



**PDHonline Course M268 (4 PDH)**

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# **Siphonic Roof Drainage Calculations**

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# Siphonic Roof Drainage Calculations

*John M. Rattenbury, PE, CIPE, LEEDap*

## Course Content

### Introduction

The main objective of this course is to become familiar with the process of calculating the capacity and performance of siphonic roof drainage systems by selecting pipe diameters and adjusting pipe lengths and other variables using hydraulic analysis methods. The nature of performing these calculations and the multi-variable conditions of siphonic roof drainage design has made the use of computer software the "standard of care" in the industry. Although calculations were originally performed by hand during the onset of this roof drainage technology in the 1960's and 1970's before the availability of the microcomputer, the advent of the desktop computer and of software tailored specifically for siphonic roof drainage design has greatly decreased the time to dimension systems and has also increased the accuracy of design and overall reliability of installed systems. Therefore, this course will center on the use of a downloadable design platform (software) that the course participant can use to evaluate the calculation of sample systems and then retain for the design of systems in actual practice.<sup>1</sup>

Any roof drainage system starts with the layout and geometry of the building's roof, normally done by the structural engineer and the architect before the plumbing engineer becomes involved. The size, shape, pitch, crickets, structure of building roofs can vary greatly so it is not possible for this course to cover every possible contingency. However, some basics will be covered that can be built upon one another to guide a designer in actual practice. The design process will be described here by using examples.

### Background Materials

It is highly recommended that the material available in course M256 "Siphonic Roof Drainage" be obtained and studied prior to engaging in the study of this course. M256 describes in some detail the theory behind the hydraulic calculations, describes the hydraulic equations employed, and discusses some issues related to drainage pipe layout. Some questions in the online quiz may be derived from this reading material. Also, the

American Society of Plumbing Engineers (ASPE) has available for purchase Technical Standard ANSI/ASPE 45 "Siphonic Roof Drainage" which is the basis for standardization in the practice of siphonic roof drainage system design. Review of this Standard is recommended but not required for completing this course.

**Software Basics**

The software<sup>2</sup> to be used in this course can be downloaded from the M268 course web page under the "Course Content" section for installation on your personal computer. The downloadable file is in the form of a ".zip" file. Choose "Save" and select a suitable location on your system. Continue by opening the zip file and following the automated instructions. The instructions given in this course assume the participant is using a Windows operating system.

When the software is installed, first launch the software and become familiar with the basic layout of the user interface in order to follow the procedures that follow in the examples. The software installation process should have placed an icon labeled "Siphonitec" on the computer desktop. Start by double clicking it or finding the software listed in your [Start] menu. The window that opens will be the user interface that looks like Figure 1.

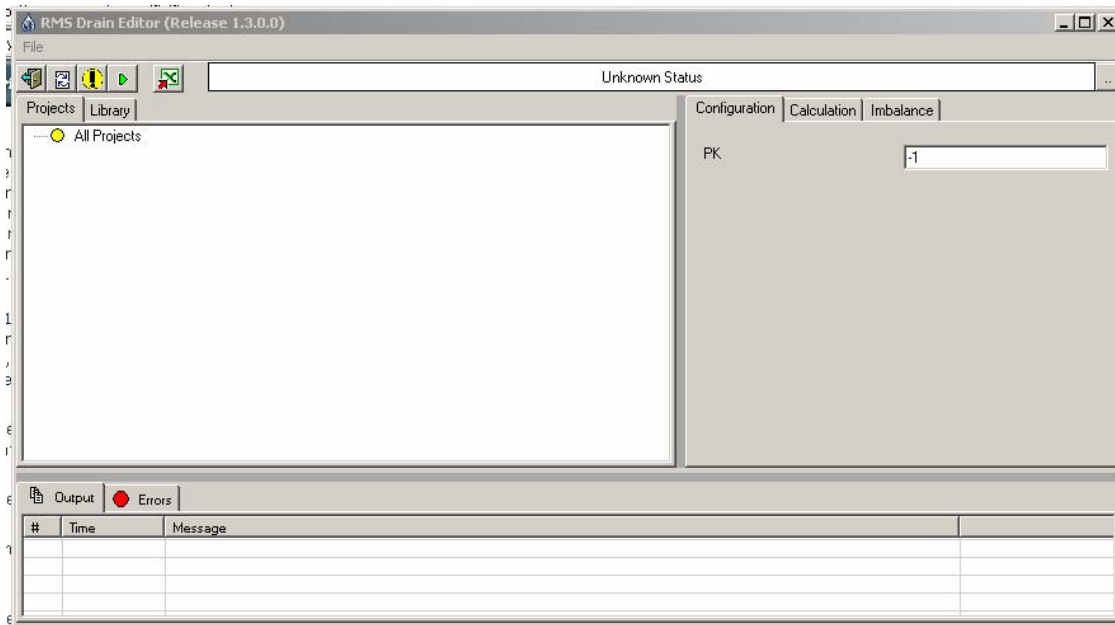


Figure 1: Siphonitec® User Interface at Start-Up

On the left hand side of the window is a white field that will display a tree structure of the system as it is entered by the user. It is a "design view" intended to show the structure of the system with each component including pipes, elbows, junctions,

drains, etc. The tree structure always begins with the [● All Projects] root element shown at the top left of the design view. The tree structure always ends with one or more roof drains. Until a roof drain is inserted into a branch to “cap off” a branch, the system will continue to prompt for subsequent components to the branch until a roof drain is added.

Also part of the left hand side of the window is a tab labeled [Library] next to the default tab labeled [Projects]. By clicking on the [Library] tab, the field will be replaced with another tree representing the library of elements included in the database. It looks like Figure 2.

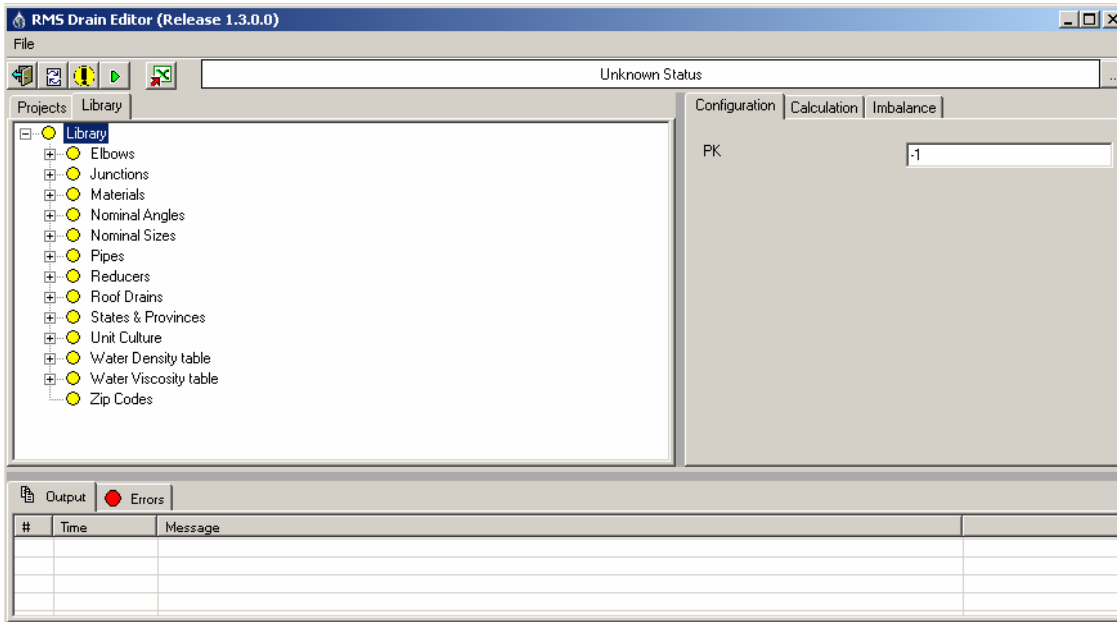


Figure 2: Library Tab

By clicking on one of the sub-headings, the list of elements of that type will appear. By clicking on one of the elements, the properties of that element will appear in the field to the right. Feel free to tour around the library; however it is not necessary to access the Library directly to design systems.<sup>3</sup> Return to the design view by clicking back to the [Projects] tap at the top left.

On the right hand side of the window is a field with three tabs along the top. They are labeled [Configuration], [Calculation], and [Imbalance]. By default, the [Configuration] tab is active. It is within this field that the physical properties of the pipe and other elements will be entered. The [Calculation] and [Imbalance] tabs will be described later.

From this point, the processes by which elements are added to the system tree are described using some examples. But before that, siphonic systems are described.

## An Overview of Siphonic Roof Drainage Systems

All roof drainage systems have three main elements in common beyond the fact that they all use pipes to convey the water. They have:

1. one or more roof drains,
2. a vertical drop from the roof level to some lower level, and,
3. a point of discharge.

This holds true for both conventionally designed systems and siphonic roof drainage systems. Conventionally designed systems use simple "pipe schedule" tables derived from Manning's Formula (Shown as Equation 1). In this equation,  $n$  is the coefficient or roughness,  $R$  is the hydraulic radius, and  $S$  is the pitch or slope of the pipe.

$$V = (1.486/n) R^{2/3} S^{1/2}$$

Equation 1: Manning's Formula for Gravity Flow

Tables in model plumbing codes assume a roughness factor ( $n$ ) based on cast iron pipe (about 0.013). They also apply for horizontal pitched piping with a hydraulic radius equal to about 2/3rds of the pipe full at the design capacity. Such systems always contain air and are essentially always at atmospheric pressure while actively draining, even at the maximum design capacity.<sup>4</sup> Venting of these systems is maintained through the roof drains themselves.

Siphonic systems differ from conventional systems in that they are designed to fill up or "surcharge" and converge on a full-bore state with little or no air and lower-than-atmospheric internal pressures. This is achieved in part by the siphonic roof drain's baffle plate or other device, but the ability to converge on the full bore state depends on adequate pressure balancing between the drains connected to a common manifold and/or stack. This ensures that all drains will prime more or less together in unison to create a "closed path" of water from the drain inlet to the point of discharge to sustain the siphoning condition as long as there is adequate rainfall to sustain the primed condition.

Roof drainage systems are designed to a set rainfall intensity that is assumed to be a constant. However, rainfall is a random event. It varies both spatially and temporally. It never rains at an exact uniform rate over a roof surface. An exact rate is also never sustained over a period of time. Therefore, siphonic roof drains will experience varying quantities of water when it rains. Some rainfall events are very light and last for long periods. In this condition, a siphonic roof drainage system performs like a conventionally designed system. The drain baffles are not primed

and act as simple "holes on the roof" connected to pipes. The pipes are simply water collectors below the roof surface with one end always connected to a vertical stack serving as a point of disposal for the water.

If rainfall increases over time, the water inside the piping experiences a variety of stages of flow with distinctive patterns and internal pressures that ultimately converge upon the full-bore state. Siphonic roof drainage systems are inherently responsive to varying rainfall rates. As the rate increases, the system approaches full-bore. As it decreases, the system de- primes and assumes one of the distinctive flow patterns with a combination of water and some air.

The most common condition these systems operate in is as "conventional" open channel flow since this is by far the most frequently encountered rainfall event (in the North American and European climates, anyway). One or more times a year, rainfall may occur such that the system will prime and de-prime several times anywhere from seconds to a few minutes. Ultimately, systems are designed for the most severe rainfall that is statistically probable to occur during the building's lifetime in the climate it is in. One way of describing siphonic roof drainage systems is they drain as fast as they need to in response to the actual rainfall. This is why they are such efficient piping systems. They use smaller pipe diameters to cater to the same range of rainfall conditions as conventional systems.

As mentioned previously, conventional roof drainage systems can be sized using "pre-engineered" sizing tables (pipe schedules). These are found in model plumbing codes and other State-maintained plumbing codes. This is possible because conventional systems may be sized based on only three parameters; roof area, rainfall intensity and pitch (which includes vertical stack orientation). At a given pipe pitch, a simple table may be constructed using the Manning Formula as the basis of determining pipe sizing thereby eliminating the designer's need to even recognize what Manning's Formula is.

Siphonic roof drainage systems, on the other hand must undergo hydraulic analysis to make sure that the entire system is capable of converging upon the full-bore state at the design rainfall intensity. If it cannot, there is no means of determining the actual rainfall drainage rate of the system. Drains that are not balanced properly may be too restrictive to handle the assigned roof area, or may always ingest air thereby impeding the flow within the connected piping. This analysis includes other parameters beyond roof area and rainfall intensity that must be examined. Among these are pipe length, velocity, resistance values of pipe components (elbows, junctions, reducers, drains, etc.), and the building height (i.e. potential energy available).

It is therefore not feasible to reduce siphonic roof drainage sizing to tables or graphs.

However, just as sizing tables for conventional roof drainage piping eliminate the burden of solving Manning's Formula over and over, design software for siphonic roof drainage systems manages the massive quantity of number crunching while the designer focuses on the overall system performance. This process is demonstrated with some examples to follow.



### Example 1: A Single Drain System

An elementary system consists of a single drain with a single stack to some point of discharge. Refer to Figure 3 for this example:

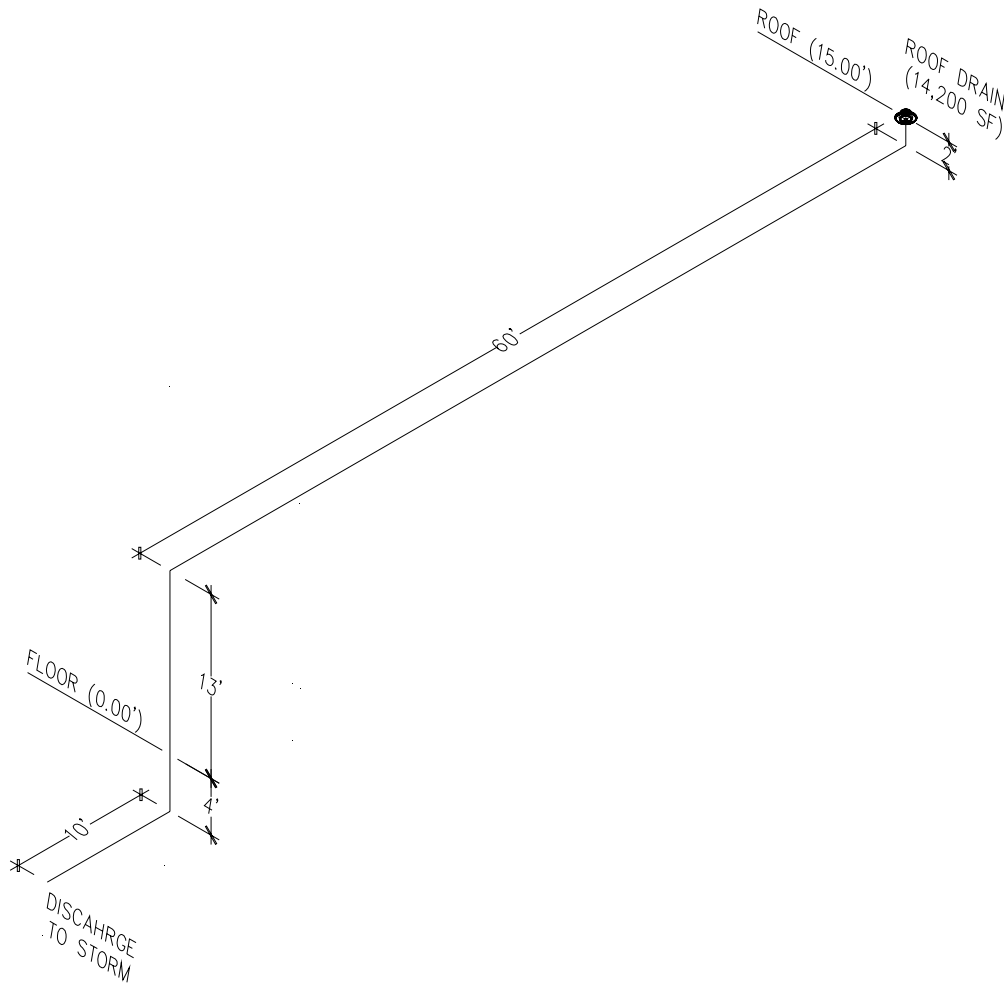


Figure 3: Single Drain System Isometric

In this example, the horizontally projected roof area to the drain is 14,200 square feet. The roof itself is a nominally "flat" roof pitched to the drain at a 2% slope with a single-ply membrane system. The rainfall intensity in this case, normally determined by consulting the local jurisdiction's plumbing code, is 4.0 inches per hour. The drain sets back from the edge of the building wall sixty feet and drops down one story a total of 15 feet. From there it runs ten feet underground before connecting to the site storm drainage system.

Let's assume that the plumbing code would allow the use of PVC DWV piping for interior roof drainage above grade. However, the ceiling space the piping is to be run is also a return air plenum, so a plenum-rated pipe material must be specified. In this case, no-hub cast iron (ASTM A 888) with heavy-duty couplings is selected.

Normally, the pipe configuration (i.e. routing and elevation) given in this example would be determined by the designer. The pipe routing and elevations are established by the best location to discharge out the building (dictated by building- or site-specific criteria), the roof framing structural members, the ceiling height, and coordination with other building elements such as duct-work, sprinkler mains, etc.

After laying out the routing of the piping, it is necessary to set the pipe centerline elevation(s) for the horizontal sections. These dimensions will be entered into the properties of these elements within the software design view tree. In this example, the pipe from the drain drops down vertically and then turns horizontal below the roof deck. The pipe should be set as high as practical or at whatever plane works with the other elements. If ductwork is to be installed in the area, the plane for the ductwork should be determined and the siphonic pipe can be set above or below (preferably not through) it. Also, roof framing members have to be considered.

In this case, the pipe is set above ductwork but below the roof framing joists and results in a centerline elevation of 2 feet below the roof (or 13 feet above the floor). The pipe then drops vertically and then out below grade to connect to the storm drainage system. The depth of the pipe is determined by the invert of the storm drain system that is available, or by a minimum cover to stay below the local frost line or protect the pipe against vehicular loading. In this example, the exterior grade is 12 inches below the interior floor elevation (referenced as 0'-0")<sup>5</sup> and the pipe needs to be 3 feet below grade to be below the frost line. This would put the lower horizontal pipe at -4'-0" elevation.

With these dimensions set, there is almost enough information to start building the system tree using the software. The last piece of information is a "first guess" at the pipe size. There is a useful rule of thumb that can be used in most cases to arrive at this first-order estimate:

1. Refer to the roof drain piping sizing tables of the plumbing code. For example, look at Table 1106.3 of the 2003 International Plumbing Code (IPC) on Page 86 (See Figure 4). To start, the horizontally projected roof area for this system is given as 14,200 square feet.

2. Entering the table at the Rainfall rate (inches per hour) at the 4 column, look down for the roof area listed in that column greater than 14,200. In this case the listing is 20,700 square feet.
3. Read across to the left to determine the required pipe size for a pipe pitched at 1/8 unit vertical in 12 units horizontal (1 percent slope). This comes to 10 inches. This would be the size of a drain pipe for a conventionally sized system.
4. Take the size of 10 inches and cut it in half. This results in a pipe size of 5 inches (if cast iron is used, otherwise the result would be 6 inches for PVC or other materials not available in 5 inch). This is the estimated pipe size for the siphonic system.

**TABLE 1106.3  
SIZE OF HORIZONTAL STORM DRAINAGE PIPING**

SIZE OF HORIZONTAL PIPING (inches)	HORIZONTALLY PROJECTED ROOF AREA (square feet)					
	Rainfall rate (inches per hour)					
	1	2	3	4	5	6
1/8 unit vertical in 12 units horizontal (1-percent slope)						
3	3,288	1,644	1,096	822	657	548
4	7,520	3,760	2,506	1,800	1,504	1,253
5	13,360	6,680	4,453	3,340	2,672	2,227
6	21,400	10,700	7,133	5,350	4,280	3,566
8	46,000	23,000	15,330	11,500	9,200	7,600
10	82,800	41,400	27,600	20,700	16,580	13,800
12	133,200	66,600	44,400	33,300	26,650	22,200
15	218,000	109,000	72,800	59,500	47,600	39,650
1/4 unit vertical in 12 units horizontal (2-percent slope)						
3	4,640	2,320	1,546	1,160	928	773

Figure 4: Pipe Sizing Table  
Courtesy of the International Code Council, Inc.

This so called "rule of thumb" is only a first guess and will need to be adjusted depending on the design conditions as will be seen during the calculation phase. However, for most of the time, it provides fairly good results for a first order estimate.\*

In this single drain example, another item to be evaluated is the size of the drain itself. Whether or not a roof drainage system is sized and pitched conventionally or engineered siphonically, the only important design criterion is the depth of water developed on a roof over a period of time. This is something missing from the design guidelines of today's model codes. This depth is a property of the physical geometry of roof drains and the geometry of the roof itself.

\* As a cautionary note: This simple rule of thumb is by itself not adequate to properly size siphonic roof drainage systems as the following hydraulic calculations will show.

Both conventional and siphonic roof drains have characteristic depth versus flow profiles that are determined predominantly by their rim diameters and also by the presence of strainers, sump depths and other physical parameters. The depth versus flow for a sample siphonic roof drain is shown in Figure 5:

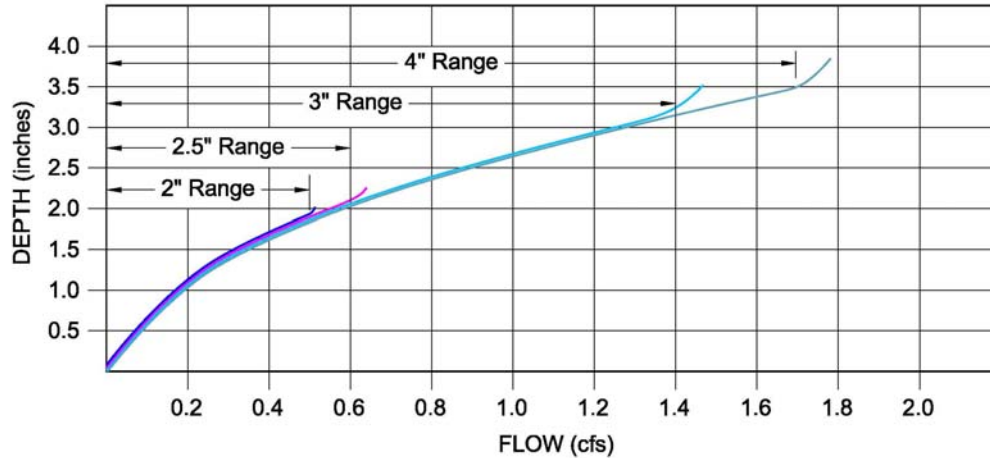


Figure 5: Depth vs. Flow of a Siphonic Roof Drain<sup>6</sup>

The profile above represents the depth at the steady-state flow (that is after the characteristic time of concentration has elapsed). The only variable missing is that time of concentration. In other words, if a roof is to be loaded by rain water, a certain period of time must elapse where the difference between the water drained off the roof and the water accumulated on the roof results in a steady-state distributed volume of water on that roof. In other words, a period of time must pass during a rainfall event when a single rain drop introduced on the roof results in an equal volume of water discharged into the roof drain(s). This period of time is generally the definition of the "time of concentration" described by civil engineers.

For roofs with shallow pitch (i.e. 2 percent), the time of concentration may be several minutes or longer. This is apparently the rationale used to determine the rainfall design criteria in plumbing codes, which is usually for a 100-year storm of a 60-minute duration. The rainfall intensity given for such a storm is a statistical average or, put another way, the amount of rain that would accumulate over an hour. Of course, any real storm will vary in intensity during that hour, but a nominally flat roof can retain the short duration peaks because the time of concentration is several minutes.

The selection of a roof drain must assume that the time of concentration has been reached during the design storm event and therefore capable of handling the resulting steady-state flow

(i.e. worst design case) without exceeding the roof loading capacity. Therefore, the depth versus flow profile for the drain should be considered when selecting either the drain size or the quantity of drains needed for a particular roof area and time of concentration.

In this example, the design rainfall intensity is 4.0 inches per hour over 14,200 square feet. This calculates to a design flow of 1.31 cubic feet per second. As mentioned earlier, the overflow scupper is set at a height of 4 inches above the primary roof drain to ensure that the roof deck is never overloaded. In order to avoid unnecessary scupper discharge, the depth of water developed on the roof at the design storm event should stay below 4 inches. Assuming we are using the data from Figure 5 above for the product to be specified, we can see that a 3 inch drain indicated by the cyan "3 inch Range" curve would be appropriate as an initial guess. At a flow of 1.3 cfs, the depth is 3 inches.

For a single drain system with a properly sized secondary overflow, adding extra capacity to the drain isn't absolutely necessary.<sup>7</sup>

In summary, the basics of the system have been set up. The estimated horizontal pipe size has been determined to be 5 inches using cast iron no-hub pipe. The drain size on the roof has been initially selected to be 3 inch. Therefore, a 3 inch pipe will connect to the drain outlet and then transition to 5 inch in the horizontal. At this point it is possible to go to the software and "build" the system tree to do the necessary calculations.

The course participant may find that the following steps seem time consuming, particularly for a single-drain calculation. However, with experience, calculations can be achieved quite rapidly.

Open the Siphonitec Software. It should appear as it does in Figure 1 shown previously. Right-click on the [● All Projects] root element and select <New> from the menu that appears. The user interface should now look like Figure 6:

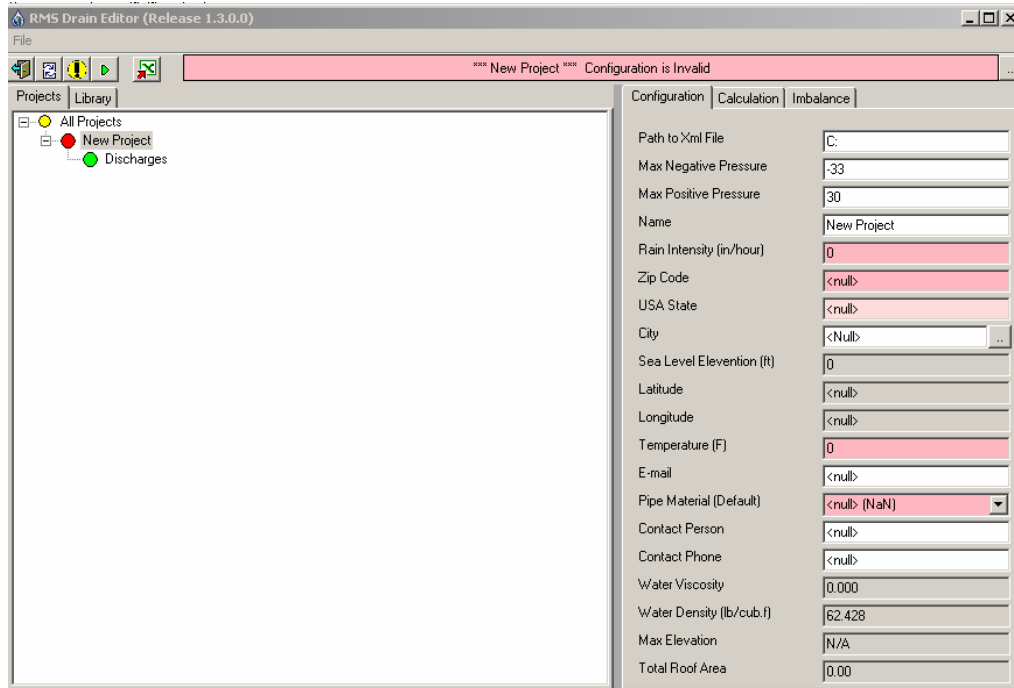


Figure 6: User Interface with New Project Inserted

A new [● New Project] heading will appear in the tree followed by a [● Discharges] sub-heading. To the right under the [Configuration] are several headings and text fields, many of them in red. This display is the project information to be entered as described below.

#### Path to Xml File

This field will show the path and file name for the project file once it is saved. It is inserted by the computer. For now, leave it as is.

#### Max Positive/Negative Pressure

These next two fields identify the maximum negative pressure and maximum positive negative pressure. The default negative pressure is -33 feet of water column. If internal static pressure were to be allowed to go below this value, the system may go into cavitation. The default value should be used. The maximum positive pressure is more a function of what the piping system can withstand. The worst case is typically the cast iron coupling rating. The heavy duty couplings are rated for up to 30 feet of water column, which is the default value appearing in this field.

#### Name

The first item needing entry is the project name. Beside "Name" type in "PDH Example 1" and click on the Zip Code field below.

You should now see the name inserted to the left in the design view tree beside the red dot (i.e. [● PDH Example 1]).

### Rain Intensity

This field is for the design rainfall intensity. It can be provided automatically by typing in the project's Zip Code (see below). If it is not available from the Zip Code database, the designer simply types in the value.

### Zip Code

This particular software package has a feature whereby the user can enter the Zip Code of the project location and the other information will be filled in automatically. For this example erase the <null> text and type in 02210 into the Zip Code field and press Tab or click to any other text field. You should see Boston, Massachusetts displayed in the respective fields below as well as the latitude and longitude. The purpose of this is to use the latitude and longitude to determine the rainfall intensity required for design in that jurisdiction. The software database is apparently not yet complete, so the Rain Intensity (in/hour) field still says zero. Just type in 4 in the Rain Intensity field and press Tab to continue.

### Temperature

Next, the user has the option to select the water temperature. This parameter relates to the value of water's viscosity, which is a function of temperature. Since rain is typically cold and water viscosity increases with decreasing temperature, the worst case is to select a low temperature. Fifty (50) degrees is usually appropriate, so type 50 in the Temperature field and press Tab to continue.

### Pipe Material (Default)

This field indicates to the software the default pipe material to be used. In this example, the material chosen is cast iron. Pull down the list by clicking on the down arrow to the right of the text field. Select "Cast Iron, Aged." This not only determines the pipe material for the computer to enter the database when entering components, but also assigns the pipe material absolute roughness value for the friction loss calculations.

The remaining fields are optional and relate only to the hard-copy printout of the calculations. They can be left as <null> for the purpose of this exercise.

At this point, select <File> at the top left of the interface and then <Save Project>. A Windows standard "Save As" screen will appear. The software will save the project as an ".xml" file in a

directory specified by the user. For this example, just stay with "Local Disk (C:)" and type in "PDH Example 1" as the File Name and click [Save].<sup>†</sup>

Now, right-click on the green [● Discharges] sub-heading in the design view. Select <New> from the menu that appears. A "New Discharge" heading will appear preceded by an icon that looks a bit like a pipe discharging into a basin. This heading identifies a point of discharge from a building. A building may have only one discharge or it may have several. For multi-discharge projects, each discharge can be added to the tree. The user interface should now look like Figure 7 below:

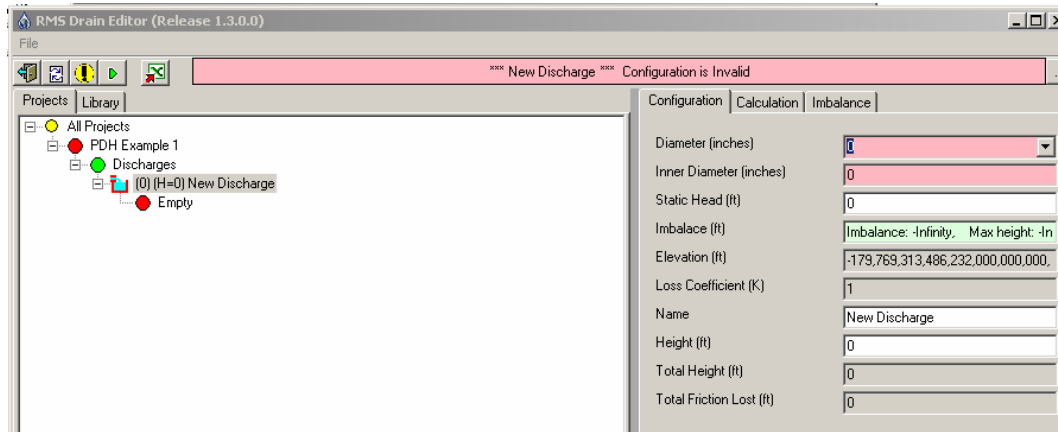


Figure 7: New Discharge Inserted

The top red/pink bar should say "\*\*\*New Discharge\*\*\* Configuration is Invalid." This status bar provides a visual guide to the status of the system configuration and the results of the calculations. At this stage it is red and says "Invalid" because the system tree has not been completed.

To the right under the [Configuration] tab are several fields representing properties of this point of discharge.

#### Nominal Diameter & Inner Diameter

First is the nominal discharge size or "Diameter." In this example, the first-order pipe size estimate is 5 inch. Pull down the list box by clicking on the down arrow to the right of the text field and a list of nominal sizes should appear. Select 5 inch from the list. The next field below is the actual inner diameter. For cast iron pipe, this value is 4.94 inches. Type in this value in the text field and press Tab to continue. The

<sup>†</sup> Feel free to save the file in any appropriate directory. However, just remember where it was saved.



nominal diameter will also appear in the design view tree next to the discharge icon.

### Static Head

The next property is "Static Head." This property has nothing to do with the height of the building or the water around the roof drain. This property allows the designer to account for the possibility that the discharge pipe may become submerged during a storm event. This might occur if the downstream storm sewer system becomes surcharged during a heavy rainfall. If this happens, the discharge would then be flowing against a static head of water instead of atmospheric pressure. This would reduce by some percentage the drainage capacity of the siphonic system. To ensure the system maintains the intended minimum design capacity, the static head can be entered in this field. The default value is zero (i.e. atmospheric). In this example, the discharge pipe is three feet below grade. The discharge then ties into a larger drainage pipe and into a catch basin at a rim elevation of -1.50 feet.

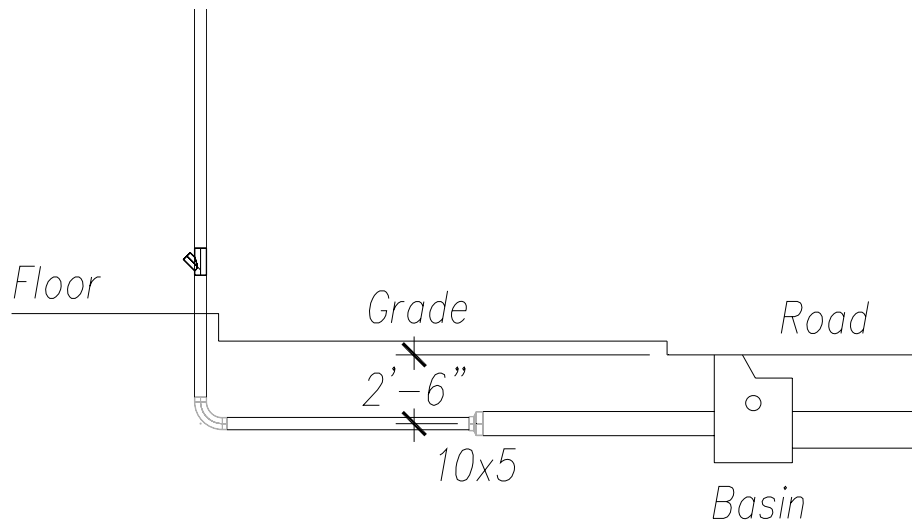


Figure 8: System Discharge to Storm Drain System

The static head value to be entered is the difference between the discharge elevation and the highest point at which water can surcharge. In this case, it is the difference between -4.00 feet and -1.50 feet or 2.50 feet (a positive number) as shown in Figure 8 above.† Enter 2.5 in the "Static head" field and press Tab to continue.

† Figure 8 is only an example of one way in which a siphonic system is connected to a storm drainage system. This diagram should not be interpreted as the only method or as representing every possible situation encountered. The important criterion in connecting the system is ensuring the storm drain system is properly vented through a perforated manhole or catch basin grate to release air.

### Imbalance

This property is the overall imbalance of the connected drains served by this discharge. It is a calculated value provided by the computer. Initially it may say "-Infinity, Max height..." Leave this field as is.

### Elevation

This property shows the elevation of the drains. It is also a calculated value provided by the computer. Initially it may show a large negative value in the field. Leave this field as is.

### Name

Each discharge point can be provided with a name to identify its location for reference. It is an open-text field that can take on any name provided by the designer. It might be most convenient to identify the discharge location relative to a column grid for the building. It might be named after an ordinal point (e.g. Northwest). It might be any other name useful to the designer.

For this example, highlight and erase "New Discharge" and enter "Discharge 1" and click Tab to continue. The discharge name will also appear in the design view tree.

### Height

This field is where the centerline elevation of the discharge is entered. This elevation was determined previously to be -4.00 feet (with the building first floor elevation referenced to 0.00 feet). This height will also appear in the design view tree.

The remaining two fields are displayed results provided by the computer calculations.

### Entering Components:

With the project and discharge parameters entered, the piping components are entered next. The components are added from the discharge point working back into the building and terminating at the drain.

The first component connected to the discharge is a pipe equal in diameter to the specified discharge diameter (5 inch). Right click on the [● Empty] heading at the end of the design view tree and select Replace> Pipe> Horizontal> from the series of menus

that appear.<sup>§</sup> Ahead of the [● Empty] heading will appear an icon representing a horizontal pipe segment with the same nominal diameter and the name "New Pipe." To the right under the [Configuration] tab appear property field of this pipe component.

#### Name

Each component can be assigned a unique name for further reference back to the drawings if desired. Otherwise, the default name can remain.

#### Library Element

The software refers to the database Library for the closest appropriate pipe available. In this example, the (5) A888 element is selected automatically. The (5) indicates the nominal size and the A888 nomenclature refers to the pipe ASTM specification number, in this instance no-hub cast iron drainage pipe and fittings.

#### Material

This heading is somewhat redundant. It repeats the default pipe material selected at the Project level. However, the designer is allowed to transition from one pipe material to another as needed. In this example, keep the "Cast Iron, Aged" entry.

#### Height

The height is, again, the centerline elevation of the pipe, which is still -4.00 feet. Enter -4 in this field and press Tab to continue.

#### Length

This is simply the length of the pipe. According to Figure X, the pipe makes a horizontal run of 10 feet. Enter 10 feet in this field and press Tab to continue.

The design view tree should now look as follows:

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<sup>§</sup> If you mistakenly select some other type of element, simply right click on the unintended element and select Replace> Pipe> Horizontal> and the element will be replaced with the pipe. If you mistakenly chose a vertical pipe orientation, right click on the pipe and select Pipe Orientation> Horizontal to correct it.

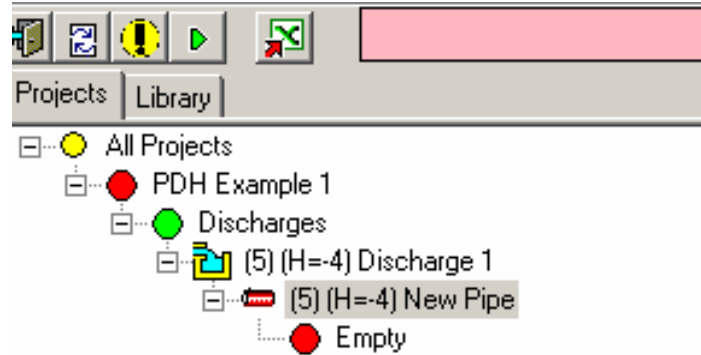


Figure 9: Design Tree

The next component in the system is the elbow at the base of the stack. Right click on the [● Empty] heading at the end of the design view tree and select Replace> Elbow> from the series of menus that appear. Ahead of the [● Empty] heading will appear an icon representing a pipe elbow with the same nominal diameter and the downstream pipe previously entered with the name "New Elbow." To the right under the [Configuration] tab appear property fields of this component.

#### Library Element

The software refers to the database Library for the closest appropriate elbow available. In this example, the 5 (45) A888 E8 element is selected automatically. The 5 indicates the nominal size, the (45) and E8 indicate the elbow bend in degrees (or eighth bend) and the A888 nomenclature refers to the elbow ASTM specification number, in this instance no-hub cast iron drainage pipe and fittings.

In this example, the elbow actually needs to be a 90 degree long sweep to transition the vertical stack to the horizontal underground pipe. Click on the down arrow to the right of the field and select the "5 (90) A888 LSE" from the list. The "LSE" stands for long sweep elbow.<sup>8</sup>

#### Diameter

This diameter property is provided by the database as an inherited property of the previously inserted element.

#### Loss Coefficient

This value is provided by the database as a property of the elbow selected. This value determines the friction loss through the elbow as a function of velocity head.

### Name

Each component can be assigned a unique name for further reference back to the drawings if desired. Otherwise, the default name can remain.

### Height

This value is an inherited property from the downstream component - in this case the previous horizontal pipe elevation.

### Total Height

This is a calculated value.

### Material

This is the inherited material property.

### Total Friction Loss

This is a calculated value.

This completes the entry of the elbow. Further descriptions of component entry are abbreviated as typical to those described above until a new component type is encountered.

The next component is the vertical stack. Right click on the [● Empty] heading at the end of the design view tree and select Replace> Pipe> Vertical> from the series of menus that appear. Ahead of the [● Empty] heading will appear an icon representing a vertical pipe segment with the inherited nominal diameter and the name "New Pipe." To the right under the [Configuration] tab appear property field of this pipe component.

### Height In

This is the elevation of the top of the stack. From Figure 3, this value is 13 feet. Type in 13 and press Tab to continue.\*\*

### Height Out

This is the elevation of the bottom of the stack. The value of -4 is inherited from the downstream elbow.

---

\*\* The only way to properly change pipe elevation in the tree is with a vertical pipe or a sloped pipe element. If the height property of a horizontal pipe, elbow, reducer, etc. is altered, the elevation of each connected element is also revised to that height. Therefore, keep an eye on the elevations shown on the tree to make sure they are not altered inadvertently.

### Height Diff

This is the overall physical length of the pipe and is calculated automatically when both the In and Out heights are entered.

This completes the entry of the vertical stack component.

The next element is an elbow to transition from the horizontal overhead pipe to the vertical stack. Right click on the [● Empty] heading at the end of the design view tree and select Replace> Elbow> from the series of menus that appear. Ahead of the [● Empty] heading will appear an icon representing a pipe elbow with the same nominal diameter and the downstream pipe previously entered with the name "New Elbow." To the right under the [Configuration] tab appear property field of this component.

Under Library Element, select "5 (90) A888 E4" to insert a standard radius elbow.<sup>9</sup> The remaining properties are inherited or entered by the database Library.

The next element is a run of horizontal pipe at a centerline elevation of 13 feet above the floor. According to Figure 3, the length of run is 60 feet. Right click on the [● Empty] heading at the end of the design view tree and select Replace> Pipe> Horizontal> from the series of menus that appear. Ahead of the [● Empty] heading will appear an icon representing a horizontal pipe segment with the same nominal diameter and the name "New Pipe." To the right under the [Configuration] tab appear property field of this pipe component.

Apparently this version of the software does not cause new horizontal pipes to inherit the elevation of the previous component. Enter 13 feet and press Tab to continue. For the length, enter 60 and press Tab.

As mentioned before, the 3 inch roof drain will increase from the 3 inch connecting pipe to the 5 inch horizontal. Right click on the [● Empty] heading at the end of the design view tree and select Replace> Reducer> from the series of menus that appear. Ahead of the [● Empty] heading will appear an icon representing a reducer with the same nominal diameter and the name "New Reducer." To the right under the [Configuration] tab appear property field of this pipe component.

The component selected by the Library in this case (5x6 A888) is not the one needed. A 5x3 reducer is needed. Select the 5x3 A888 from the pull down list by scrolling down until found. The remaining properties are inherited.

The next component is a 3 inch long sweep elbow to transition up to the roof drain. Right click on the [● Empty] heading at the

end of the design view tree and select Replace> Elbow> from the series of menus that appear. Ahead of the [● Empty] heading will appear an icon representing a pipe elbow with the same nominal diameter and the downstream reducer previously entered with the name "New Elbow." To the right under the [Configuration] tab appear property fields of this component. Select the "3 (90) A888 LSE" from the pull down list. The remaining properties are inherited.

The next component is a 3 inch vertical pipe to the roof drain. Right click on the [● Empty] heading at the end of the design view tree and select Replace> Pipe> Vertical> from the series of menus that appear. Ahead of the [● Empty] heading will appear an icon representing a vertical pipe segment with the inherited nominal diameter and the name "New Pipe." To the right under the [Configuration] tab appear property field of this pipe component.

Enter 15 as the "Height In" value and press Tab to continue. The remaining properties are inherited or calculated.

The last component of the system is the roof drain itself. Right click on the [● Empty] heading at the end of the design view tree and select Replace> Roof Drain> from the series of menus that appear. The [● Empty] heading will disappear and an icon representing a roof drain with an unspecified nominal diameter will be entered with the name "New Roof Drain." To the right under the [Configuration] tab appear property field of this component.

The reason why the Library did not look up a proper drain size is apparently due to the difference in inner diameters of the available drains in the database and the inner diameter of the connecting pipe. This is remedied with a set of "adaptors" in the Library to account for this slight difference. The following steps will demonstrate how an element is inserted into the tree.

Right click on the roof drain element and select Insert Before > Reducer> from the menus that appear. A reducer icon appears between the drain and the connecting pipe. Go to the Library pull down box and scroll down to the "3x3.1 1005T Adaptor."<sup>††</sup>

Next go back to the roof drain by clicking on it. From the Library, select the 3.1 JRS 1005T roof drain. In the Area field, enter 14200 as the square footage and press Tab to continue. The resulting design view tree should appear as follows:

---

<sup>††</sup> This element is not an actual fitting installed in the system. The cast iron pipe butted up to the drain spigot forms this step-wise reduction in the inner diameter. The "adaptor" element accounts for this difference and provides a calculated resistance coefficient.

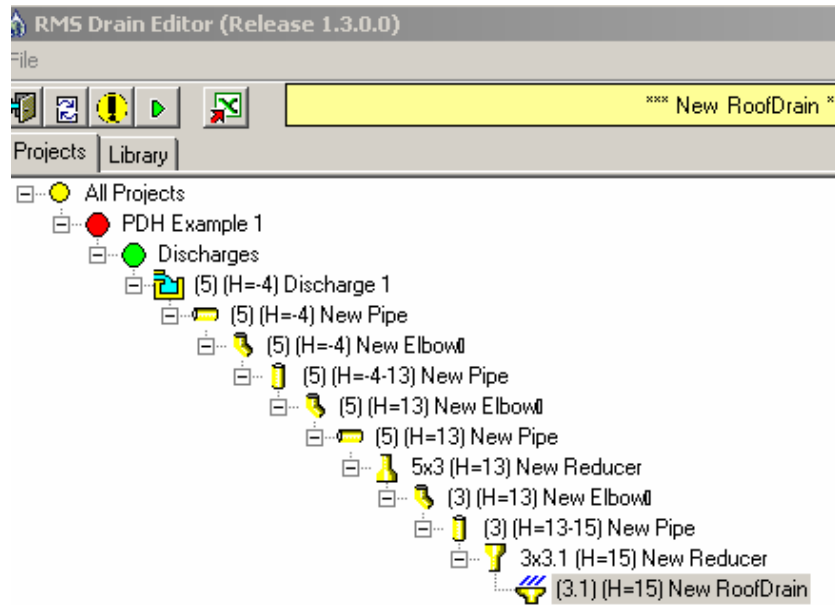



Figure 10: Completed System Tree in Design View

Notice that all of the component's icons appear yellow and the status bar at the top appears yellow. The bar should say "Configuration is Valid." This indicates that there is a proper continuity from component to component meaning that a 3 inch pipe is not connected to a 5 inch elbow without including a proper reducer element.

#### Executing the Calculation

To calculate the resulting residual head and imbalance as well as the flow, velocity, and pressures, click on the icon at the top

with the green arrow .## The software will pause for a second and the component's icons should all appear green, indicating that calculations are complete without error. To view the results of the first guess at pipe sizing, first click on the [Imbalance] tab to the right. A grid will appear looking like Figure 11:

## Before clicking the calculation button, make sure any one of the tree elements is highlighted (selected). If not, nothing will happen.



Name	Library ...	Area (sq.f)	Height (ft)	Total E...	Residua...	Diamete...	Friction...	Exit Vel...	Min/Max
1 New Ro...	3.1 JRS...	14,200	15	18.576	-2.076	3.100	17.060	1.516	min/max

Figure 11: Imbalance Tab Calculation Summary

Although the calculations are complete, the resulting “Residual Head” value is a negative number (-2.076 feet w.c.). This indicates that the flow rate needed to provide the drainage capacity requires more energy than is available by a little over 2 feet.<sup>§§</sup> The remedy is to find some way to reduce the overall resistance of the piping system so the capacity can be reached with the energy available.

One means of reducing the resistance is to reduce the horizontal run of the underground pipe from 10 feet to some shorter length (say, 5 feet). Click on the first horizontal pipe of the tree and change the Length property from 10 to 5. Then click on the Calculate icon again to update the results. The resulting Residual Head is -1.630 feet. This is a reduction, but not quite enough.

Another means to further increase the capacity (i.e. reduce resistance), is to upsize the underground discharge pipe by a pipe size. This has a two-pronged effect. First, the large pipe diameter has a lower loss per linear foot. Second, the velocity head is reduced at the discharge thereby gaining it back into the energy available to the system.

To do this, go back to the [Configuration] tab and then highlight the Discharge 1 in the design view tree. In the properties, change the 5 to a 6 and the inner diameter from 4.94 to 5.94. The other properties remain the same. Then press Tab to continue.

Notice how the upstream connected pipe appears red. This happened because the software is seeing a discrepancy in connecting diameters (a 5 to a 6 inch). Now, right click on the pipe element and select Insert (Before)> Pipe> Horizontal. This inserts a pipe segment between the Discharge element and the 5 inch pipe. Go to the pipe properties and enter the Height at -4 feet and a length of 5 feet.

The tree should now appear as follows:

<sup>§§</sup> Refer to Course M256 “Siphonic Roof Drainage” Course Content for a more detailed explanation of both Residual Head and Imbalance.

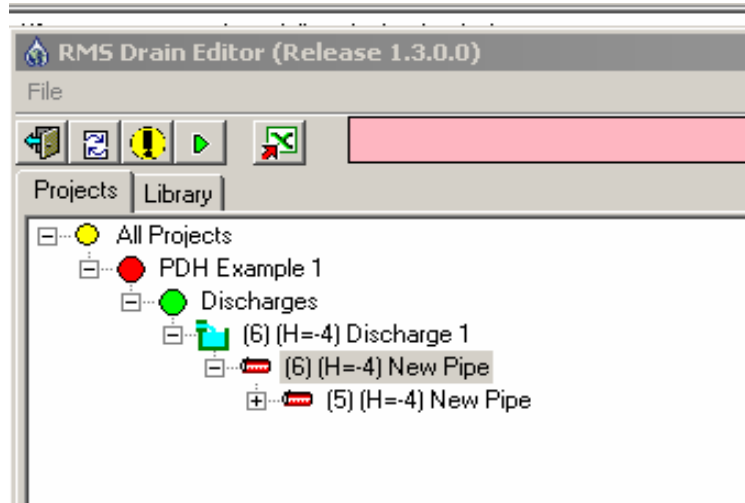


Figure 12:

Note that the design view tree tends to "collapse" down to the nearest element. To make the tree expand out again, simply double click on the [+] sign next to that element.

The new 6 inch pipe and the 5 inch pipe are still red. To correct this, right click on the 5 inch pipe and select Insert (Before)> Reducer. Select a 6x5 A888 from the Library.

The tree should now appear as follows:

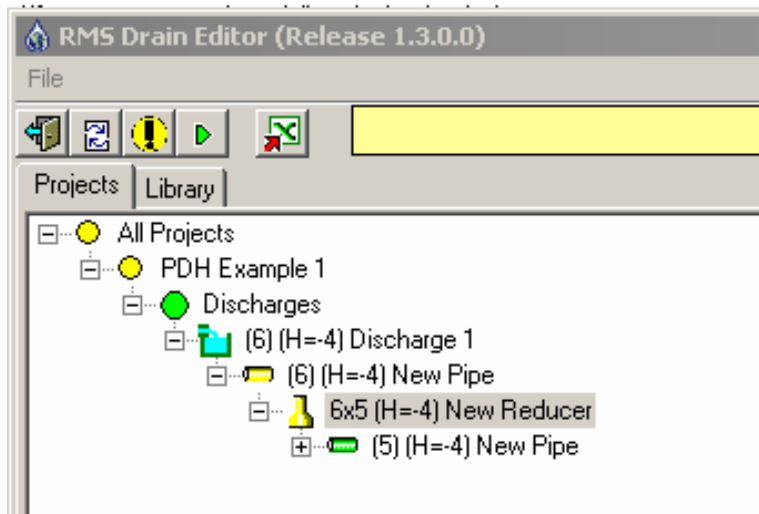


Figure 13:

The newly inserted elements appear yellow indicating a valid configuration but they have not yet been included in hydraulic calculations so they are not green. Now click on the Calculation icon to update the results and go to the [Imbalance] tab. The imbalance should now say -1.421. Again, some progress, but still not enough.

Click on any one of the 5 inch components (like the overhead run at 13 feet above the floor) and then click on the [Calculation] tab to the right (not the execute calculation button at the top). Read from the list of calculated values the Velocity in the pipe which is 9.878 feet per second. This is a fairly reasonable velocity.

Now click on the 3 inch pipe before the roof drain. The velocity here is quite high at 27.514 feet per second. The Friction Energy Lost is also 2.619 feet.

An apparent remedy available is to upsize the drain and 3 inch piping to 4 inch. Go back to the [Configuration] tab and then select the 5x3 reducer. From the Library, locate the 5x4 A888 reducer. Click on the 3 inch elbow and select the 4 (90) A888 E4 from the Library. Do likewise with the vertical pipe and the roof drain.

Now recalculate the system and return to the [Imbalance] tab. The resulting Residual Head is positive 3.91 feet. This means that the system has an excess of energy available to meet the required flow.

To see what the system's actually drain capacity would be with this piping configuration, go back to the PDH Example 1 project heading of the design view tree and click on the [Configuration] tab. Enter in the "Rain Intensity" field the value 4.583 (this was determined by trial and error). Highlight any of the tree elements and recalculate the system. Return to the [Imbalance] tab. The resulting "Residual Head" is 0.005, or essentially zero. This means that the actual system's capacity is about 4.6 inches per hour which is above the minimum requirement by Code of 4.0 inches per hour by about 15%.

For a quality assurance check, click on the 5 inch elbow at the top of the stack and then go to the [Calculation] tab. The Pressure In and Pressure Out values are -11.566 and -11.828 respectively. This shows the siphonic condition of having a negative static pressure in the full primed system. It is always prudent to check these values to make sure the minimum allowable pressure is not exceeded.

Another quality assurance check is to click on the roof drain element and go to the [Calculation] tab. The calculated flow rate at the adjusted rainfall intensity (4.6 in/hr) is 1.506 cfs. The

software should alert the designer if the drain's maximum capacity is not exceeded as documented in Figure 5. At a flow of 1.5 cfs, the drain's maximum listed capacity of 1.7 is not exceeded and the depth ahead of the drain at that flow and time of concentration is 3.3 inches. That is still below the secondary overflow height set for the roof deck.

At the top of the user interface, go to File> Save Project> and then save the file again. The software will ask if the previously saved file is to be replaced. Select Yes.

This completes the sizing and calculation of the single drain system. The next step for the designer is to transfer this information back to the drawings to communicate it to the installing contractor.

### Example 2: A Two Drain System

This example is similar to and builds upon Example 1. The difference is that two roof drains are provided on the roof instead of one and the drainage areas have been divided equally between them. These drains are labeled A and B. Refer to Figure 14 for this example:

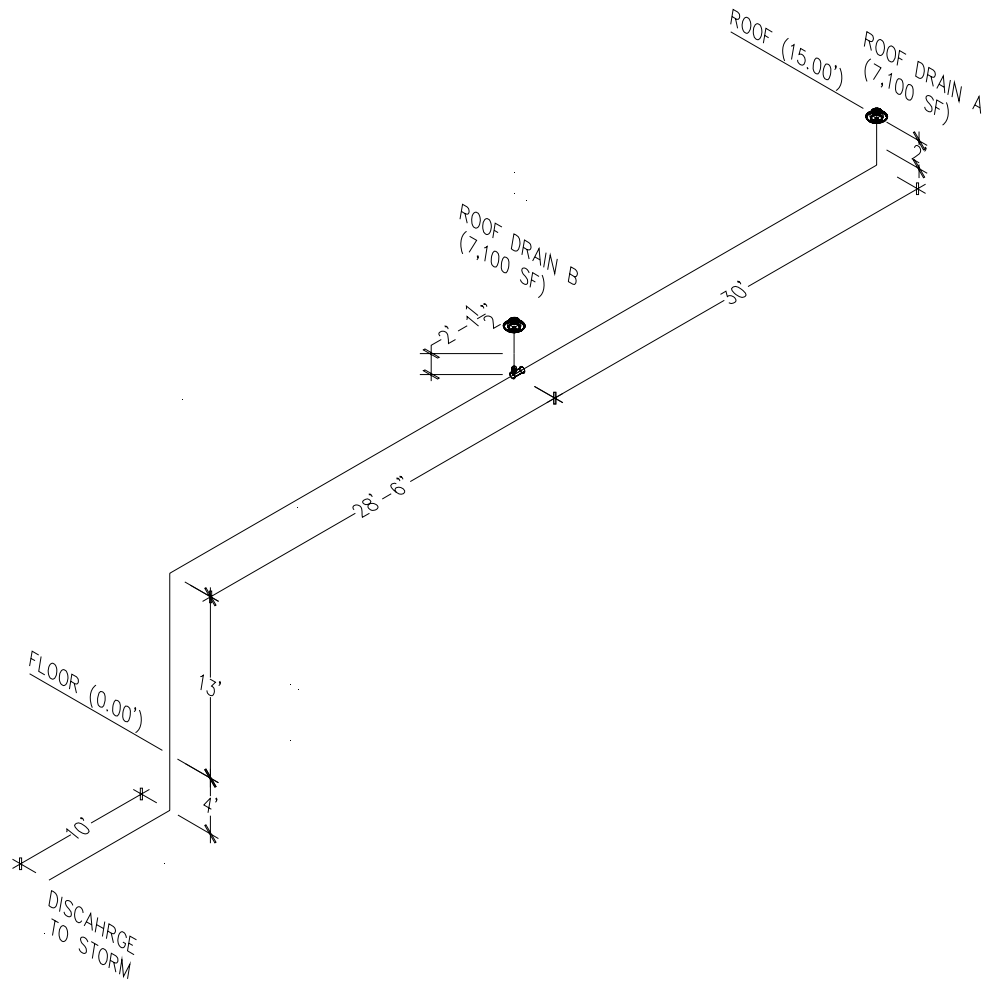


Figure 14: Two Drain System Isometric

In this example, the horizontally projected roof area to each drain is 7,100 square feet for a total drainage area of 14,200 square feet as in Example 1. The roof itself is a nominally "flat" roof pitched to the drain at a 2% slope with a single-ply membrane system. The rainfall intensity is still 4.0 inches per hour. Drain A sets back from the edge of the building wall sixty feet and Drain B is set back 30 feet. The tie together into a single manifold that then drops down one story a total of 15

feet. From there it runs ten feet underground before connecting to the site storm drainage system.

The instructions to follow assume the course participant has completed Example 1 and is familiar with most of the mechanics of entering in pipe and fitting elements into the software design view tree and navigating around the user interface. The course participant should complete Example 1 before proceeding with this example.

As done previously for Example 1, the main pipe sizing and drain sizes need to be selected as a first guess. Since the roof surface area and rain intensity are the same as Example 1, the sizing of the stack and the manifold remain as 5 inch for now. However, the 30 foot section from the junction out to Drain A needs to be estimated.

Going by the sizing table in Figure 4 again, the required pipe size for a conventional system for 4 inches per hour and 7,100 square feet is 8 inches. Using the rule of thumb estimate, the siphonic pipe size would be 4 inch.

The flow to each drain will be divided equally (equal areas). The total flow for Example 1 was 1.31 cubic feet per second (cfs). In this example, Drains A and B will each receive 0.655 cfs. Consulting the chart in Figure 5, it is evident that this flow is just beyond the capacity of a 2 ½" drain size (the pink 2.5" Range curve). Therefore, a 3 inch drain should be selected. At this flow, the developed depth after the time of concentration has elapsed is about 2.2 inches.<sup>10</sup>

With this basic information obtained, open a new session of the Siphonitec® software. Go to <File> and then <Load Project>. A standard Windows "Open" dialogue box will appear. Navigate through the directory and find the "PDH Exercises" file previously saved during Example 1.

Right click on [● All Projects] and select <New> from the menu that appears. A [● New Project] heading will appear below the [● PDH Example 1] heading with a new [● Discharges] sub-heading.

Highlight the "New Project" heading and go to the [Configuration] tab to the right. Enter properties as follows:

Name: PDH Example 2  
Rain Intensity: 4  
Zip Code: 02210  
  
Temperature: 50  
  
Pipe Material: Cast Iron, Aged

Save the file by selecting <File> then <Save Project>

Right click on [**Discharges**] and select <New> from the menu that appears. A "New Discharge" icon will appear. The pipe sizing assumed for Example 1 stays the same at first. Going by what was covered for entering pipe elements into the design view tree from Example 1 proceed as follows:

Highlight the "New Discharge" heading and go to the [Configuration] tab to the right. Enter properties as follows:

Diameter: 5  
Inner Diameter: 4.94  
Static Head: 2.5

Name: Discharge 2  
Height: -4

Right click on the [**Empty**] heading and select Replace> Pipe> Horizontal. Enter properties as follows:

Height: -4  
Length: 10

Right click on the [**Empty**] heading and select Replace> Elbow. Revise as follows:

Library Element: 5 (90) A888 LSE

Right click on the [**Empty**] heading and select Replace> Pipe> Vertical. Enter properties as follows:

Height In: 13

Right click on the [**Empty**] heading and select Replace> Elbow. Revise as follows:

Library Element: 5 (90) A888 E4

Right click on the [**Empty**] heading and select Replace> Pipe> Horizontal. Enter properties as follows:

Height: 13  
Length: 28.5

At this point, the pipe elements up to the Junction have been entered. The Junction is the next element that allows the design view tree to branch off to Drain B and then continue on to Drain A. Since this element was not introduced in Example 1, a more detailed description follows:

Right click on the [● Empty] heading and select Replace> Junction. An icon will appear that resembles a pipe lateral wye. It should look as shown in Figure 15:

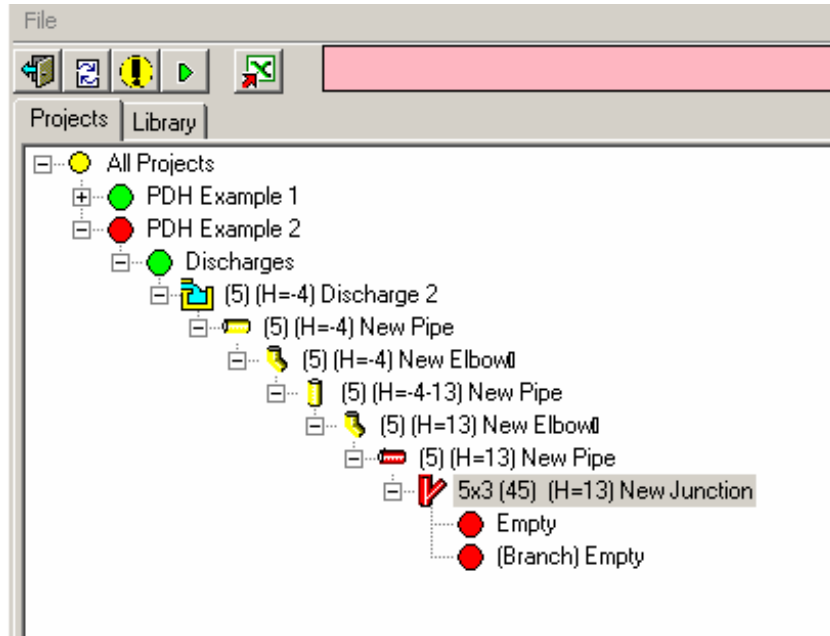


Figure 15: Insertion of a Junction

Notice that there are two "offshoots" attached to this element. The first one represents the "leg" of the Junction, which is the part that continues straight. The second represents the "branch" of the Junction, which is the part that branches off at the 45 degree angle.<sup>11</sup> The distinction between the two is important because each segment has a characteristic resistance coefficient for each stream of water as they merge together at the Junction into one stream. The resistance (as it is called) is related to the turbulence and circulation of flow and to the exchange of momentum that occurs between two streams of different mass and velocity as they mix. The resistance is also a function of the ratio of the cross sectional areas of the leg and the branch piping. Thus, each Junction in the Library has a pipe diameter property assigned.

In this instance, a 5x3 (45) Library element has been inserted. This is actually the fitting needed. Since the connecting pipe is 5 inch, a 5x\_\_ fitting is needed. The branch size to Drain B will initially be sized at 3 inch to connect to the 3 inch drain size as estimated from the chart in Figure 5.

The value of the resistance for the leg and the branch, like that of elbows and reducers, is determined by a characteristic coefficient,  $K$ , as shown in Figure 16. These values are based on



complex algebraic empirical equations and are thus handled by the software when calculations are executed.

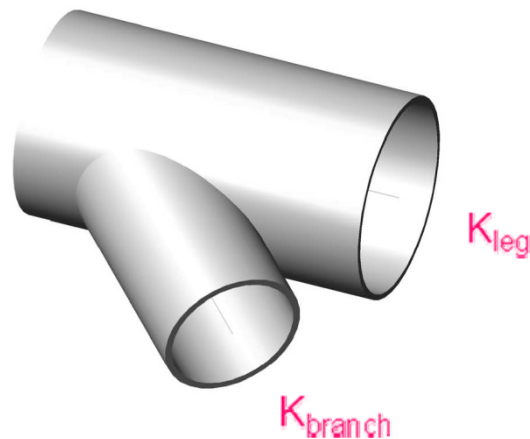


Figure 16: Junction Resistance Coefficients

Before continuing with the next step, notice that a Junction as a physical fitting is basically two pipes joining together at an angle (in this case 45 degrees). The element in the design view tree just entered is essentially a node point carrying with it the resistance coefficients and other inherited and calculated properties occurring at that point. Therefore, it is necessary to next add pipe segments to the "leg" and "branch" offshoots to represent the physical dimensions of the two arms of the fitting.

Start by right clicking on the first [● Empty] heading and select Replace> Pipe> Horizontal. An icon will appear that resembles a horizontal pipe. Enter the following:

Height: 13  
Length: 1\*\*\*

Next, right click on the second [● (Branch) Empty] heading and select Replace> Pipe> Horizontal. An icon will appear that resembles a horizontal pipe. Enter/revise the following:

Library Element: (3) A888  
Height: 13  
Length: 1

This completes the addition of the Junction fitting with both the leg and branch "stubbed out" for continuation by connecting

---

\*\*\* Exact values of these laying lengths can be obtained by manufacturer data or ASTM standards. For purposes of calculation, a value of 12 inches is acceptable.

pipes, reducers or elbows. The design view tree should look Figure 17:

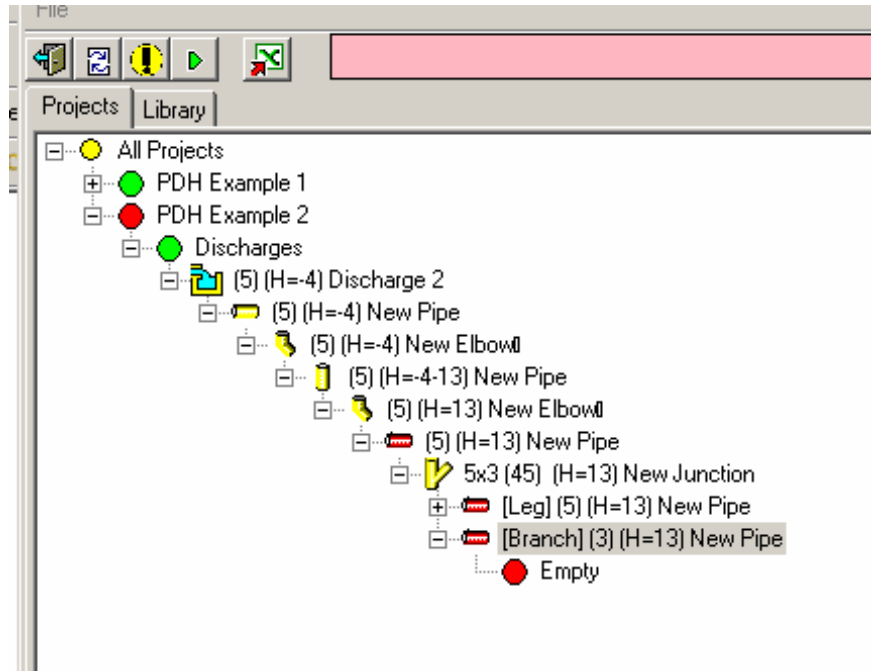


Figure 17: Completed Junction

A plan view of the branch pipe to Drain B is shown in Figure 18:

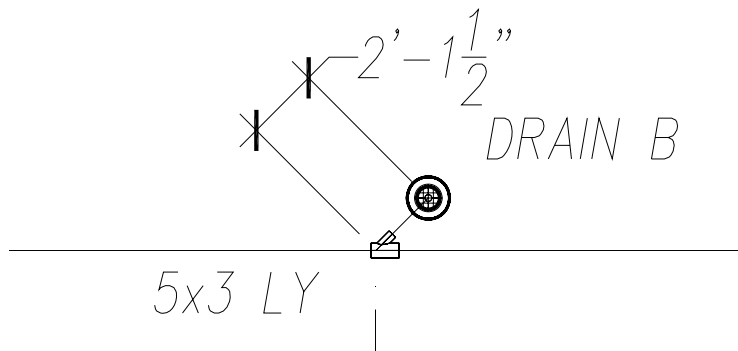


Figure 18: Branch to Drain B

To continue, right click on the [● Empty] heading connected to the Branch heading and select Replace> Pipe> Horizontal. An icon will appear that resembles a horizontal pipe. Enter the following:

Height:	13
Length:	1.1

The segment of pipe just entered is a continuation of the 2'-1.5" branch extending to the base of the drain.

Right click on the [● Empty] heading and select Replace> Elbow>. An icon will appear that resembles an elbow. Revise:

Library Element: 3 (90) A888 LSE

Next, right click on the [● Empty] heading and select Replace> Pipe> Vertical. An icon will appear that resembles a vertical pipe. Enter the following:

Height In: 15

As shown in Example 1, an "adaptor" element is needed prior to connecting the roof drain. Right click on the [● Empty] heading and select Replace> Reducer. An icon will appear that resembles a reducer. Revise:

Library Element: 3x3.1 1005T Adaptor

Next, right click on the [● Empty] heading and select Replace> Roof Drain. An icon will appear that resembles a roof drain. Enter the following:

Area: 7100  
Name: B

The design view tree should now look the same as Figure 19:

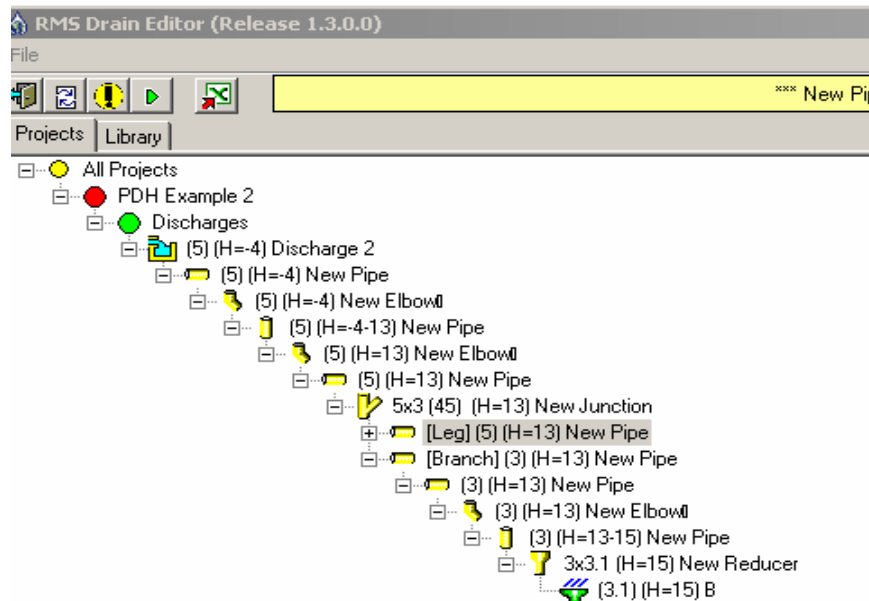


Figure 19: Completed Piping to Drain B

With Drain B completed, continue on to Drain A. First click on the [+] sign to the left of the pipe element representing the Junction's leg. Right click on the [● Empty] heading that appears and select Replace> Reducer. An icon will appear that resembles a reducer. Revise:

Library Element: 5x4 A888

Recall that the initial pipe size estimate for the pipe leading to Drain A is 4 inch. The insertion of this reducer allows the connection of the 4 inch pipe to the Junction. This illustrates why it is important to insert the Junction "stub outs" at first to represent the short pipe segments. Just connecting a 4 inch pipe to the 5x3 Junction (besides resulting in an "invalid" configuration error) would fail to account for the sudden reduction in velocity as the stream of water transitions from the 4 inch pipe to the 5 inch barrel of the Junction. This not only results in an energy loss from the reducer fitting, but also influences the proper value of the resistance coefficient of the Junction.

By thinking of the inserted elements in terms of physical fittings, the designer will achieve faster results and have greater flexibility to revise pipe sizing with a minimum of insertion of new pipe components.

Next, right click on the [● Empty] heading and select Replace> Pipe> Horizontal. An icon will appear that resembles a horizontal pipe. Enter the following:

Height:           13  
Length:           29

Note that the length entered is 29 feet. The length shown in Figure 14 is 30 feet overall. Since the 30 feet includes the one foot section of the leg of the Junction, the length of the 4 inch segment is reduced by that amount.

As was done for the drain in Example 1, there is a reduction to 3 inch to connect the 3 inch drain to the horizontal piping.

Right click on the [● Empty] heading that appears and select Replace> Reducer. An icon will appear that resembles a reducer. Revise:

Library Element: 4x3 A888

Right click on the [● Empty] heading and select Replace> Elbow>. An icon will appear that resembles an elbow. Revise:

Library Element: 3 (90) A888 LSE



entire tree can be displayed by double clicking on the [+] symbol to the left of the Branch icon.

Next, click on the calculation button and go to the [Imbalance] tab to the right. The Imbalance table should look as it does in Figure 21:

Name	Library ...	Area (sq.ft)	Height (ft)	Total E...	Residual Head (ft)	Diamete...	Friction ...	Exit Vel...	Min/Max
1 A	3.1 JRS...	7.100	15	11.729	4.771	3.100	10.213	1.516	min
2 B	3.1 JRS...	7.100	15	9.347	7.153	3.100	7.830	1.516	max

Figure 21: Result of First Calculation

Notice that the resulting Imbalance is 2.382. This is 15.9 percent of the height of the building. The accepted rule is less than 10% of the building height or 1.5 feet, whichever is less.<sup>†††</sup> This is why the Imbalance status bar is red (pink).

Also the Residual heads for Drains A and B are 4.771 and 7.153, respectively. Therefore, there is a little bit excess capacity in the system.

The first step to take is achieving an acceptable Imbalance between the two drains, regardless of the excess (or deficit) in overall capacity (i.e. Residual Heads). That can be adjusted later. However, notice that since the two drain locations are fixed points on the roof and Drain B is tied directly into the manifold, there is no opportunity to revise the piping length to manipulate the Residual Head of Drain A or Drain B to balance them. This leaves only the opportunity to revise pipe diameter.

One remedy would be to change the 3 inch branch to Drain B to 2 inch to increase resistance and try to bring the Residual Head closer to that of Drain A. Without going through all of the mechanics of revising the design view tree, this reduction of the 3 inch branch to Drain B to 2 inch results in a Residual Head of about -9.6 feet and an imbalance of 14.4 feet. Not only does it widen the Imbalance, but it also reduces the capacity of Drain B below the target of 4 inches per hour. Thus, this remedy is not helpful.

<sup>†††</sup> Refer to ASPE 45 "Siphonic Roof Drainage," Section 7.6.2.

This Example was set up in this way to illustrate a point. It is always prudent to include a segment of horizontal pipe from a drain that can be adjusted in length and/or diameter to provide the best flexibility in balancing a system. As such, the branch piping to Drain B is revised as shown in Figure 22:

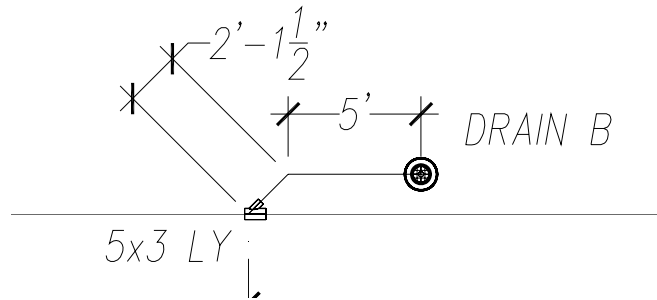


Figure 22: Revised Branch Piping to Drain B

A 5 foot segment of 3 inch piping is added from Drain B that then turns 45 degrees before connecting to the manifold.

The following steps will revise the design view tree accordingly.

First, right click on the 3 inch long sweep elbow and select Insert (Before)> Pipe> Horizontal as shown in Figure 23:

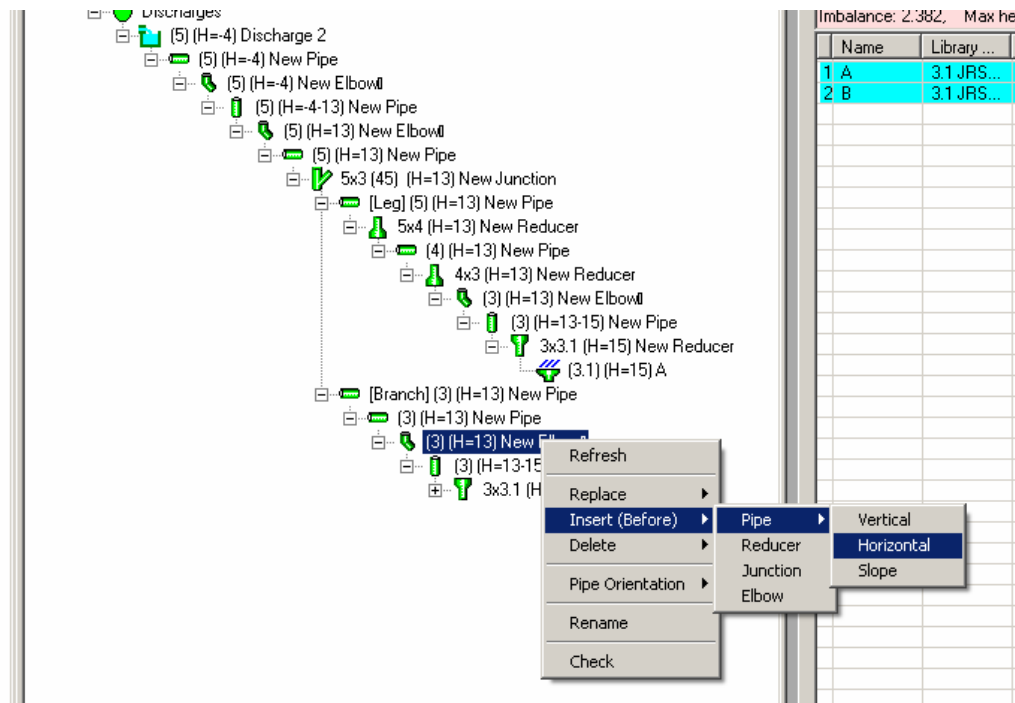


Figure 23: Insertion of a Pipe Element

Go to the [Configuration] tab and enter as follows:

Height: 13  
 Length: 5

The next element is a 45 degree elbow to make the turn. Right click on the new pipe element and select Insert (Before)> Elbow. A 3 inch 45 degree elbow will be inserted. No revision of the properties is necessary.

Because this 5 foot section was added, the position of the Junction must shift 5 feet toward the stack. Correspondingly, the length of the 5 inch manifold must be reduced by 5 feet and the length of 4 inch pipe to Drain A must be increased by 5 feet.

Click on the 5 inch pipe just ahead of the Junction and in the [Configuration] tab, revise the length from 28.5 to 23.5. Click on the 4 inch pipe leading to Drain A and revise the length from 29 feet to 34 feet.

Recalculate the system and return to the [Imbalance] tab. The results will look like Figure 24:

*** PDH Example 2 *** Configuration is Valid, Calculations are Complete										
Imbalance: 0.659, Max height: 15, Imbalance as a percent of max height: 4.39%, Max height percent: 10%										
Name	Library ...	Area (sq.f)	Height (ft)	Total E...	Residual Head (ft)	Diamete...	Friction ...	Exit Vel...	Min/Max	
1 A	3.1 JRS...	7.100	15	12.099	4.401	3.100	10.583	1.516	min	
2 B	3.1 JRS...	7.100	15	11.440	5.060	3.100	9.924	1.516	max	

Figure 24: Revised Calculations

The resulting Imbalance has been reduced to 0.659 feet or 4.39 percent of the height of the building. Since this result is within accepted limits, the status bar is now green. The resulting Residual heads are now 4.401 and 5.060.

It is recommended to bring these values down to less than a foot. As was done in Example 1, first adjust the rainfall intensity to see what the actual capacity would be. By trial and error, this value would be 4.67 inches per hour or about 17% higher than the minimum design rate.



Now, just to take the extra step, go back to the 5 foot branch pipe and change it from 5 feet to 7 feet. Reduce the 5 inch pipe from 28.5 to 26.5 and increase the 4 inch pipe from 34 feet to 36 feet. Recalculate the system.

The resulting Imbalance is now 0.1938 feet or just 1.29%. This is even better.

Take some time to navigate through the [Calculations] tab to view the resulting velocities, flows and pressures.

This completes Example 2.

### **Additional Notes**

The two examples provided in this course material involved fairly simple systems draining one-story buildings. However, many building configurations are suitable for siphonic roof drainage, even multi-story buildings. As mentioned at the beginning, it is not possible for a course of a limited size to examine all potential situations a designer may encounter. However, the previous examples should arm designers with at least the basics necessary to build upon in practice.

However, one scenario deserves discussion. As shown in the two previous examples, the preliminary sizing estimates used to build the system tree have to be adjusted based on the resulting Imbalance and the overall Residual Heads. In one type of situation, it is sometimes tempting to proceed with pipe size adjustment that addresses drain Imbalance, but leads the designer into a situation where the danger of system cavitation (i.e. excessively low static pressures) can occur. This can come about for systems that are multi story.

If this situation were to occur, the software used in this course will display one or more of the tree elements in yellow instead of green, indicating a calculation issue. If the yellow element is highlighted, the [Calculation] tab will display the "Pressure In (ft)" or "Pressure Out (ft)" in yellow or red. If either of the pressures is lower than -33 feet, an error is indicated by the yellow or red color. Sometimes the calculations will result in pressures below -34 feet. This is, of course impossible, because it is beyond perfect vacuum which is about negative 33.9 feet of water column. Water will go into cavitation before that when the pressure approaches water's vapor pressure (about 0.41 ft absolute). To be conservative, the software starts to warn at about -25 to -26 feet and indicates an error (in red) at -33 feet.

The implication to this is that the system will never be able to drain at the design rainfall intensity. It will proceed to prime up and then go into cavitation at a much lower rainfall capacity. It will shake and make alarming noises inside the building.

This situation can arise as follows: The initial pipe sizing results in a very high residual head for each drain. This can happen for systems with tall stacks. The tempting solution is to add the resistance at the drain branches by necking them down to a pipe size or two smaller until the resulting Residual Heads and Imbalance looked good. Unfortunately, by adding the resistance at the beginning of the system (at the drain), the pressure downstream drops into cavitation territory.

The approach to take in this situation is to avoid necking down at the branches to the drains. Keep the branch sizes to the

drains as is at first. Then work on the imbalance between drains regardless of the overall value of Residual Heads, even if the residual pressures are high and the static pressures are coming up low. It may seem counter-intuitive, but sometimes it is easier to increase the Residual Head of a drain or drains to get into a reasonable imbalance. It is also sometimes necessary to increase the diameters of some sections of the manifold. This is handy when trying to increase the residual head of several drains upstream to match that of the downstream drains. When a decent imbalance is attained, reduce the Residual Heads in a combination of ways:

First try reducing the stack by one pipe size.<sup>12</sup> This introduces the necessary resistance after all of the drains and where static pressure is being gained on the way down while more energy is lost due to a higher velocity.

The next thing to consider when using PVC is to change the stack from PVC to cast iron. This has the effect of introducing a higher internal roughness value thereby decreasing the Residual Heads of the system. This isn't a bad idea anyway because cast iron is less prone to damage and is quieter.

Sometimes even after doing this there is still some residual head left. It is then necessary to increase the design rainfall intensity a bit to see what capacity the system will actually drain. When increasing the rainfall intensity, always double check the system pressures to make sure they are still within limits.

This completes the course material.

#### Endnotes:

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<sup>1</sup> There are several software packages used to design siphonic roof drainage systems. However, there are few that make the software available to engineers, preferring instead to keep design work "in house." The software package used in this course is available to engineers at no cost.

<sup>2</sup> The software used for this course is called Siphonitec® and is a copyrighted product of Rainwater Management Solutions, Inc. of Salem, Virginia. The download of this software includes a User Guide that can be used to obtain further detail on its use including file operations, printing reports, etc. The software downloaded is a functional but unregistered version. Those who wish to continue using this software need to go to [www.jrsmith.com](http://www.jrsmith.com) to download the latest version and register for continued technical support, notification of upgrades, etc.

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<sup>3</sup> The software will allow the user to enter new elements into the database to build upon the default library with other pipe materials and fittings as needed.

<sup>4</sup> An aside: Roof drainage systems are designed for the maximum probable rainfall event both in intensity and duration during the expected lifespan of a building. However, "normal and everyday" rainfall is only a small percentage of this design intensity, resulting in only relative trickling of water through piping of conventional design. One design criteria of drainage systems in plumbing codes is a flow velocity of 2 to 3 feet per second. This is intended to provide adequate carrying velocity of debris. However, unlike sanitary waste systems which are almost daily used at their design capacities, roof drainage systems operate at these velocities only a very small percentage of the time. This introduces a kind of paradox in roof drainage design. Bigger is not necessarily better. Larger diameters result in lower hydraulic radius and thereby lower carrying velocities. Although siphonic roof drainage systems are laid flat with no gradient, they have smaller diameters and thus drain during low intensity rainfalls at adequate velocity with flow patterns not predicted by Manning.

<sup>5</sup> This software package allows the user to use whatever elevation datum is most convenient without requiring the side-calculation of elevation differences. Many times both the structural and civil engineering drawings use United States Geological Survey (USGS) elevation as the datum. In this case, the same reference can be used in the software. For example, if the floor elevation is called out as +367.76' then the top of steel elevation on the roof framing plans may be (in Examples 1 and 2) +382.76'. The elevations of drains and piping can be entered in the software likewise. If, however, it is easier to use the architects reference (usually 0.0' for grade level), then this may be used as well.

<sup>6</sup> This chart is the depth vs. flow data for Model 1005 roof drains manufactured by the Jay R. Smith Manufacturing Co. Further information is available at [www.jrsmith.com](http://www.jrsmith.com).

<sup>7</sup> Most all siphonic roof drain manufacturers recommend that roof drains be selected based on a maximum of 70% of their tested capacity. This allows each drain to handle additional water should any one drain or drains become blocked.

<sup>8</sup> In accepted drainage design practice, a long sweep is required. Model plumbing codes required either a long sweep or a combination of eighth bends to transition from horizontal to vertical. Because siphonic roof drainage systems operate as conventional atmospheric systems also, long sweeps are still necessary.

<sup>9</sup> One might ask why a standard radius in this location and not a long sweep or a pair of 45 degree bends. A short radius bend at the top of a stack has been shown by experimentation to help prime the stack faster than with a gradual bend. This is possible due to the short radius initiating a plug flow condition quicker as the water enters the stack.

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<sup>10</sup> A comparison of Example 1 and Example 2 will show how the quantity of drains on a roof (and not their outlet size) influences developed water depth (i.e. hydraulic head) on a roof surface. With a single drain (Example 1) the water depth in steady-state flow would be 3 inches. With two drains and the same roof surface area and rain intensity, the depth would be 2.2 inches. Notice that the initial sizing for both examples led to a 3 inch outlet on the roof drain(s). In Example 1, this size was increased to 4 inch to increase the connected pipe, but the developed depth of water is the same.

<sup>11</sup> Most European practitioners will insist that fittings other than standard DWV pattern (i.e. 45 degree) can be used in siphonic systems. This is true. However, in order to achieve a consensus among the United States, standard DWV fittings should be used in design.

<sup>12</sup> Model plumbing codes almost universally contain a prohibition for reducing pipe sizing of sanitary roof drainage systems in the direction of flow (even in stacks). This rule is typically carried over into conventional roof drainage design. However, it is often desirable and in most cases necessary to reduce the size of a siphonic stack to achieve satisfactory performance. ANSI/ASPE 45 addresses this issue further.