
   4. Vacuum exposed surfaces of process piping, drain lines, interior and exterior of ductwork, electrical raceways, including interior, utility rack framing, and all connections to process equipment.
   5. Vacuum floors, including integral coved base and reducer strips, floor penetration coverings, and other floor attachments and accessories.
   6. Final wipe-down: After vacuuming of cleanroom areas has been completed, wipe down hard surfaces, including glazing, using wipe-down fabric soaked in wipe-down liquid.
   7. Complete cleaning by repeating steps 3, 4 and 5.

B. Completed work areas shall be subjected to certification testing to confirm conformance to specified cleanliness standards:
   1. Re-clean areas not conforming to the extent necessary for certification.

3.5 CLEANROOM CONSTRUCTION STAGES / PROTOCOL SUMMARY

A. Stage 1:
   1. Step 1-A for Cleanroom, and Interstitial:
      a. Work: Dirty; concrete, structural steel, grinding, welding, gas torch cutting, heavy piping, insulation on piping, interstitial sprinkler piping, plumbing and air handlers.
      b. Garments: No special requirements.
      c. Cleaning: Remove trash daily and sweep floors daily.
      d. Maintain an "office-clean" environment.
   2. Step 1-B for Cleanroom, and Interstitial:
      a. Work: After completion of Step 1-A, provide initial wipe down and vacuum from top structure down.
      b. Remove trash daily and vacuum floors daily.
      c. Smoking, spitting, eating, or drinking shall not be allowed.
      d. Gas powered or fume and particulate-emitting equipment shall not be allowed.
      e. Maintain an "office-clean" environment.

B. Stage 2:
   1. Step 2-A for Cleanroom, and Interstitial:
      a. Work: Semi-clean; cleanroom perimeter established, firewalls constructed, controlled staging area and entry area erected, and rough-in of cleanroom recirculating supply and return ductwork, electrical, ceiling support steel, utility racks, and sprinkler pipe.
      b. Garments: Clean construction boots.
      c. Cleaning: Continuously remove trash and continuously remove floor debris.
      d. Maintain an "Office Clean" environment.
   2. Step 2-B for Cleanroom, and Interstitial:
      a. Work: After completion of Step 2-A, vacuum and "coarse clean" all building elements from structure down.
      b. Garments: Clean booties.

3. Step 2-C for Cleanroom, and Interstitial:
    a. Work: After completion of Step 2-B, begin 24 hour per day pressurization with makeup air handler, and recirculation air handler blowdown.
4. Step 2-D for Cleanroom:
    a. Work: After initiating pressurization and blowdown, provide a "final" coarse cleaning from structure down for those areas not complying with "office clean" environment.
    b. Garments: Clean booties.
    c. Cleaning: Damp mopping daily.

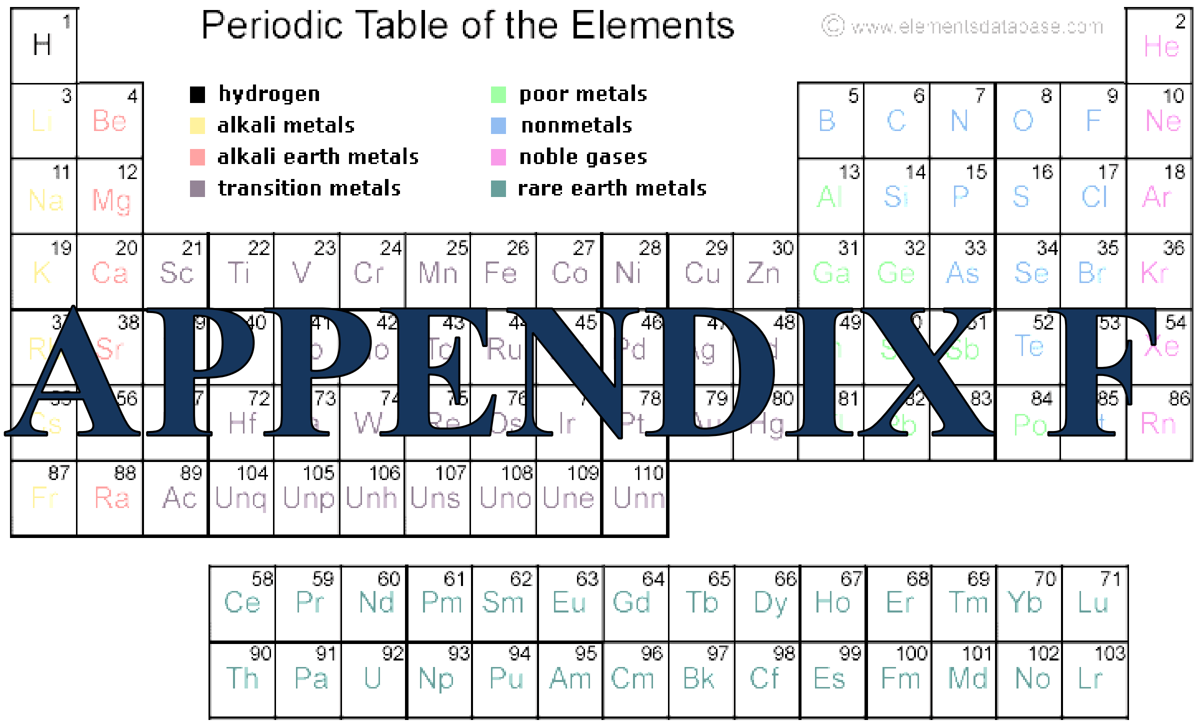
C. Stage 3:
1. Step 3-A for Cleanroom and Interstitial:
    a. Work: Clean; complete controlled gowning area, access flooring, ceiling grid, cleanroom wall partitions, and utility and service connections.
    b. Garments: Clean smock jacket, clean booties, gloves, hair covers, facial hair covers, and safety glasses.
    c. Cleaning: Continuously remove trash and debris, and vacuum and wipe down of all surfaces.
2. Step 3-B for Cleanroom:
    a. Work: After completion of Step 3-A, provide clean zone initial washdown from interstitial elevation down.
    b. Garments: Full-length suit, clean booties, gloves, hair covers, facial hair covers, and safety glasses.

D. Stage 4:
1. Step 4-A for Cleanroom:
    a. Work: Clean; Clean HEPA filter materials and provide continuous cleaning, including wipedown, vacuuming and trash removal.
    b. Garments: Clean smock jackets, clean booties, gloves, hair covers, full-face hood headgear, and safety glasses.
    c. Clean equipment, tools and delivered materials before entering.
2. Step 4-B for Cleanroom:
    a. Work: After Step 4-A, provide a final washdown of all surfaces within cleanroom, followed by a successful black and white felt rubdown test when complete.
    b. Garments: Full-length suit, knee-high boots, gloves, hair covers, full-face hood headgear, and safety glasses.

E. Stage 5:
1. Cleanroom:
    a. Work: Test and certification.
    b. Garments: Full-length suit, knee-high boots, gloves, hair covers, full-face hood headgear, and safety glasses.
    c. Clean equipment, tools, and delivered materials before entering.

END OF SECTION

APPENDIX F


Periodic Table of the Elements
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hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
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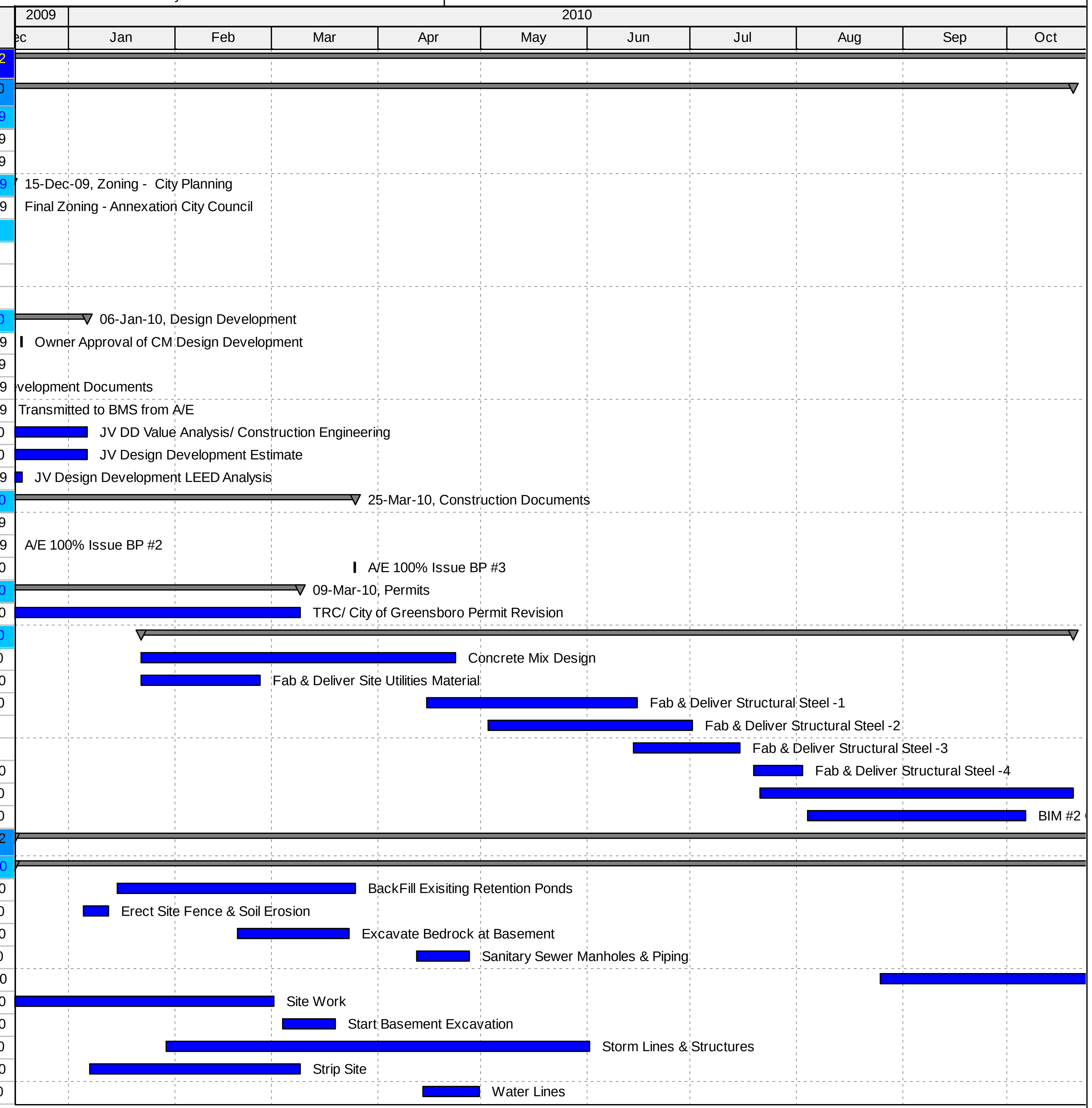
noble gases
rare earth metals

Activity ID	Activity Name	Original Duration	Start	Finish
The Joint School of Nanoscience and Nanoe		756	02-Mar-09	09-Feb-12
Pre-Construction		424	02-Mar-09	20-Oct-10
Due Dilligence		17	02-Mar-09	24-Mar-09
A1000	Boundary, Utility and Topography	1	02-Mar-09	02-Mar-09
A1010	Geotechnical Subsurface Exploration	1	24-Mar-09	24-Mar-09
Zoning - City Planning		66	15-Sep-09	15-Dec-09
A1020	Final Zoning - Annexation City Council	66	15-Sep-09	15-Dec-09
Schematic Design		16	29-Jun-09	20-Jul-09
A1030	Refine Pre-Con Management	10	07-Jul-09	20-Jul-09
A1040	Schematic Design Estimate	16	29-Jun-09	20-Jul-09
A1050	Value Analysis/ Construction Engineering	16	29-Jun-09	20-Jul-09
Design Development		137	29-Jun-09	06-Jan-10
A1160	Owner Approval of CM Design Development	1	18-Dec-09	18-Dec-09
A1170	Owner Prep Proposal on Clean Room	56	29-Jun-09	14-Sep-09
A1180	A/E Design Development Documents	76	04-Aug-09	17-Nov-09
A1190	DD Package - Transmitted to BMS from A/E	1	17-Nov-09	17-Nov-09
A1200	JV DD Value Analysis/ Construction Engineering	35	18-Nov-09	06-Jan-10
A1210	JV Design Development Estimate	35	18-Nov-09	06-Jan-10
A1220	JV Design Development LEED Analysis	23	18-Nov-09	18-Dec-09
Construction Documents		167	04-Aug-09	25-Mar-10
A1240	A/E 100% Issue BP #1	1	04-Aug-09	04-Aug-09
A1250	A/E 100% Issue BP #2	1	15-Dec-09	15-Dec-09
A1260	A/E 100% Issue BP #3	1	25-Mar-10	25-Mar-10
Permits		111	05-Oct-09	09-Mar-10
A1230	TRC/ City of Greensboro Permit Revision	111	05-Oct-09	09-Mar-10
Procurement		191	22-Jan-10	20-Oct-10
A1270	Concrete Mix Design	66	22-Jan-10	23-Apr-10
A1280	Fab & Deliver Site Utilities Material	25	22-Jan-10	25-Feb-10
A1290	Fab & Deliver Structural Steel -1	43	15-Apr-10	15-Jun-10
A1300	Fab & Deliver Structural Steel -2	43	03-May-10	01-Jul-10
A1310	Fab & Deliver Structural Steel -3	23	14-Jun-10	15-Jul-10
A1320	Fab & Deliver Structural Steel -4	11	19-Jul-10	02-Aug-10
A1330	BIM #1 Coordination	65	21-Jul-10	20-Oct-10
A1340	BIM #2 Coordination	45	04-Aug-10	06-Oct-10
Construction Phase		549	16-Dec-09	09-Feb-12
Site Work		256	16-Dec-09	15-Dec-10
A1350	BackFill Exisiting Retention Ponds	50	15-Jan-10	25-Mar-10
A1360	Erect Site Fence & Soil Erosion	6	05-Jan-10	12-Jan-10
A1370	Excavate Bedrock at Basement	23	19-Feb-10	23-Mar-10
A1380	Sanitary Sewer Manholes & Piping	12	12-Apr-10	27-Apr-10
A1390	Site Electrical Ductbanks and Power	79	25-Aug-10	15-Dec-10
A1400	Site Work	53	16-Dec-09	01-Mar-10
A1410	Start Basement Excavation	12	04-Mar-10	19-Mar-10
A1420	Storm Lines & Structures	87	29-Jan-10	01-Jun-10
A1430	Strip Site	44	07-Jan-10	09-Mar-10
A1440	Water Lines	13	14-Apr-10	30-Apr-10



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

TASK filter: All Activities

			2011											2012				
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr

09-Feb-12, The Joint School of Nanoscience a

20-Oct-10, Pre-Construction

20-Oct-10, Procurement

BIM #1 Coordination

Coordination

09-Feb-12, Construction Phase

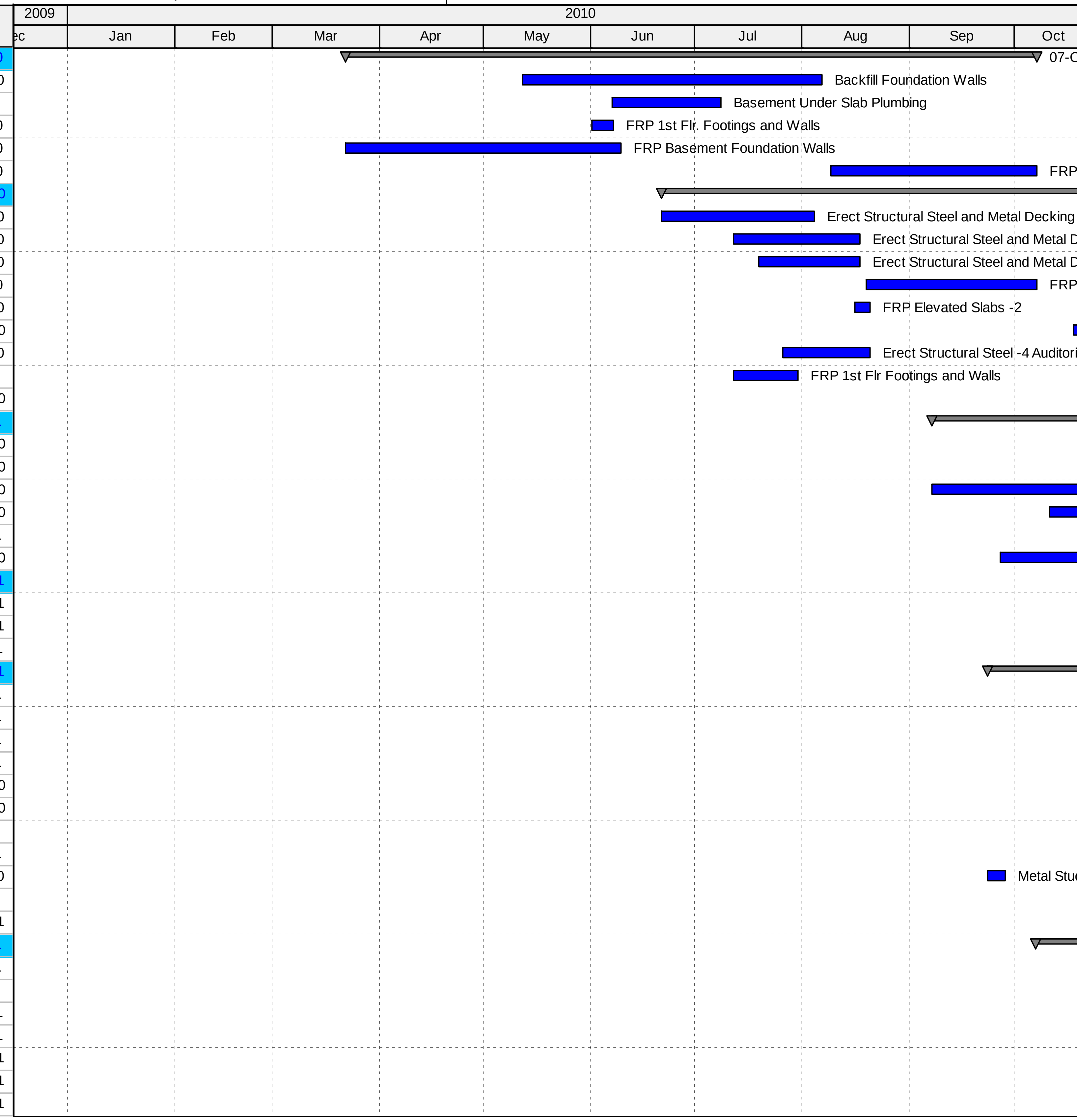
15-Dec-10, Site Work

Site Electrical Ductbanks and Power

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

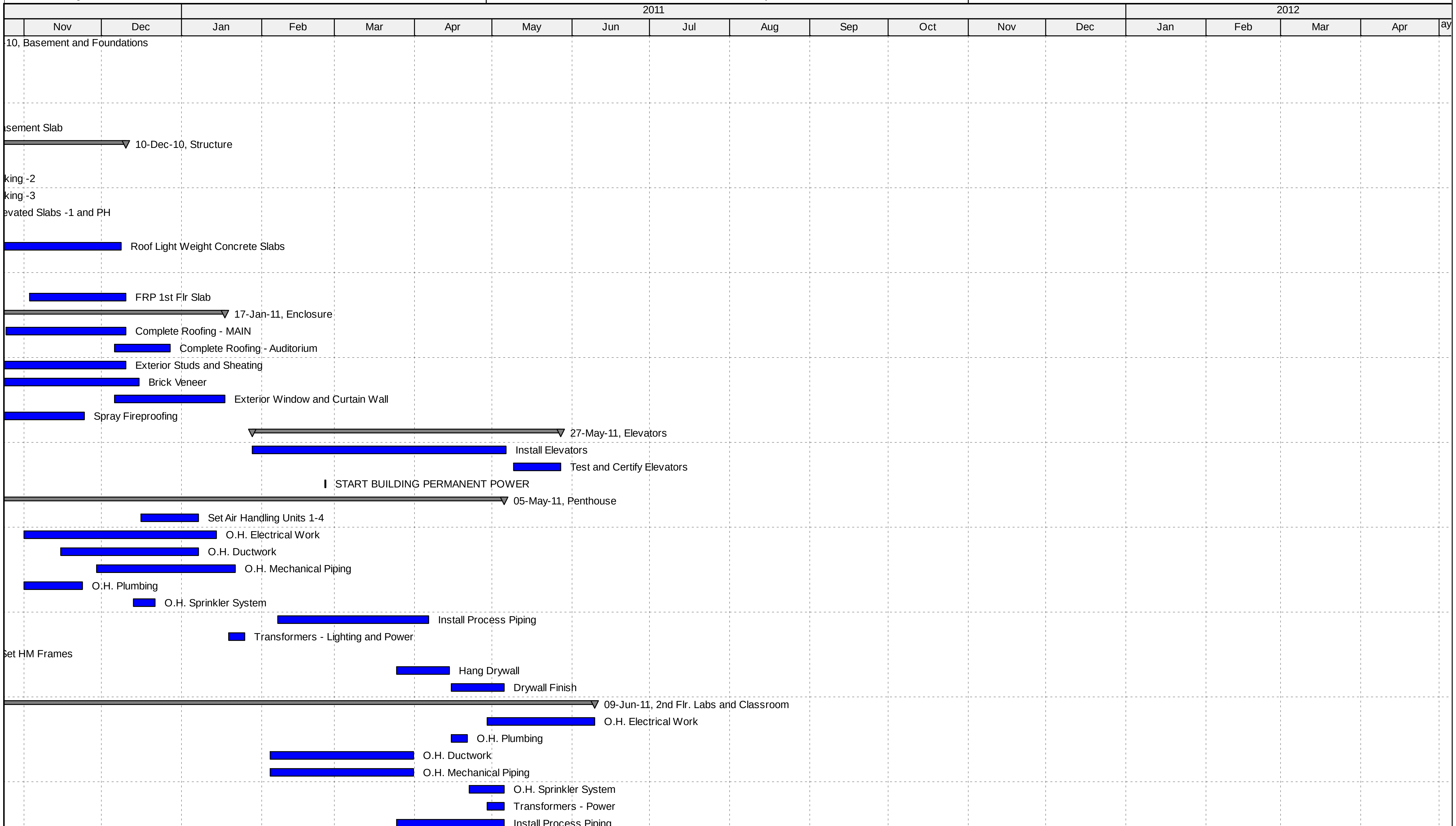
TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
Basement and Foundations		141	22-Mar-10	07-Oct-10
A1450	Backfill Foundation Walls	61	12-May-10	06-Aug-10
A1460	Basement Under Slab Plumbing	23	07-Jun-10	08-Jul-10
A1470	FRP 1st Flr. Footings and Walls	5	01-Jun-10	07-Jun-10
A1480	FRP Basement Foundation Walls	57	22-Mar-10	09-Jun-10
A1490	FRP Basement Slab	43	09-Aug-10	07-Oct-10
Structure		122	21-Jun-10	10-Dec-10
A1500	Erect Structural Steel and Metal Decking -1	32	21-Jun-10	04-Aug-10
A1510	Erect Structural Steel and Metal Decking -2	27	12-Jul-10	17-Aug-10
A1520	Erect Structural Steel and Metal Decking -3	22	19-Jul-10	17-Aug-10
A1530	FRP Elevated Slabs -1 and PH	35	19-Aug-10	07-Oct-10
A1540	FRP Elevated Slabs -2	5	16-Aug-10	20-Aug-10
A1550	Roof Light Weight Concrete Slabs	37	18-Oct-10	08-Dec-10
A1560	Erect Structural Steel -4 Auditorium	20	26-Jul-10	20-Aug-10
A1570	FRP 1st Flr Footings and Walls	15	12-Jul-10	30-Jul-10
A1580	FRP 1st Flr Slab	27	03-Nov-10	10-Dec-10
Enclosure		92	07-Sep-10	17-Jan-11
A1590	Complete Roofing - MAIN	34	25-Oct-10	10-Dec-10
A1600	Complete Roofing - Auditorium	15	06-Dec-10	27-Dec-10
A1610	Exterior Studs and Sheating	68	07-Sep-10	10-Dec-10
A1620	Brick Veneer	47	11-Oct-10	15-Dec-10
A1630	Exterior Window and Curtain Wall	29	06-Dec-10	17-Jan-11
A1670	Spray Fireproofing	43	27-Sep-10	24-Nov-10
Elevators		86	28-Jan-11	27-May-11
A1640	Install Elevators	71	28-Jan-11	06-May-11
A1650	Test and Certify Elevators	15	09-May-11	27-May-11
A1660	START BUILDING PERMANENT POWER	1	25-Feb-11	25-Feb-11
Penthouse		158	23-Sep-10	05-May-11
A1680	Set Air Handling Units 1-4	15	16-Dec-10	07-Jan-11
A1690	O.H. Electrical Work	52	01-Nov-10	14-Jan-11
A1700	O.H. Ductwork	37	15-Nov-10	07-Jan-11
A1710	O.H. Mechanical Piping	38	29-Nov-10	21-Jan-11
A1720	O.H. Plumbing	17	01-Nov-10	23-Nov-10
A1730	O.H. Sprinkler System	7	13-Dec-10	21-Dec-10
A1740	Install Process Piping	43	07-Feb-11	06-Apr-11
A1750	Transformers - Lighting and Power	5	19-Jan-11	25-Jan-11
A1760	Metal Stud/ Set HM Frames	4	23-Sep-10	28-Sep-10
A1770	Hang Drywall	15	25-Mar-11	14-Apr-11
A1780	Drywall Finish	15	15-Apr-11	05-May-11
2nd Flr. Labs and Classroom		172	07-Oct-10	09-Jun-11
A1790	O.H. Electrical Work	29	29-Apr-11	09-Jun-11
A1800	O.H. Plumbing	5	15-Apr-11	21-Apr-11
A1810	O.H. Ductwork	40	04-Feb-11	31-Mar-11
A1820	O.H. Mechanical Piping	40	04-Feb-11	31-Mar-11
A1830	O.H. Sprinkler System	10	22-Apr-11	05-May-11
A1840	Transformers - Power	5	29-Apr-11	05-May-11
A1850	Install Process Piping	30	25-Mar-11	05-May-11



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

TASK filter: All Activities



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

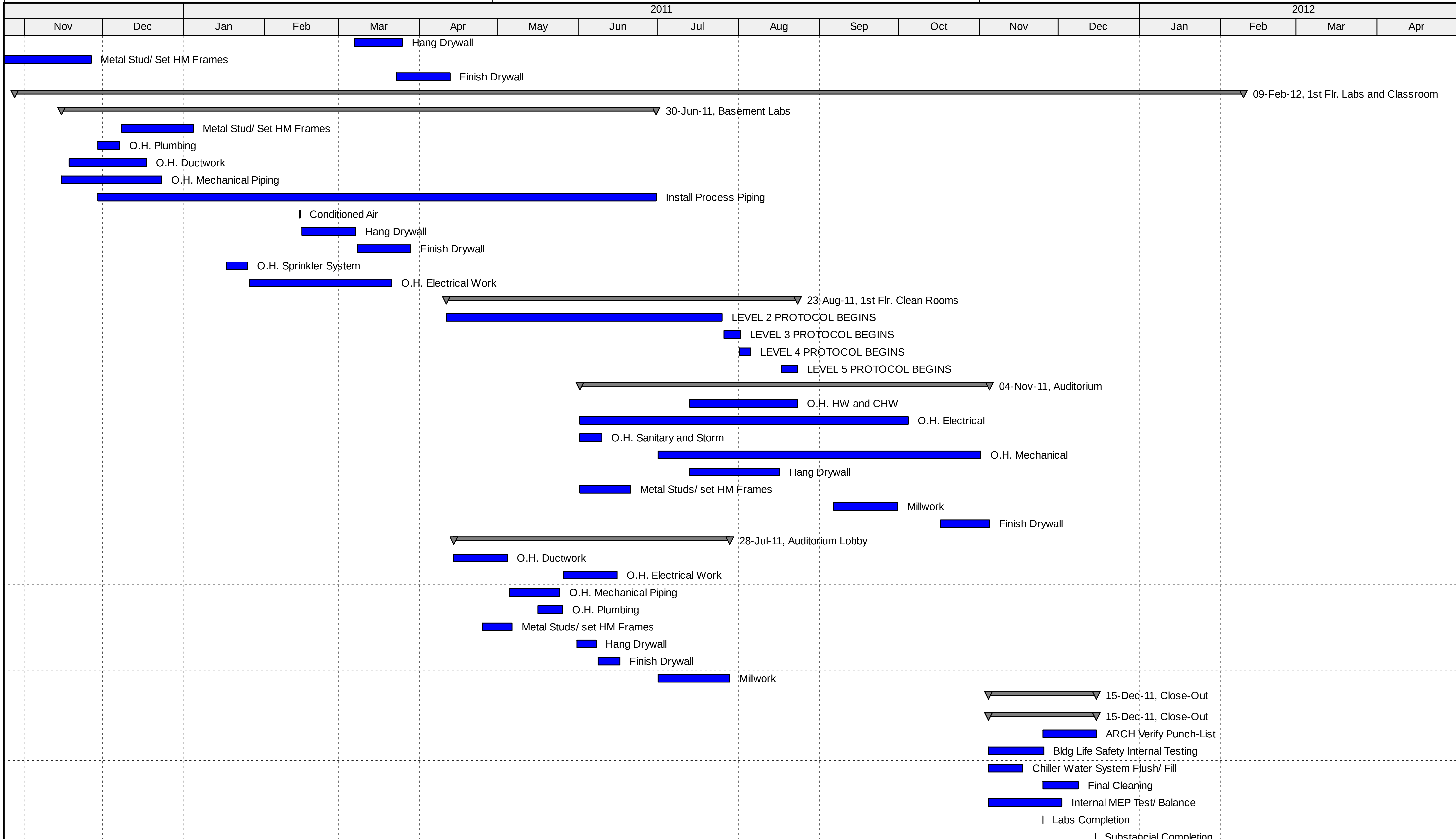
TASK filter: All Activities

Activity ID	Activity Name	Original Duration	Start	Finish
A1860	Hang Drywall	15	07-Mar-11	25-Mar-11
A1870	Metal Stud/ Set HM Frames	36	07-Oct-10	26-Nov-10
A1880	Finish Drywall	15	23-Mar-11	12-Apr-11
1st Flr. Labs and Classroom		327	28-Oct-10	09-Feb-12
Basement Labs		160	15-Nov-10	30-Jun-11
A1980	Metal Stud/ Set HM Frames	18	08-Dec-10	04-Jan-11
A1990	O.H. Plumbing	7	29-Nov-10	07-Dec-10
A2000	O.H. Ductwork	21	18-Nov-10	17-Dec-10
A2010	O.H. Mechanical Piping	28	15-Nov-10	23-Dec-10
A2020	Install Process Piping	151	29-Nov-10	30-Jun-11
A2030	Conditioned Air	1	14-Feb-11	14-Feb-11
A2040	Hang Drywall	15	15-Feb-11	07-Mar-11
A2050	Finish Drywall	15	08-Mar-11	28-Mar-11
A2060	O.H. Sprinkler System	7	17-Jan-11	25-Jan-11
A2300	O.H. Electrical Work	39	26-Jan-11	21-Mar-11
1st Flr. Clean Rooms		95	11-Apr-11	23-Aug-11
A2070	LEVEL 2 PROTOCOL BEGINS	74	11-Apr-11	25-Jul-11
A2080	LEVEL 3 PROTOCOL BEGINS	5	26-Jul-11	01-Aug-11
A2090	LEVEL 4 PROTOCOL BEGINS	5	01-Aug-11	05-Aug-11
A2100	LEVEL 5 PROTOCOL BEGINS	5	17-Aug-11	23-Aug-11
Auditorium		111	01-Jun-11	04-Nov-11
A2210	O.H. HW and CHW	30	13-Jul-11	23-Aug-11
A2220	O.H. Electrical	88	01-Jun-11	04-Oct-11
A2230	O.H. Sanitary and Storm	7	01-Jun-11	09-Jun-11
A2240	O.H. Mechanical	86	01-Jul-11	01-Nov-11
A2250	Hang Drywall	25	13-Jul-11	16-Aug-11
A2260	Metal Studs/ set HM Frames	14	01-Jun-11	20-Jun-11
A2270	Millwork	19	06-Sep-11	30-Sep-11
A2280	Finish Drywall	15	17-Oct-11	04-Nov-11
Auditorium Lobby		74	14-Apr-11	28-Jul-11
A2110	O.H. Ductwork	15	14-Apr-11	04-May-11
A2120	O.H. Electrical Work	14	26-May-11	15-Jun-11
A2130	O.H. Mechanical Piping	14	05-May-11	24-May-11
A2140	O.H. Plumbing	8	16-May-11	25-May-11
A2150	Metal Studs/ set HM Frames	10	25-Apr-11	06-May-11
A2160	Hang Drywall	6	31-May-11	07-Jun-11
A2170	Finish Drywall	7	08-Jun-11	16-Jun-11
A2180	Millwork	19	01-Jul-11	28-Jul-11
Close-Out		29	04-Nov-11	15-Dec-11
Close-Out		29	04-Nov-11	15-Dec-11
A1060	ARCH Verify Punch-List	15	25-Nov-11	15-Dec-11
A1070	Bldg Life Safety Internal Testing	15	04-Nov-11	25-Nov-11
A1080	Chiller Water System Flush/ Fill	10	04-Nov-11	17-Nov-11
A1090	Final Cleaning	10	25-Nov-11	08-Dec-11
A1100	Internal MEP Test/ Balance	20	04-Nov-11	02-Dec-11
A1110	Labs Completion	0	25-Nov-11	25-Nov-11
A1150	Substancial Completion	0	15-Dec-11	15-Dec-11

2009 | 2010: ec, Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct

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

TASK filter: All Activities



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 Building 1		687	11-Jun-12	10-Feb-15
Structure		196	16-Sep-13	18-Jun-14

2009	2010									
ec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct

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

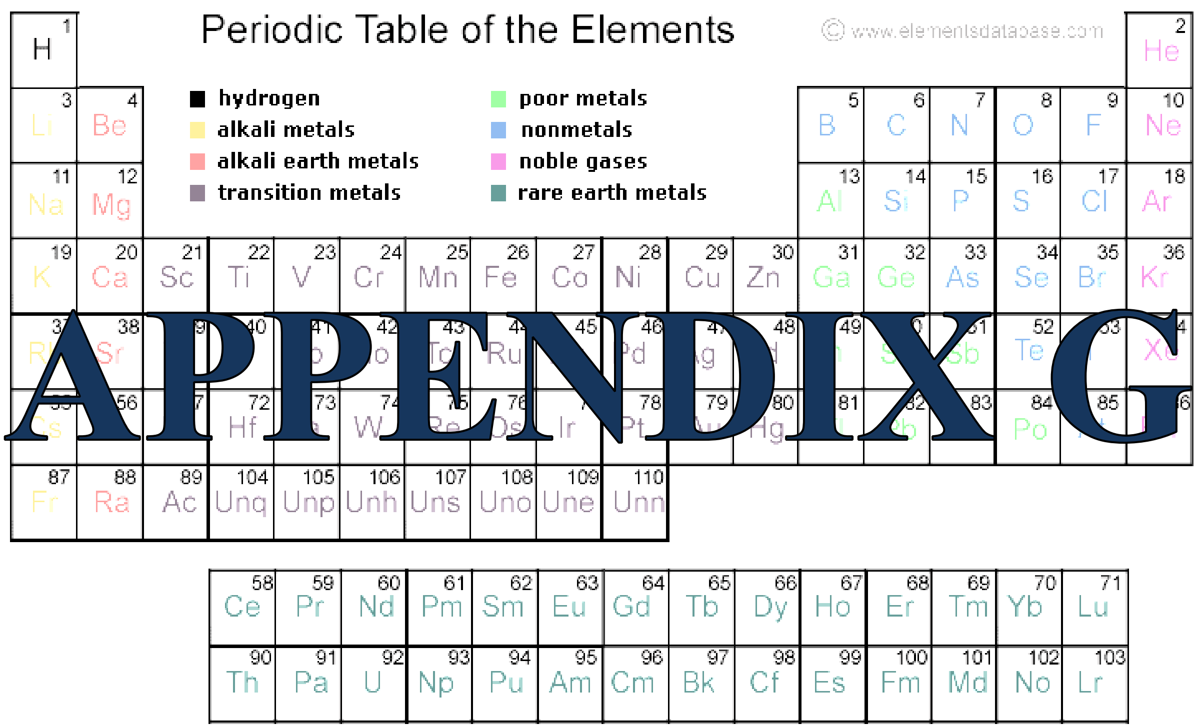
TASK filter: All Activities

		2011												2012				
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	ay

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

TASK filter: All Activities

APPENDIX G



Periodic Table of the Elements
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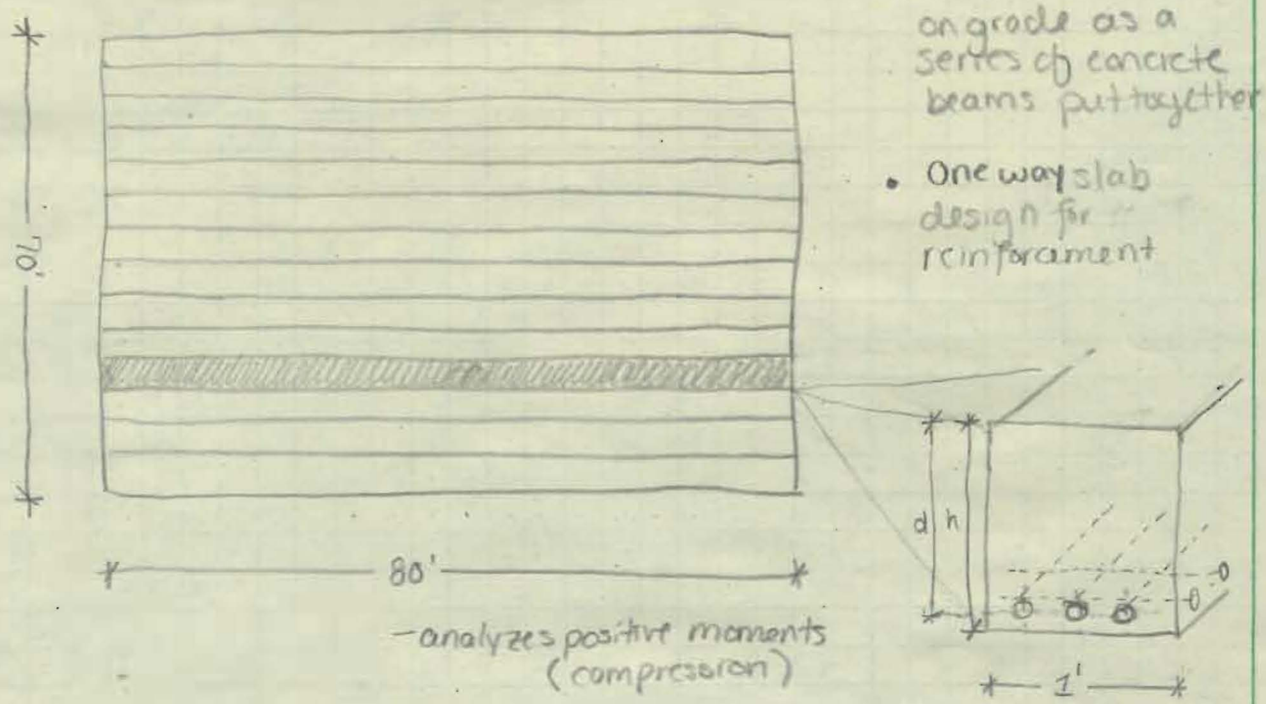
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

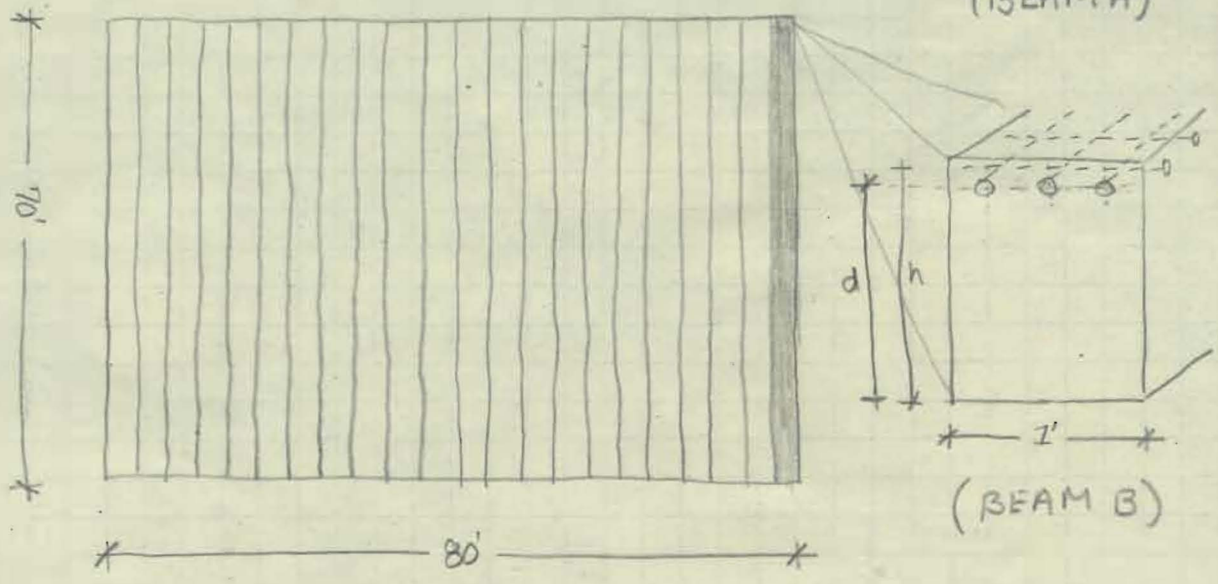
Redesign of Concrete Slab for added loading → MRI

- Treat the slab on grade as a series of concrete beams put together
- One way slab design for reinforcement



- analyzes positive moments (compression)

(BEAM A)



(BEAM B)

- analyzes negative moments (tension)

From geotech report:

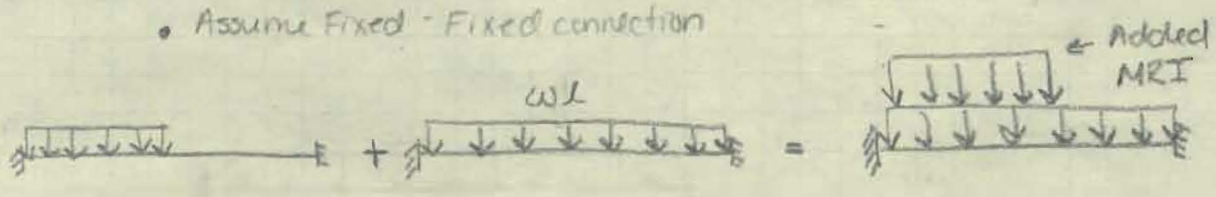
Sandy Silt soil (SS) → subgrade reaction (K)

3,000 PSF

S001: • concrete: 3000psi, normal weight

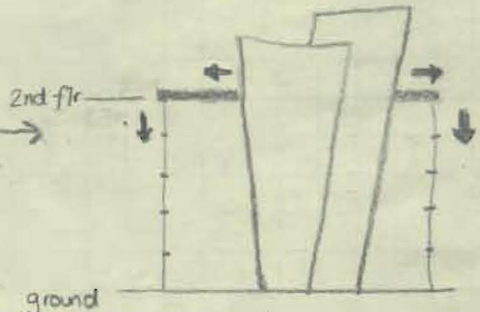
• minimum concrete coverage on soil = 0'-1.5"

• Assume Fixed - Fixed connection



Determining Loading on Beams (ω):

- assuming curtain wall supported by roof from auditorium constructed in center →



$P_u = 1.2D + 1.6L + 0.5S$
$= 1.2(20\,PSF) + 1.6(100\,PSF) + 0.5(11\,PSF)$
ROOF LOBBY SNOW LOAD

$= -0.19\ K/ft^2$

MRI load = $\frac{26,000\,lbs}{6ft \times 4ft}$

$= 1083\ lb/ft^2$

☆ See attached datasheets from RISA-2D Educational software

Max negative moment = 117 ft-K
Max positive moment = 51 ft-K

TOPS 35502

Global

Display Sections for Member Calcs	5

Boundary Conditions

Joint Label	X Translation (k/in)	Y Translation (k/in)	Rotation (k-ft/rad)
N1	Reaction	Reaction	Reaction
N2	Reaction	Reaction	Reaction

Member Data

Member Label	I Joint	J Joint	Area in^2	Moment of Inertia in^4	Elastic Modulus ksi	End Releases I-End	J-End	Length ft
M1	N1	N2	10	100	29000			80

Member Distributed Loads

Member Label	Direction	Start Magnitude (k/ft, F)	End Magnitude (k/ft, F)	Start Location (ft or %)	End Location (ft or %)
M1	Y	-.19	-.19	0	80
M1	Y	-1	-1	0	6

Reactions

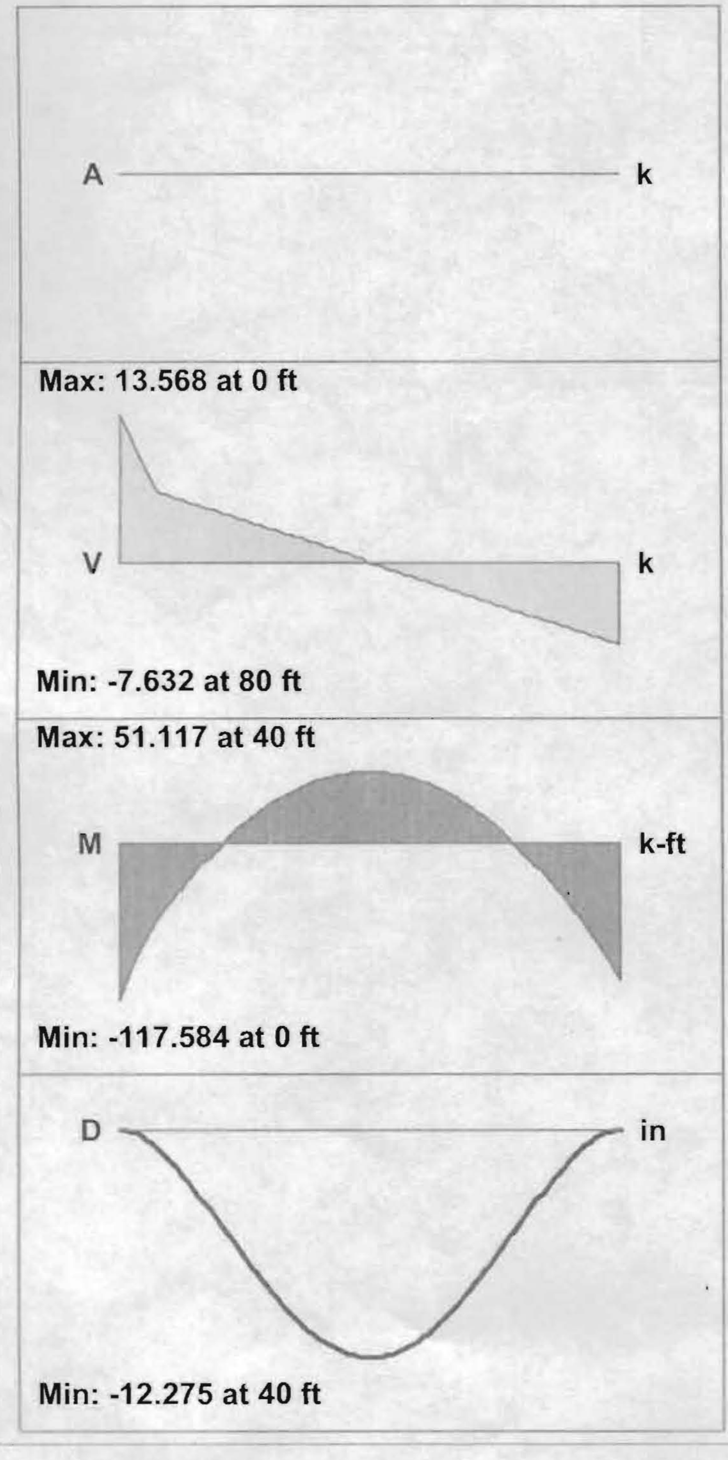
Joint Label	X Force (k)	Y Force (k)	Moment (k-ft)
N1	0	13.568	117.584
N2	0	7.632	-102.183
Totals:	0	21.2	

Member Section Forces

Member Label	Section	Axial (k)	Shear (k)	Moment (k-ft)
M1	1	0	13.568	-117.584
	2	0	3.768	13.766
	3	0	-.032	51.117
	4	0	-3.832	12.467
	5	0	-7.632	-102.183

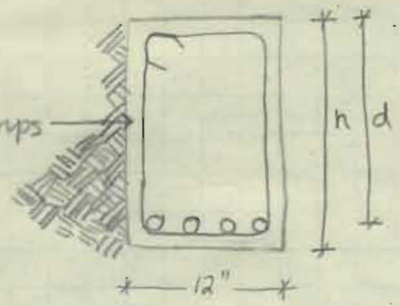
Member: *M1*

Length: **80 ft**
I Joint: **N1**
J Joint: **N2**



Beam A

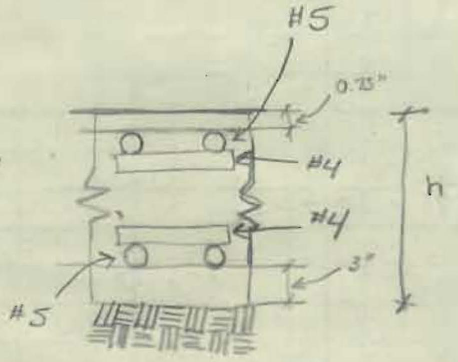
Max moment = 51 ft-K (M_u)



$$b = 12" = 1.5" + 0.75" + x(0.625) + 8(x-1) \quad (\#5)$$

x = # of rebar

$$9.75" = 8.625x - 8$$
$$18.375 = 8.625x$$
$$x = 2, \ \#5 \text{ bar}$$



$$h = 3" + 0.75" + 0.625" + 0.625" + 3"$$

$h = 8"$ → new slab depth

CHECKS:

Nominal moment strength

$$A_s = 2(0.31)$$
$$A_s = 0.62 \text{ in}^2$$

$$d = 8" - 0.75" - 3" - \frac{0.625"}{2} - 0.625" = 3.3125$$

$$a = \frac{60(0.62)}{0.85(3)(3.3125)}$$

$$a = 4.4"$$

$$M_n = 60(0.62)\left(3.3125 - \frac{4.4}{2}\right)$$
$$\underline{M_n = 41.39 \text{ ft-K}}$$

Tension Control

$$c = \frac{a}{\beta} = \frac{4.4}{0.85} = 5.17$$

$$0.375(3.3125) \le 5.17$$

∴ tension controled ✓

Flexural design strength

$\phi = 0.9$ for tension control

$$\phi M_n \le M_u$$
$$0.9(41.39) \le 51 \text{ ft-K}$$

✓ OK for flexural strength

Check minimum steel

$$A_s \geq \frac{3\sqrt{f'c}}{f_y} bd$$

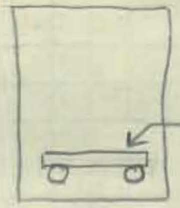
$$A_s \geq \frac{3\sqrt{3000}}{60{,}000}(12'')(3.3125'')$$

59.75

$A_s = 0.162 in^2 >> 0.109$ ✓ OK for minimum steel

Beam A → with #4 opposite direction

Max moment = 51 ft-K , M_u



b = same as Beam A

$h = 3'' + 0.75 + 0.625'' + 0.625'' + 2(0.5) + 2''$
$h = 8''$

added #4, subtracted from 3" concrete fill

CHECKS:

. Nominal moment strength

$A_s = 2(.20)$
$= 0.40\,in^2$

$d = 8'' - 0.75'' - 2(0.5) - 0.625 - \frac{0.625}{2} - 2'' =$
$= 3.3125''$

$a = \frac{60(0.20)}{0.85(3)(3.3125)} = 1.42''$

$M_n = 60(0.62)(3.3125 - \frac{1.42}{2})$
$= 96.813$

Tension Control

$c = \frac{a}{\beta} = \frac{1.42}{0.85} = 1.67$

$0.375(3.3125) < 1.67$
$1.242 < 1.67$ ∴ tension controlled ✓

Flexural Design strength

$\phi = 0.9$ for tension control
$0.9(96.813) \leq 51$ ft-K

not designed for flexural strength
↓
proves that 2 #4 bars alone are not suffient

Check minimum steel

$A_s \geq \frac{3\sqrt{f'c}\ bd}{fy}$

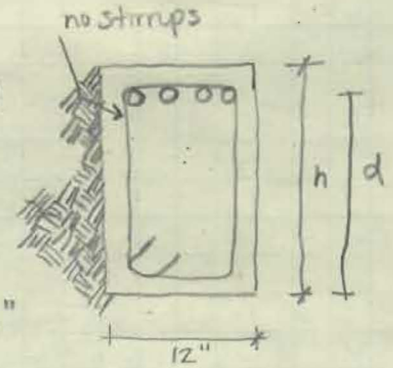
$A_s \geq \frac{3\sqrt{3000}}{60,000}(12)(3.3125)$

$A_s = 0.40\,in^2 >> 0.109$ ✓ ok for minimum steel

TOPS. 35502

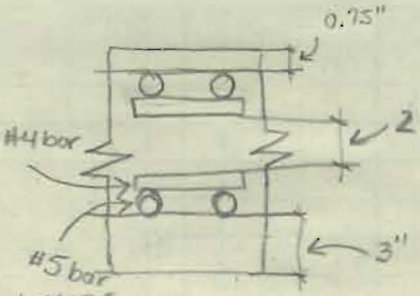
Beam B

Max moment -117 ft-K (M_u)



$b = 12"$, same as Beam A

$h = 3" + 0.75" + 2(0.5) + 2(0.625) + 2"$
$h = 8"$



CHECKS:

Nominal moment strength

$A_s = 0.20 + 0.31$
$= 0.51 \text{ in}^2$

$d = 8" - 3" - 2(0.5) - 0.625 - \frac{0.625}{2} - 2" = 1.0625$

$a = \frac{60(.51)}{0.85(3)(1.0625)}$ $\quad a = 11.29$

$M_n = 60(.51)\left(1.0625 - \frac{11.29}{2}\right)$

$M_n = -140.2875$

Tension Control

$c = \frac{a}{\beta} = \frac{11.29}{0.85} = 13.28$

$0.375(1.0625) \leq 13.28$ ✓ ∴ tension controlled

Flexural Strength

$\phi = 0.9$ for tension control

$\phi M_n \leq M_u$
$0.9(140) \leq 117$. does not check for flexural strength

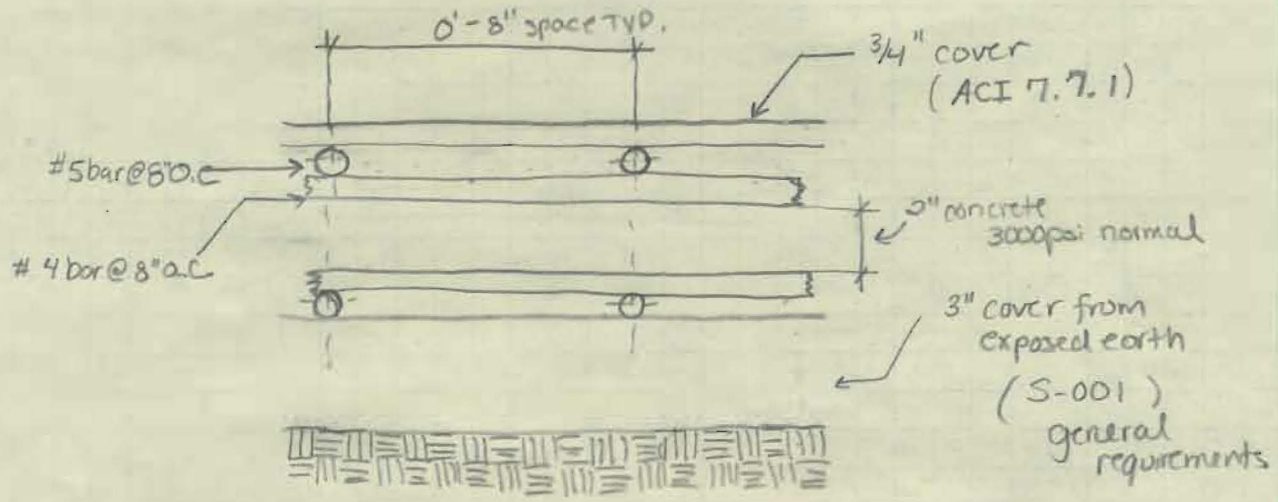
check minimum steel

$$A_s \geq \frac{3\sqrt{f'c}}{fy} bd$$

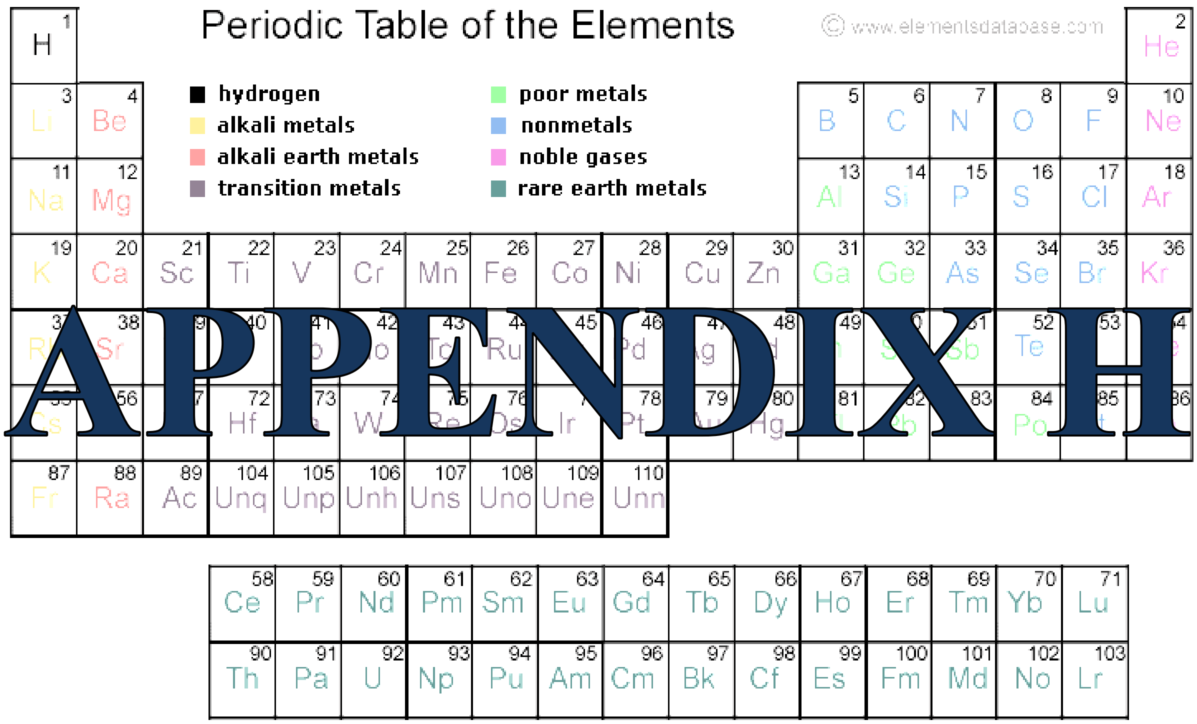
$$A_s \geq \frac{3\sqrt{3000}}{40{,}000} (12)(1.0625)$$

$A_s = 0.51 \text{ in}^2 >> 0.0349$ ✓ ok minimum steel

Design of the slab:



APPENDIX H


Periodic Table of the Elements
© www.elementsdatabase.com
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

11. Sand Filter

Description

A sand filter is a device that allows stormwater to percolate down through a sand media where pollutants are filtered out.

Regulatory Credits

Pollutant Removal

85%	Total Suspended Solids
35%	Total Nitrogen
45%	Total Phosphorus

Water Quantity

possible	Peak Attenuation
possible	Volume Capture

Feasibility Considerations

Med	Land Requirement
High	Cost of Construction
High	Maintenance Burden
Small	Treatable Basin Size
Med	Possible Site Constraints
Med	Community Acceptance

Major Design Elements

- * Sizing shall take into account all runoff at ultimate build-out including off-site drainage.
- * Vegetated side slopes shall be no steeper than 3:1.
- * BMP shall be located in a recorded drainage easement with a recorded access easement to a public ROW.
- ** Seasonally high groundwater table must be at least 2 feet below the bottom of the filter for open-bottom designs, and at least 1 foot below the bottom of the filter for pre-cast designs.
- ** Maximum contributing drainage basin is 5 acres.
- ** Sand filters must be designed off-line with a flow-splitting device.
- ** Minimum width (parallel to flow) of a sedimentation chamber or forebay shall be 1.5 feet.
- ** Sand filter must completely drain within 40 hours.
- ** Sand media shall be as specified below and shall be a minimum of 18" deep (minimum of 12" over the drainage pipes).
- ** For underground sand filters, provide at least 5 feet of clearance between the surface of the sand filter and the bottom of the roof of the underground structure.

* *This provision is specified in the NC Administrative Rules of the Environmental Management Commission. Other specifications may be necessary to meet the stated pollutant removal requirements of the rules.*

** *This provision, which is based on available research studies, is what the Division of Water Quality considers necessary to meet the removal efficiencies provided in this Manual.*

Advantages

- Highly effective at filtering TSS.
- Underground sand filters are useful where space is limited.
- Perimeter sand filters useful for small sites with flat terrain or high water table.

Disadvantages

- If anoxic conditions develop in the sand filter due to poor drainage, phosphorus levels can increase as water passes through the sand filter.
- May not be effective in controlling peak discharges.
- Large sand filters without vegetation may not be attractive in residential areas.
- Expensive.

11.1. General Characteristics and Purpose

Sand filters can be of open basin design, as shown in Figure 11-1, or of buried trench design (a closed basin), as shown in Figures 11-2a, and 11-2b. Sand filters will typically have underdrain systems to collect the stormwater for discharge from the BMP, but they can also be designed as infiltration type systems if the in-situ soils have appropriate permeability. In contrast to the infiltration devices presented in Section 16, sand filters require that the stormwater pass through a specific depth of specific sand media prior to leaving the device, whereas infiltration devices don't have a media requirement other than sometimes to provide void storage space (such as in an infiltration trench).

Sand filters are designed primarily for water quality enhancement; flow volume control is typically a secondary consideration. They are generally applied to land uses with a large fraction of impervious surfaces. Although an individual sand filter can only handle a small contributing drainage basin, multiple units can be dispersed throughout a large site.

11.2. Meeting Regulatory Requirements

A listing of the major design elements is provided on the first page of this section. At a minimum, any sand filter must meet the major design elements indicated as being from the North Carolina Administrative Code. To receive the pollutant removal rates listed in the front of this Section, the sand filter must meet all of the major design elements listed in the beginning of this Section.

Pollutant Removal Calculations

The pollutant removal calculations for sand filters are as described in Section 3.4, and use the pollutant removal rates shown at the beginning of this Section. Construction of an open basin sand filter also passively lowers nutrient loading since it is counted as pervious surface when calculating nutrient loading. Buried trench sand filters receive whatever runoff values the surface above them is assigned.

Volume Control Calculations

A sand filter can be designed with enough storage to provide active volume capture (calculations for which are provided in Section 3.4), however, special provisions must typically be made to the outlet to provide peak flow attenuation. An open basin sand filter provides some passive volume control capabilities by providing pervious surface and therefore reducing the total runoff volume to be controlled, however, buried trench sand filters may not.

Figure 11-1
Site Built Sand Filter (Open Basin)

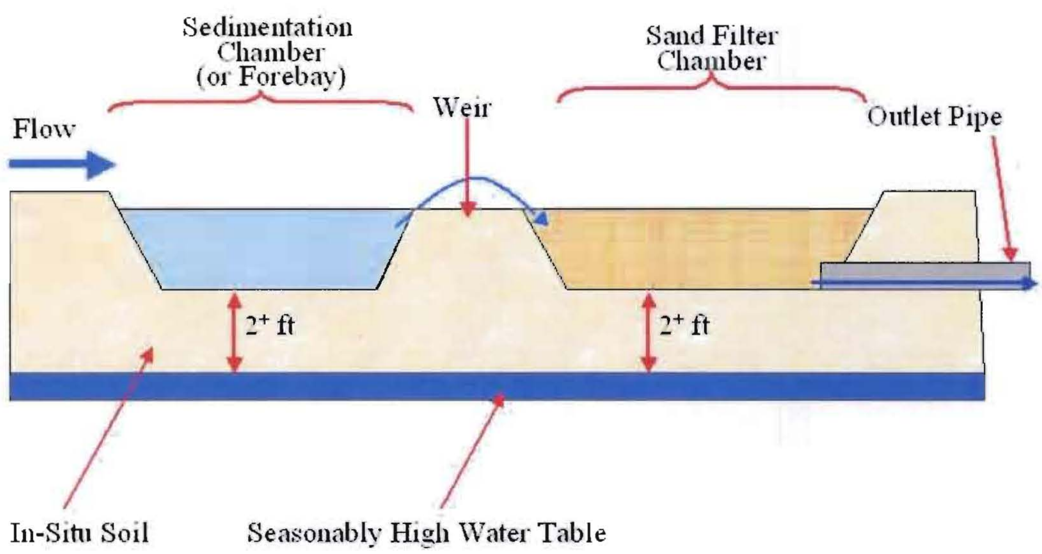


Figure 11-2a
Buried Trench (Closed-Basin) Sand Filter, 3-D View
Derived from Shaver, 1992

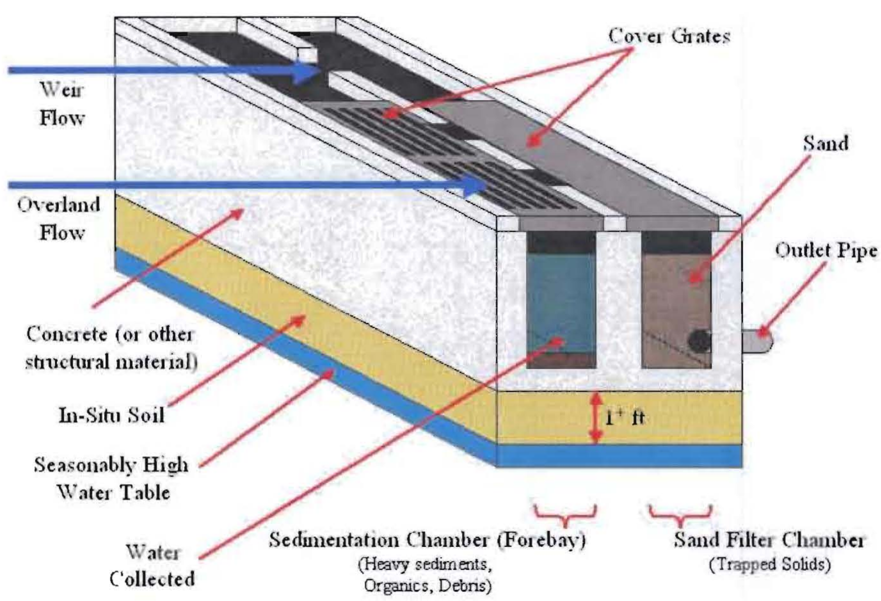
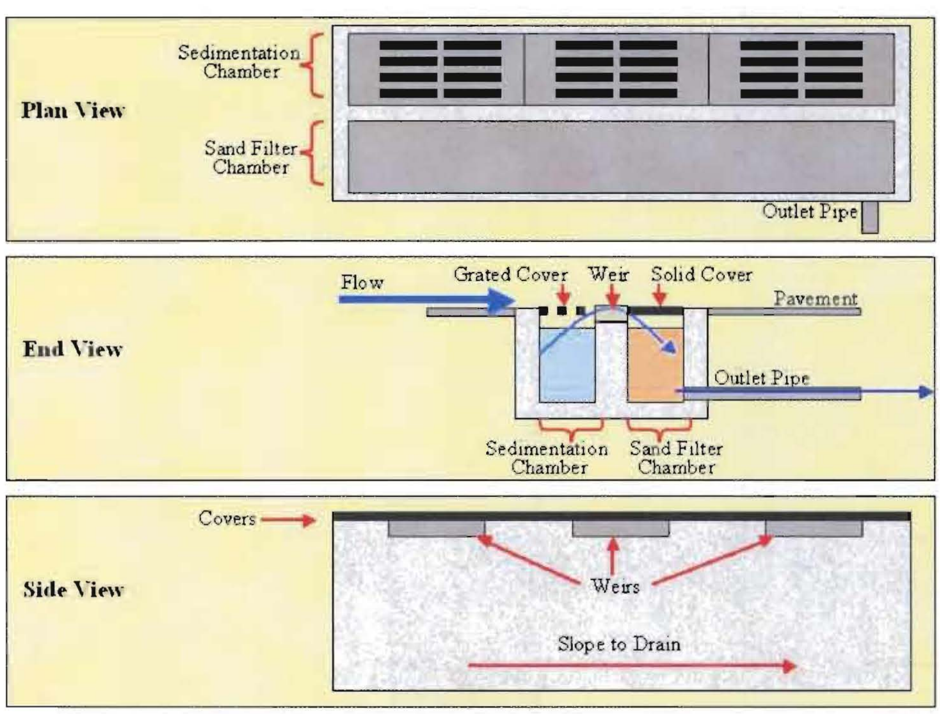


Figure 11-2b
Buried Trench (Closed Basin) Sand Filter
Derived from Shaver, 1992



11.3. Design

11.3.1. Converting Sediment and Erosion Control Devices

A basin used for construction sediment and erosion control can be converted into an open basin type sand filter if all sediment is removed from the basin prior to construction of the sand filter and proper sand filter design is followed. Buried trench type sand filters are typically newly constructed after site construction and not placed in modified site construction sediment and erosion control basins.

11.3.2. Siting Issues

Sand filters shall *not* be used in areas with the following characteristics:

- The seasonal high water table is less than 2 feet below the proposed bottom of the facility for an open basin design. If a concrete bottom is used, then the separation can be reduced to a minimum of 1 foot.
- If site restrictions such as bedrock or hydraulics prevent the facility from being constructed to a depth that will allow for the required media thickness, ponding depth, and other appurtenances.

11.3.3. Contributing Drainage Basin

The maximum contributing drainage area to an individual sand filter shall be less than 5 acres, however, 1 acre or less is recommended. Multiple sand filters can be used throughout a development to provide treatment for larger sites.

11.3.4. Pretreatment and Inflow

Erosive velocities and high sediment loads are a concern with sand filters. Sediment can quickly blind a sand filter and cause premature failure of the BMP. Two devices that can help reduce the impact of these factors on the sand filter are flow splitter devices and forebays.

Flow beyond the design flow can overload the hydraulic capacity of a sand filter (usually resulting in an overflow), cause erosion in open basin sand filters, and deliver more sediment to the sand filter than is necessary. Because of these issues, sand filters are required to be designed "off-line", meaning only the design volume of the stormwater flow is sent from the conveyance system into the treatment unit, and the excess is diverted. Please see Section 5.3 for more information on the design and regulatory compliance issues related to flow splitters and designing systems off-line.

A forebay or sedimentation chamber is required on all sand filters to protect the sand filter from clogging due to sediment, and to reduce the energy of the influent flow. The forebay can be in the form of an open basin (typical with an open basin sand filter design), or a subsurface concrete chamber (typical with a buried trench design). Please see Section 5.5 for design information on forebays. The forebay must contain ponded water (not be drained down with the sand filter). If a subsurface concrete chamber is provided, appropriate means of removing accumulated sediment must be demonstrated. Since individual sand filters treat relatively small volumes of stormwater and the design of the forebay is a percent of the total design volume, the forebay can also be very small. Besides the minimum requirements from Section 5.5, the minimum width (measurement parallel to flow direction) of the sedimentation chamber or forebay shall be 1.5 feet.

After the sedimentation chamber or forebay, the stormwater flow can be distributed over the surface of the sand filter is a variety of ways. For an open sand filter it could flow onto the sand filter as sheet flow via a level spreader, but depending on the geometry of the sand filter, that may not provide even enough flow distribution to prevent overloading and clogging of the leading edge of the sand filter. A common way of distributing flow onto sand filters, both open basin and buried trench type, is through the use of a pipe distribution or weir system. Design of the pipe distribution system could mimic the design of the underdrain system as presented in Section 5.7.

11.3.5. Length, Width and Geometry

The area required for a sand filter device is calculated similar to many other BMP types. The applicable regulation will determine whether the Runoff Capture Design Storm or the Runoff Peak Attenuation Design Storm will be used to calculate the design volume of the unit (see Sections 2 and 3). Since a sand filter must be completely drained within 40 hours, the ponding depth is limited by the media's infiltration rate. Once the ponding depth is known, the surface area can be calculated based on the design volume. No credit is given for storage within the media since the influent can come at such a rate that all of the volume would need to be stored above the media since essentially no infiltration will have taken place yet. A sand filter consists of two parts, the sedimentation basin which serves as a sort of forebay and the sand filter itself. These two parts are collectively referred to as the "sand filter". The geometry of these components can vary. An open basin type sand filter can be rectangular, square, circular or irregular. Buried trench systems (closed basin systems) are often very rectangular, approaching linear. The important factor is that the incoming stormwater is distributed relatively evenly over the surface of the sand filter. Use the following series of steps to determine the appropriate sand filter size.

Step 1: Compute the water quality volume (WQV) using Schueler's Simple Method, as described in Sections 2 and 3 and summarized below, and the adjusted water quality volume (WQV_{Adj}) as defined below (Center for Watershed Protection, 1996). :

$$WQV(ft^3) = \frac{R_v(unitless)}{1} x \frac{A_D(acres)}{1} x \frac{43{,}560 ft^2}{1Acre} x \frac{1inchRain}{1} x \frac{ft}{12in}$$

$$WQV_{Adj}(ft^3) = (0.75)WQV$$

- WQV: Water Quality Volume (ft^3). This is used to size the surface areas of the sedimentation chamber and the sand filter.
- WQV_{Adj}: Adjusted Water Quality Volume (ft^3). This is used as the volume that must be contained between the sedimentation chamber and the sand filter (above the sand).
- A_D: Drainage area to the sand filter (acres)
- R_v: Volumetric runoff coefficient (unitless)=0.05+0.009(%Imp)
    - %Imp: Percent of impervious of land draining to the sand filter

Step 2: Determine the maximum head on the sand filter and the sedimentation basin, and determine the surface areas of the sand filter and the sedimentation tank.

Maximum Head on the Sand Filter and the Sedimentation Basin

$$h_A(ft) = \frac{h_{MaxFilter}(ft)}{2}$$

- h_A=Average head (ft). The average head on the sand filter is approximately equal to the average head on the sedimentation basin.
- $h_{MaxFilter}$(ft): Maximum head on the sand filter (ft). This head should be between 2 and 6 feet. Choose the maximum head so that the following equation is true:

$$h_{MaxFilter}(ft) = \frac{WQV_{Adj}(ft^3)}{A_S(ft^2) + A_f(ft^2)}$$

- A_S: Surface area of the sedimentation basin (ft^2)
- A_f: Surface area of the sand filter bed (ft^2)

Sedimentation Basin Surface Area:

The minimum surface area for the sedimentation basin is determined by the Camp Hazen Equation:

$$A_s(ft^2) = -\frac{Q_o\left(\frac{ft^3}{\sec}\right)}{w\left(\frac{ft}{\sec}\right)} x \ln(1-E)$$

$$A_S(ft^2) = -\frac{\left(\frac{WQV(ft^3)}{24hr}\right) x \left(\frac{1hr}{3600\sec}\right)}{0.0004\left(\frac{ft}{\sec}\right)} x \ln(1-0.9)$$

$$A_S(ft^2) = 0.066WQV(ft^2)$$

$$A_S(ft^2) = 0.066\left[\frac{R_v(unitless)}{1} x \frac{A_D(Acres)}{1} x \frac{43{,}560(ft^2)}{(Acre)} x \frac{1(in)}{1} x \frac{1(ft)}{12(in)}\right](ft^2)$$

$$A_S(ft^2) = [240 * R_v(unitless) * A_D(acres)](ft^2)$$

- Q_o: Average rate of outflow from the sedimentation chamber (ft^3/sec). (Center for Watershed Protection, 1996.)

- E: Trap Efficiency of the chamber = 0.9 (unitless)
- w: Settling velocity of particle. Assume that the particles collected by the filter are 20 microns in diameter. For 20 microns, w=0.0004 (ft/sec). This varies depending on the imperviousness of the land draining to the sand filter, but the value presented here is representative of most situations. (Center for Watershed Protection, 1996).

Sand Filter Bed Surface Area:

The minimum surface area for the sand filter bed is determined by Darcy's Law:

$$A_f(ft^2) = \frac{(WQV)(d_F)}{(k)(t)(h_A + d_F)}$$

- d_F: Depth of the sand filter bed, (ft). This should be a minimum of 1.5 ft.
- k: Coefficient of permeability for the sand filter bed=3.5 (ft/day).
- t: Time required to drain the WQV through the sand filter bed (day). This time should be 40 hours (1.66 days). (Center for Watershed Protection, 1996.)
- h_A: Average head (ft)
  - Determine the average head of water above the sand filter. The average head above the sand filter is half of the maximum head on the filter (Center for Watershed Protection, 1996).

Step 3: Ensure that the Water Quality Volume is Contained:

- Ensure that this combination of variables will contain the required volume (WQV_{Adj} (ft^3)):
  - $[A_f(ft^2) + A_s(ft^2)] x [h_{MaxFilter}(ft)] \geq WQV_{Adj}(ft^3)$

Step 4: Additional Design Requirements:

For underground sand filters, provide at least 5 feet of clearance between the surface of the sand filter and the bottom of the roof of the underground structure to facilitate cleaning and maintenance.

Example Calculation:: Design a sand filter to treat the first inch of water from a 1 acre site that is 100% impervious. There is 720 ft^2 of space available for this underground project.

1. Step 1
   - Rv=0.05+0.09(%Imp)=0.05+0.009(100)=0.95
   - $WQV(ft^3) = \frac{0.95(unitless)}{1} x \frac{1(acres)}{1} x \frac{43{,}560 ft^2}{1Acre} x \frac{1inchRain}{1} x \frac{ft}{12in} = 3{,}449 ft^3$
   - $WQV_{Adj}(ft^3) = (0.75)(3{,}449) = 2{,}587(ft^3)$
2. Step 2
   - $h_{MaxFilter}(ft) = \frac{2{,}587(ft^3)}{A_S(ft^2) + A_f(ft^2)}$, for maximum heads between 2 and 6 feet, the following combinations of variables will work:

$h_{MaxFilter}$ (ft)	WQV_{Adj} (ft^3)	As+Af (ft^2)
2.0	2,586	1,293
3.0	2,586	862
3.6	2,586	720
4.0	2,586	647
5.0	2,586	517
6.0	2,586	431

- A_s(ft^2)=240*0.95*1=228 (ft^2), this is the minimum value for the area of the sedimentation basin. Larger basins are acceptable.

- Choose a combination of A_f and h_A to meet the available space onsite. Typically, the sedimentation chamber and the sand filter bed should be approximately the same size. If there is 720 ft^2 of space available, then A_s and A_f can both be 360 ft^2, and the maximum head on the sand filter will be 3.6 ft. The average head is half of the maximum head, 1.8 ft. Check to ensure that the minimum area for the sand filter is attained:

  - $A_f(ft^2)=\dfrac{(3{,}449(ft^2))(1.5(ft))}{(3.5(ft/day))(1.66(day))(1.8(ft)+1.5(ft))}=270\ ft^2.$

    This is the minimum value for the area of the sand filter. Larger sand filters are acceptable, and therefore the chosen combination of variables is acceptable for this design.

- There are several combinations of surface areas and depths that would be acceptable for this design. In this example:
  - A_f=360ft^2
  - A_s=360ft^2
  - $h_{MaxFilter}$=3.6 ft
  - h_A=1.8ft

3. Step 3
   - $2{,}592(ft^3)=[360(ft^2)+360(ft^2)]x[3.6(ft)]\geq 2{,}587(ft^3)$
4. Step 4
   - Because this is an underground project, 5 feet of clearance between the surface of the sand filter and the bottom of the underground structure is required to facilitate cleaning.

11.3.6. Drainage Considerations

The sand filter chamber shall drain completely within 40 hours. The length of time that it takes to drain the media of a filter is controlled by the infiltration rate of the media (or possibly the infiltration rate of the in-situ soil if the system is designed as an infiltration type system).

11.3.7. Media Requirements

The media in the sand filter shall be cleaned, washed, course masonry sand such as ASTM C33. The sand particles shall be less than 2 mm average diameter. The filter bed shall have a minimum depth of 18 inches, with the minimum depth of sand above the drainage pipe being 12 inches.

11.3.8. Outlet Design

If the sand filter is designed as an infiltration type system, please refer to the in-situ soil requirements and other applicable design and construction recommendations of Section 16 Infiltration Devices. In general, only sand filters constructed in the coastal areas will have in-situ permeabilities that allow construction of infiltration type sand filters.

In general, sand filter BMPs in the Mountain and Piedmont regions of North Carolina will require underdrains. The underdrain system shall be designed as shown in Section 5.7. The underdrain system will connect to another BMP or to the conveyance system.

Observation wells and/or clean-out pipes must be provided (one minimum per every 1,000 square feet of surface area). The observation wells, as well as the ends of underdrain pipes that do not terminate in an observation well, must be capped.

11.4. Maintenance

11.4.1 Common Maintenance Issues

Sand filters should be inspected at least once per month, and after any large storm events to check for damage. They must be maintained as needed to remove visible surface sediment accumulation, trash, debris, and leaf litter to prevent the filter from clogging prematurely. Sediment should be cleaned out of the forebay/sedimentation chamber when it accumulates to a depth of more than 6 inches. Any structures (outlets, flow diversions, embankments, etc.) should be checked at least annually for damage or degradation. Figures 11-3a and 11.3b show an example of a sand filter that is overdue for maintenance.

Figure 11-3a
Sand Filter Overdue for Maintenance: Sedimentation Chamber

Figure 11-3b
Sand Filter Overdue for Maintenance: Sand Filter Chamber

When the filtering capacity diminishes substantially (e.g., when water ponds on the surface for more than 40 hours), remedial actions must be taken. One possible problem is that collector pipe systems can become clogged. Annual flushing through pipe cleanouts is recommended to facilitate unclogging of the pipes without disturbing the filter area. If the water still ponds for more than 40 hours, the top few inches of material should be removed and replaced with fresh material. The removed sediments should be disposed of in an acceptable manner (e.g., landfill). If that does not solve the problem, more extensive rebuilding is required.

11.4.2. Sample Inspection and Maintenance Provisions

Important maintenance procedures:

- The drainage area will be carefully managed to reduce the sediment load to the sand filter.
- Once a year, sand media will be skimmed.
- The sand filter media will be replaced whenever it fails to function properly after vacuuming.

The sand filter will be inspected **quarterly and within 24 hours after every storm event greater than 1.0 inches (or 1.5 inches if in a Coastal County)**. Records of inspection and maintenance will be kept in a known set location and will be available upon request.

Inspection activities shall be performed as follows. Any problems that are found shall be repaired immediately.

Table 11-1

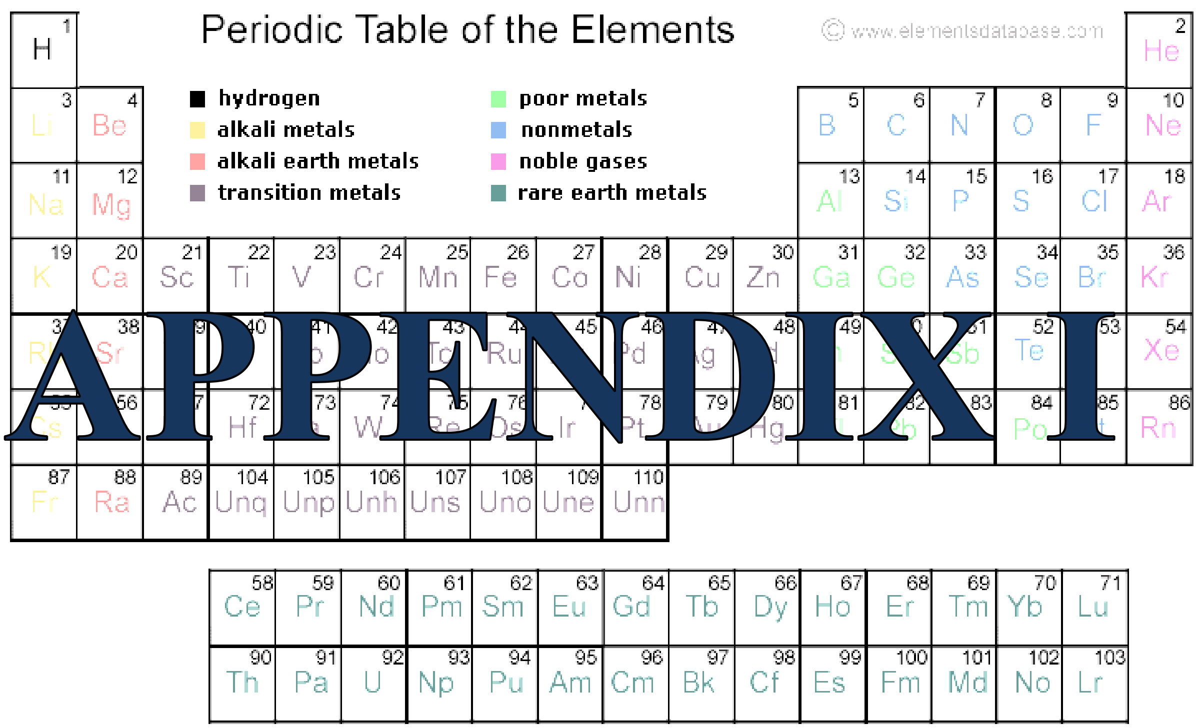
Sample Inspection and Maintenance Provisions for Sand Filters

BMP element:	Potential problems:	How to remediate the problem:
The entire BMP	Trash/debris is present.	Remove the trash/debris.
The adjacent pavement (if applicable)	Sediment is present on the pavement surface.	Sweep or vacuum the sediment as soon as possible.
The perimeter of the sand filter	Areas of bare soil and/or erosive gullies have formed.	Regrade the soil if necessary to remove the gully, and then plant a ground cover and water until it is established. Provide lime and a one-time fertilizer application.
	Vegetation is too short or too long.	Maintain vegetation at a height of approximately six inches.
The flow diversion structure	The structure is clogged.	Unclog the conveyance and dispose of any sediment off-site.
	The structure is damaged.	Make any necessary repairs or replace if damage is too large for repair.
The pretreatment area	Sediment has accumulated to a depth of greater than six inches.	Search for the source of the sediment and remedy the problem if possible. Remove the sediment and dispose of it in a location where it will not cause impacts to streams or the BMP.
	Erosion has occurred.	Provide additional erosion protection such as reinforced turf matting or riprap if needed to prevent future erosion problems.
	Weeds are present.	Remove the weeds, preferably by hand. If a pesticide is used, wipe it on the plants rather than spraying.

Table 11-1, continued
Sample Inspection and Maintenance Provisions for Sand Filters

BMP element:	Potential problems:	How to remediate the problem:
The filter bed and underdrain collection system	Water is ponding on the surface for more than 24 hours after a storm.	Check to see if the collector system is clogged and flush if necessary. If water still ponds, remove the top few inches of filter bed media and replace. If water still ponds, then consult an expert.
The outflow spillway and pipe	Shrubs or trees have started to grow on the embankment.	Remove shrubs and trees immediately.
	The outflow pipe is clogged.	Provide additional erosion protection such as reinforced turf matting or riprap if needed to prevent future erosion problems.
	The outflow pipe is damaged.	Repair or replace the pipe.
The receiving water	Erosion or other signs of damage have occurred at the outlet.	Contact the NC Division of Water Quality 401 Oversight Unit at 919-733-1786.

APPENDIX I


Periodic Table of the Elements
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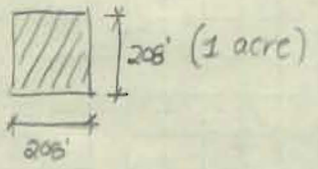
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

Analysis III

Total LF to cover: 1120 LF

$$[\Theta]$$
$$g_h = (25+19v)A(x_s - x)$$

g_h = amount of evaporated water per hour (kg/h)
Θ = evaporation coefficient (kg/m^2h)
v = velocity of air above surface (m/s)
A = water surface area (m^2)
X_s = humidity ratio in saturated air
↳ 100%
X = humidity ratio in air



	v (MPH)	X(avg.)
JAN	8.1	66.5
FEB	8.5	64
MAR	9.1	63.5
APR	8.8	62.5
MAY	7.6	69
JUNE	6.9	70
JUL	6.5	73
AUG	6.2	75
SEP	6.6	74.5
OCT	7.0	71.5
NOV	7.5	67.5
DEC	7.6	67

STEP 1:

$$WQV(ft^3) = \frac{R_v \text{ (unitless)}}{1} \times \frac{A_D \text{ (acres)}}{1} \times \frac{43{,}560 ft^2}{1 \text{ Acre}} \times \frac{1 \text{ inch Rain}}{1} \times \frac{ft}{12 in} = \boxed{25{,}410 ft^3 \to WQV}$$

$$WQV_{adj} = 0.5(WQV)$$
$$= 0.5(25{,}410)$$
$$= \underline{12{,}705 ft}$$

STEP 2:

$$h_{max\,filter} = \frac{WQV_{adj}}{A_s + A_f}$$

A_s = area of sedimentation basin
1677.06

A_f = area of sand filter
2050.075

$$A_s = 0.066\, WQV$$
$$= 0.066(25410)$$
$$= \underline{1677.06}$$

** $h_{a_{avg}} = \frac{1}{2} h_{a_{max}}$

$$A_f = \frac{WQV(d_f)}{(K)(t)(h_A + d_f)} = \frac{(25410)(1.5)}{(3.5)(1.66)\left(\frac{h_{a_{max}}}{2} + 1.5\right)}$$

$$A_f = \frac{6560.24}{\left(\frac{h_{a_{max}}}{2} + 1.5\right)}$$

$$h_{max} = \frac{12705}{\left[1677.06 + \frac{6560.24}{\left(\frac{h_{max}}{2} + 1.5\right)}\right]} \quad = \quad h_{max}\left[1677.06 + \frac{6560.24}{\left(\frac{h_{max}}{2} + 1.5\right)}\right] = 12705$$

$$h_{max}\,1677.06 + \frac{6560.24\,h_{max}}{\left(\frac{h_{max}}{2} + 1.5\right)} = 12705$$

$$\left(\frac{h_{max}}{2} + 1.5\right) h_{max}\,1677.06 + 6560.24\,h_{max} = 12705\left(\frac{h_{max}}{2} + 1.5\right)$$

$$838.53\,h_{max}^2 + 2515.59\,h_{max} + 6560.24\,h_{max} = 6352.5\,h_{max} + 19057.5$$

$$838.53\,h_{max}^2 + 2723.33\,h_{max} - 19057.5 = 0$$

$$h_{max} = \underline{3.4} \text{ or } \cancel{-6.66}$$

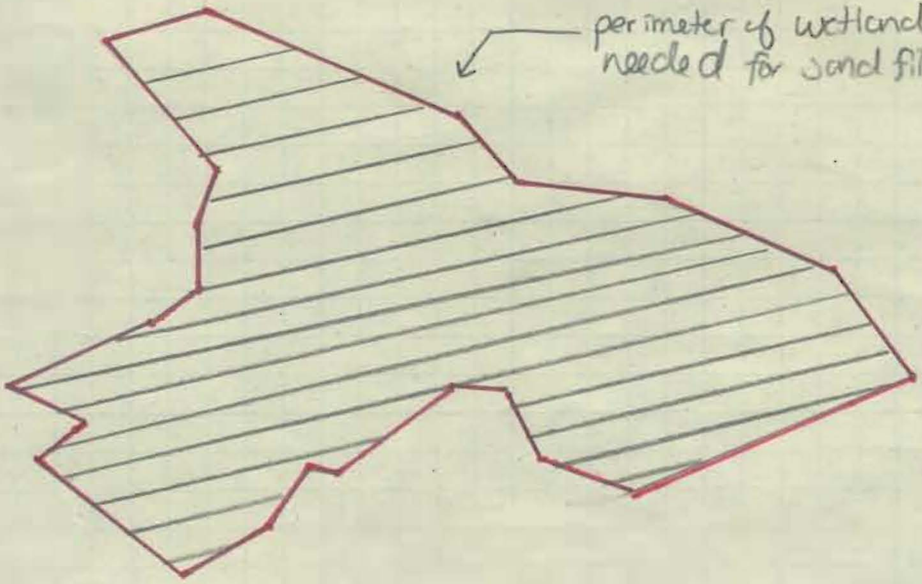
STEP 3: Check volume contained

$$[1677.06 + 2050.075] \times (3.4) \geq 12{,}705 \text{ ft}^3$$

$$12672.259 \not\geq 12{,}705$$

$\rightarrow$ increase head to 4 ft.

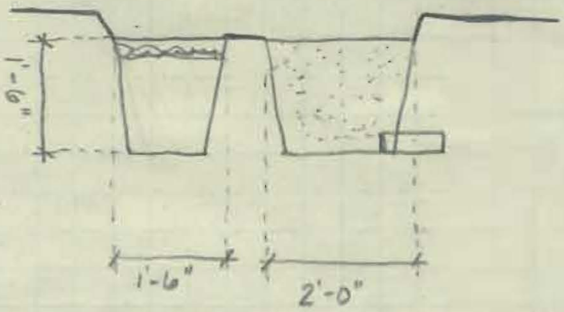
TOPS 35502

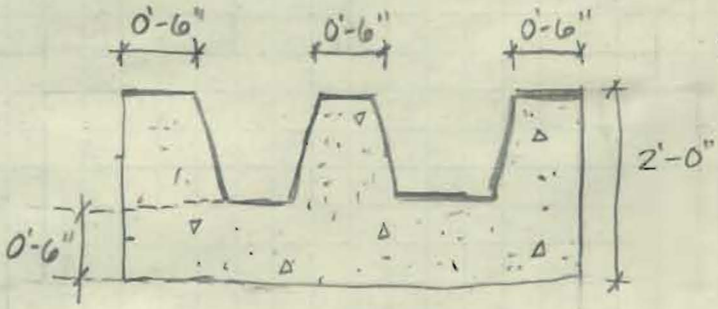


perimeter of wetland and linear footage needed for sand filter.

A_s = area of sedimentation base = 1677 ft^2 } length = 1120 ft
A_f = area of sand filter base = 2050 ft^2 }

A_s width = 1677/1120 = 1.5 ft 1'-6"
A_f width = 2050/1120 = 1.8 ft 1'-10" → 2'-0" for safe measures

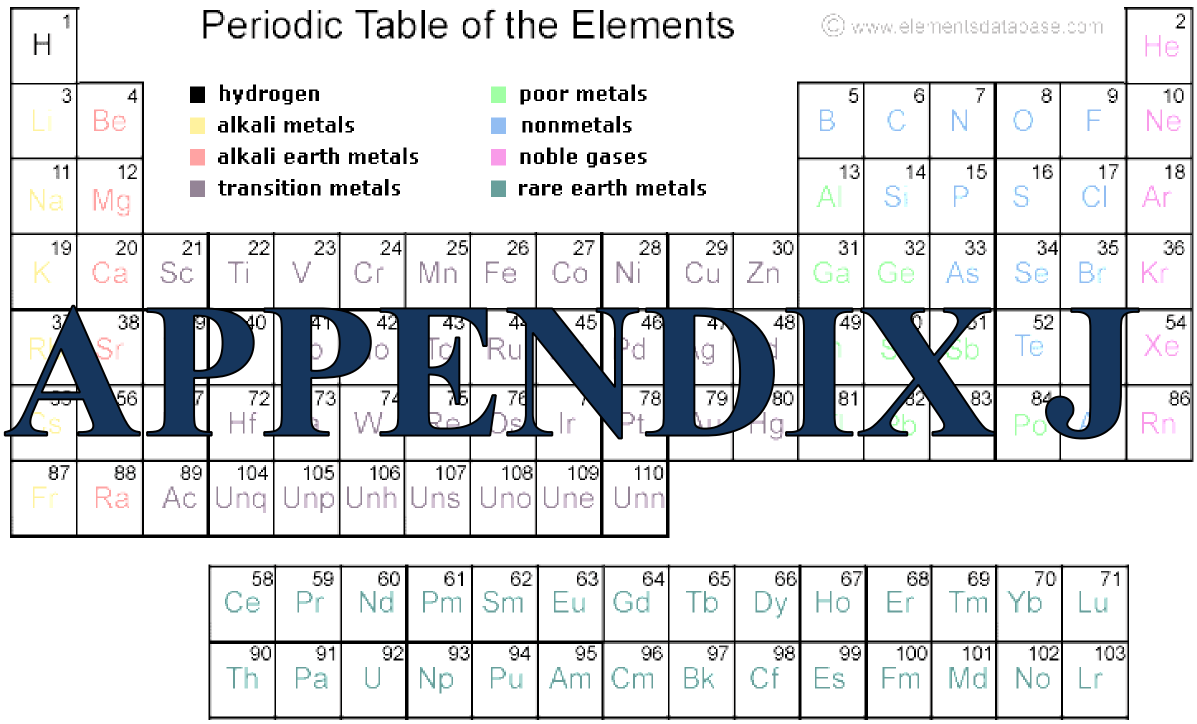




Constructed by Concrete

TOPS
35502

APPENDIX J


Periodic Table of the Elements
© www.elementsdatabase.com
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals

Determining Velocity Coefficent by Average Wind Speed			
	Velocity (MPH)	Velocity (m/s)	Velocity Coefficient Θ
Jan	8.1	3.6207	93.7933
Feb	8.5	3.7995	97.1905
Mar	9.1	4.0677	102.2863
Apr	8.8	3.9336	99.7384
May	7.6	3.3972	89.5468
Jun	6.9	3.0843	83.6017
Jul	6.5	2.9055	80.2045
Aug	6.2	2.7714	77.6566
Sept	6.6	2.9502	81.0538
Oct	7	3.129	84.451
Nov	7.5	3.3525	88.6975
Dec	7.6	3.3972	89.5468

	X_s	X	X_s - X	A	Θ	g_h
Jan	1	0.665	0.335	155	93.7933	4870.217
Feb	1	0.64	0.36	155	97.1905	5423.23
Mar	1	0.635	0.365	155	102.2863	5786.847
Apr	1	0.625	0.375	155	99.7384	5797.295
May	1	0.69	0.31	155	89.5468	4302.724
Jun	1	0.7	0.3	155	83.6017	3887.479
Jul	1	0.73	0.27	155	80.2045	3356.558
Aug	1	0.75	0.25	155	77.6566	3009.193
Sep	1	0.745	0.255	155	81.0538	3203.651
Oct	1	0.715	0.285	155	84.451	3730.623
Nov	1	0.675	0.325	155	88.6975	4468.137
Dec	1	0.67	0.33	155	89.5468	4580.319

	X_s	X	X_s - X	A	Θ	g_h
Jan	1	0.665	0.335	0.21	93.7933	6.598359
Feb	1	0.64	0.36	0.21	97.1905	7.347602
Mar	1	0.635	0.365	0.21	102.2863	7.840245
Apr	1	0.625	0.375	0.21	99.7384	7.854399
May	1	0.69	0.31	0.21	89.5468	5.829497
Jun	1	0.7	0.3	0.21	83.6017	5.266907
Jul	1	0.73	0.27	0.21	80.2045	4.547595
Aug	1	0.75	0.25	0.21	77.6566	4.076972
Sep	1	0.745	0.255	0.21	81.0538	4.340431
Oct	1	0.715	0.285	0.21	84.451	5.054392
Nov	1	0.675	0.325	0.21	88.6975	6.053604
Dec	1	0.67	0.33	0.21	89.5468	6.205593

g_h	Hours/ Month	kg/hr	in^3/hr	in^3 /month
6.598359	720	0.009	0.559	403
7.347602	720	0.010	0.623	448
7.840245	720	0.011	0.664	478
7.854399	720	0.011	0.666	479
5.829497	720	0.008	0.494	356
5.266907	720	0.007	0.446	321
4.547595	720	0.006	0.385	277
4.076972	720	0.006	0.345	249
4.340431	720	0.006	0.368	265
5.054392	720	0.007	0.428	308
6.053604	720	0.008	0.513	369
6.205593	720	0.009	0.526	379
	Averages/ Month	0.008	0.501	361