Designing & Building a Rainbarrel System

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Contents

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1. Introduction

This guide is organized to follow the flow of water through a collection system from when it first hits the roof through to the storage container(s). Each section discusses design considerations, materials used, techniques and lessons learned. I have focused on the system I built; it may be bigger and more complex (or smaller and less complex) than the system you intend to build but all systems have similarities, constraints and challenges. At the end of this document I have included a list of resources from local materials suppliers (local to Northern Virginia) to helpful websites and a number of PDF documents. If you would like to suggest other resources for inclusion in a revision to this document, please send them on to me. ~EZ

2. Catchment Area

The catchment area is, generally, the surface area of your roof which drains into your gutters which, ultimately, drains into your rainbarrels. To calculate how much water you can collect from your roof, you need to know how big it is. It does not matter how peaked, articulated or flat your roof is. What matters is the flat surface area. This makes it easier for those of you who may not have done so well in geometry. Once you know how big the flat area of your roof is, the calculation will look something like this:

Formulas:

* **Area = Length x Width**
* **Volume = Area x Height**

Constants/Conversions:

* 12 inches = 1 foot
* 231 cubic inches = 1 gallon

First, calculate the area of the roof:

* **Width** of house: ~15’
* **Length** of house: ~27’
* **Area = Width x Length** = 15’ x 27’ ~= **400 sq. ft.**
* Flat surface area of roof ~= 400 sq. ft.

Second, convert area of roof to sq. inches:

* 1 square foot = 12 inches x 12 inches = 144 square inches
* 400 sq. ft. x 144 sq. inches = 57,600 sq. inches of roof area

Third, calculate the volume of rain and convert to gallons:

* **Volume = Area x Height**

* **Area** = 57,600 sq. inches
* Assume we get 1/2 inch of rain (**Height)**
* Volume of rain = 57,600 sq. inches * 1/2 inch
* Volume (in cubic inches) = 28,800 cubic inches
* Volume (in gallons) = 28,800 cubic inches / 231 cubic inches

  = **124 gallons of rain**

The theoretical maximum amount of water I can collect from my roof if we get 1/2 inch of rain is 124 gallons. But, there are losses along the way:

* There is a certain amount of rain required to wet the roof before any water runs off
* There is loss due to evaporation (especially on a hot summer day)
* The First Flush Device (FFD) prevents some water from reaching the barrels
* The rate of rainfall also has an effect on the amount which can be collected. 1/2 inch of rain over 30 minutes will result in more being collected than 1/2 inch falling over several hours.

Several resources I have read state that one should assume that about 2/3 of the theoretical amount is what will actually be collected. I have not done any experiments to see if this holds true for my system but it sounds about right.

3. Gutters & Plumbing

Almost every rain collection system I have seen requires some modification to your existing gutters but it is usually quite simple. When modifying the gutters/downspout there are a few things to consider:

* Dissimilar metals do not mix well. If you have aluminum gutters, be sure to use aluminum in your modifications and even aluminum rivets. Same for copper and steel. If you do “mix” metals you will set up a galvanic reaction which will quickly corrode the metals.
* I have galvanized gutters/downspouts and, even with extensive prep, had a tough time painting the new downspout and got poor results. I recommend using aluminum or copper.
* If you will have a long lateral run such as I do, make sure the downspout drops 1/8” vertically for every foot laterally. This will keep water flowing, prevent pooling and buildup of sediments.

4. First Flush Device (FFD)

4.1. Background

There are three distinct periods during a rain event. These include:

(1) The **initial rain** which wets and soaks in. When it first starts raining, water wets surfaces and, only once the surface is wet and can no longer absorb water does water begin to flow. The amount of water required to wet/soak into a surface depends on how wet the surface already is, the weather (temperature, cloud cover, humidity), etc. The water from this period primes the system and does not run off nor can it be collected.

(2) The "**first flush**" which begins once no more water can be absorbed. The "first flush" carries all of the dust and dirt which has accumulated since the last time it rained and can be quite dirty. The volume and duration of the first flush varies by the intensity of the rain, how dirty the material is, the texture and porosity of the material and even how long it has been since it last rained. Because of how dirty it usually is, you want to prevent the first flush from being collected. Preventing this water from entering your system is the purpose of a FFD.

(3) The **actual flow**. All of the water which follows the first flush. This water is much cleaner than the first flush and is what you want to collect.

There is no set duration or volume for each flow because of all of the variables involved such as the porosity of the material the rain falls on, how dirty the material is, the weather, the intensity of the rain and how long it rains.

4.2. Benefits

A First Flush Device (FFD) is not a requirement for your rainbarrels but having one will provide cleaner water for the barrels and, because of less dirt/detritus less maintenance of the system.

4.3. Design

Designs of FFDs are many and some work better than others but the basic theory behind most all of them is that the first "dirty" water (the first flush) is discarded. The one exception I have seen to this are gravel/sand boxes which filter all of the water coming out of the downspout. These require more maintenance than those which discard water but clean the water better.

For my own system I read quite a bit and drew on my own experience to decide on a FFD which holds 5 gallons. The size of your FFD will depend on the size of your catchment area, the ultimate use for the water and other considerations. The bigger the catchment area, the dirtier the environment or the cleaner you desire the water to be, the larger the FFD must be.

I chose the design I did because I wanted the minimal number of moving parts and the least amount of maintenance. There are other designs which have moving parts and some which are quite fun to watch but, inevitably, moving parts break. The only maintenance I have had to perform to my FFD in the nearly three years since I built the system is to periodically (about twice a year) clean it out.

The design of my FFD was constrained by the following:

* I wanted it to be about 5 gallons
* I did not want the tube to be longer than the height of the barrels
* Cost of the tube – (8" PVC pipe was too expensive so I used 6")

Once I decided on a pipe design, I used the formulas for determining the volume of a cylinder to figure out how long to make the pipe to hold five gallons:

Formulas:

* **Volume of a cylinder = Pi x Radius^2 x Height**
* **Radius = ½ Diameter**

Constants/Conversions:

* Pi = ~3.14
* Diameter of PVC pipe used = 6 inches
* 1 gallon = 231 cubic inches
* 5 gallons = 1155 cubic inches

First, plug in the numbers we know:

* 1155 cu. In. = 3.14 x 3^2 x **Height**

Second, solve for the Height:

* 1155 = 3.14 x 9 x **Height**
* 1155 = 28.26 x **Height**
* 1155 / 28.26 = **Height**
* **Height** = 41 inches

When using 6 inch diameter pipe, the pipe length needed for approx. 5 gallons in volume is 41 inches The two pictures below show the parts I used to build my FFD:

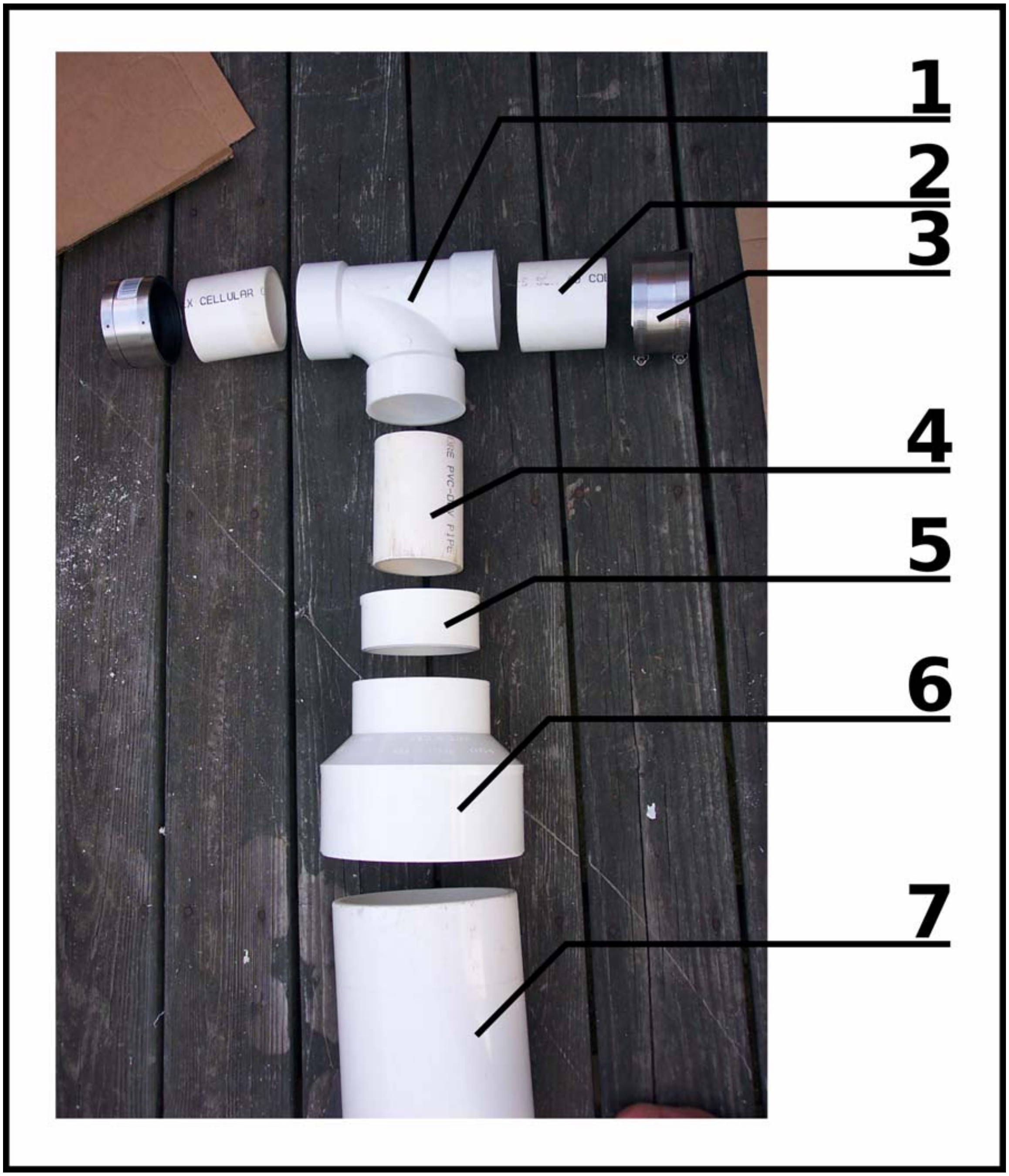

Figure 1: Top end of the FFD

1 Sanitary Tee

2 4" Diameter PVC Schedule 40 pipe (about 4" in length)

3 Coupling (sort of like a hose clamp, can be found in a plumbing supply store)

4 4" Diameter PVC Schedule 40 pipe (about 8" in length)

5 PVC Male Threaded Ring (4")

6 PVC Female Threaded Reducer Ring (6" to 4")

7 6" Diameter PVC Schedule 40 pipe (need approx. length)

8 (not shown) 4" Rubber Ball (inside device)

Water enters the FFD from the left, fills the device and then, once the device is full, water flows out to the right through a short section of downspout and into the barrels.

Inside the FFD I have placed a 4" rubber ball which floats on top. Since there is no gate or valve at the top of the FFD, this ball blocks the opening at the top when the FFD is full and helps to prevent mixing of the dirty water with the clean water which flows on to the barrels.

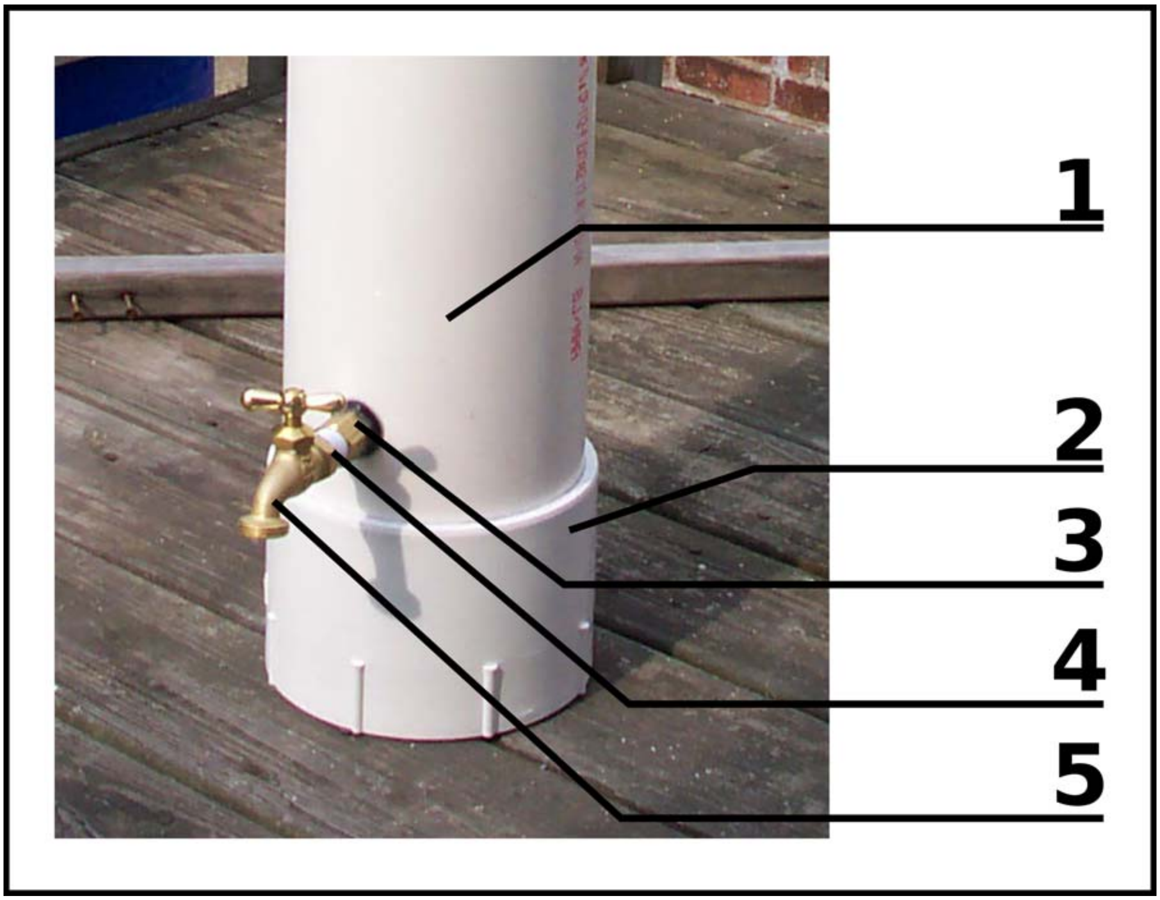

Figure 2: Bottom end of the FFD

1 6" Diameter PVC Schedule 40 Pipe (41")

2 PVC Female Threaded Ring (6")

3 Brass Hex Coupling

4 Teflon Tape

5 Stopcock

6 (not shown) Close Thread (through the 6" pipe)

7 (not shown) Brass Hex Coupling (inside 6" pipe)

8 (not shown) PVC Male Threaded Plug (6”, screwed into the PVC Female Threaded Ring)

The bottom end of the FFD is where the drainage valve and cleanout plug are located. The drainage valve assembly consists of a close thread through the 6” PCV pipe and secured in place by a brass hex coupling and an o-ring on either side as well as a generous amount of silicon sealant. On the outside of the pipe a small stopcock is screwed into the brass hex coupling.

The stopcock is left cracked open at all times to allow slow drainage of the FFD. I try to keep this valve adjusted so that it takes 3-6 hours for the FFD to drain. This causes a small loss of collectable water but is almost insignificant when compared to how much is collected (maybe 1/2 gallon lost compared to 110 gallons collected).

The PCV male threaded plug at the bottom of the FFD is what I open up to periodically clean the FFD. Before opening it up I disassemble the FFD from the downspouts and lay the FFD on its side. Once open, I use a garden hose to clean the inside out and the ball and then put it all back together. Total cleaning time takes about 15 minutes.

5. Stand

Figure 3: The completed stand for the rainbarrels

Depending on the configuration of your rain barrel system, you may want to put your barrels up on a stand to provide some natural pressure. A stand can be anything from a few bricks or cinder blocks to a steel structure but the most important consideration for a stand is the weight it will bear. Water is quite heavy (1 gallon of water is ~8.3 pounds) and that weight adds up quickly. By way of example, here is the calculation I used for my rainbarrels:

Constants/Conversions:

* 1 gallon of water = 8.3 pounds
* 1 rainbarrel = 55 gallons

Calculate weight of system:

* System = 2 barrels = 110 gallons
* System = 110 x 8.3 pounds
* **System weight = ~920 pounds**

As you can see, when my barrels are full there is about half a ton of weight sitting on the stand. With this in mind, I decided to use the strategy that Roebling used when he built the Brooklyn Bridge and overbuilt by as much as was feasible[1] using three sets of legs. Each leg is a 4x4 and the load path of

[1] According to the amazing book titled "The Great Bridge", Roebling designed the Brooklyn Bridge with twelve times redundancy. i.e. when new the bridge should have been able to carry twelve times the required weight.

the stand is designed to transfer the weight from the barrels through the wood and not rely on the fasteners (heavy lag bolts and wood screws) to carry the weight.

When building a stand (or anything, for that matter), keep in mind galvanic action (mentioned above in the Gutters & Plumbing section). I spent an inordinate amount of time trying to find aluminum stand-offs for my stand because I felt the black plastic ones were…. plastic and cheap. I ended up using the black plastic ones because what I discovered is that:

(1) aluminum stands are hard to find

(2) aluminum stands are quite expensive

(3) the black plastic stands are at least as good as, if not better than the aluminum ones

(4) because the wood is treated with copper, the aluminum and the copper would have reacted to quickly corrode the stand and rot the wood.

6. Barrels

Figure 4: Completed Rainbarrel System

The heart of your rain collection system is the container for the water. There are many different containers of varying materials, design and cost. You could build an underground cistern, put a steel tank on your roof or even use a large plastic bladder (I've seen them for sale!). Most common for households are to use some sort of barrel, usually plastic and typically the 55-gallon size. Since this is what I used, this is what I will focus on. If you would like to use something else, there are many ideas in the resources section.

6.1. Size

As stated in the introduction to this section, 55-gallon plastic drums are the easiest and most cost effective container. You can purchase these barrels for as little as $5 and, if you desire more volume than a single barrel provides, you can plumb them together as I have done.

The theoretical maximum size of your barrels is determined by annual rainfall and the size of your roof. The Texas Rainwater Harvesting Manual has an excellent discussion on the maximum size a system should be. But there are practical limiting factors such as time, money and space in your yard. Given these constraints, I settled on a two-barrel (110 gallon) system but may expand it to a third barrel (165 gallons) in the future.

6.2. Materials

There are many materials you can use – metal, masonry even wood but the best material to use is plastic; it will not crack when the water freezes and expands, it is easy to clean and the plastic barrels can be obtained quite cheaply.

I purchased my barrels from McCutcheon's in Frederick, MD. As noted in the resources section, there are many other barrel suppliers. The best feature of the barrels I purchased is the removable lid. This makes for easy cleaning and an unexpected benefit when I built the barrels, provides a bird bath which attracts LOTS of birds.

If you do not like the color blue, you can paint your barrels with Krylon paint. I have read that this is the ONLY paint which will adhere to the blue plastic. An additional reason to paint your barrels is to keep light out of them which will reduce algae growth. I have not had much of an algae problem but my barrels are shaded and because of the amount of rainfall we get and how much water I use, there is a high turnover of water in the barrels which prevents algal growth.

6.3. Inlets

Figure 5: Screened Inlet to Rainbarrels

Any and all openings to your barrels must be screened to prevent mosquitoes and other critters from breeding in them. There are alternative strategies such as a larvicidal product called “Dunkers” or adding goldfish to your barrels but all alternative methods require added cost and maintenance and are not as good at preventing mosquito breeding as good old-fashioned screening.

The inlet to your rainbarrel(s) should be large enough to allow the free flow of water into the barrels. Some barrel designs direct the downspout right into the barrels while others take an approach more like I have.

My “funnel” is an 8”-6” heater duct purchased at Restore for about a dollar. I cut a piece of screening to rough size, attached it to the 8” opening of the duct and affixed it with zip-ties. I then trimmed the screening and smeared silicon sealant around the edge to glue the screening in place and ensure a tight seal.

I cut the 6” opening in the top of the barrel very carefully to be the precise size needed. I was prepared to attach the funnel to the barrel with silicon sealant but found the fit to be tight enough to hold water – clearly tight enough to keep mosquitoes out – so I did not use the sealant.

Water enters the second barrel through the plumbing so there was no need for an inlet on that barrel.

6.4. Outlets

When designing/building your barrels, you need to design a way for excess water to flow out of the tanks. There are a number of reasons for this including good design and directing water away from the foundation of your house.

Like the rest of the system, I designed the overflow pipe for my barrels to be modular and easy to assemble/disassemble. Instead of gluing the 2” PCV pipes together directly, I glued threads to each piece so that I can simply unscrew the pieces.

6.5. Plumbing

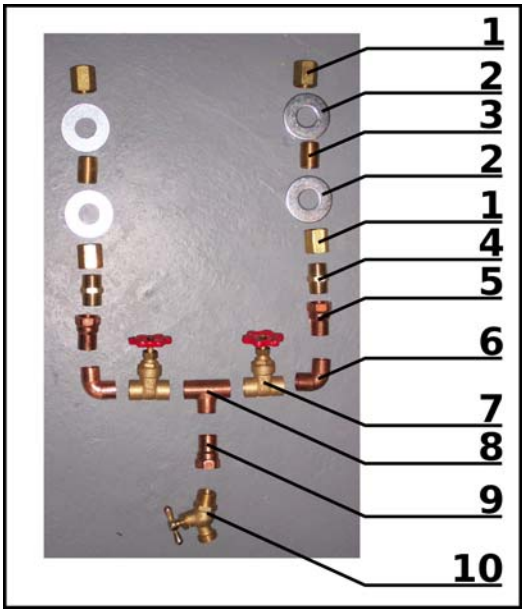

Figure 6: Original plumbing plan showing only fixtures, not the copper pipe.

1 Brass Hex Coupling

2 Zinc Washer

3 Brass Close Thread

4 Threaded Hex Coupling

5 Female Threaded Fitting (See Figure 7 for final fitting design/usage)

6 90° Copper Elbow

7 Ball Valve

8 Copper Tee

9 Female Threaded Fitting

10 Stopcock

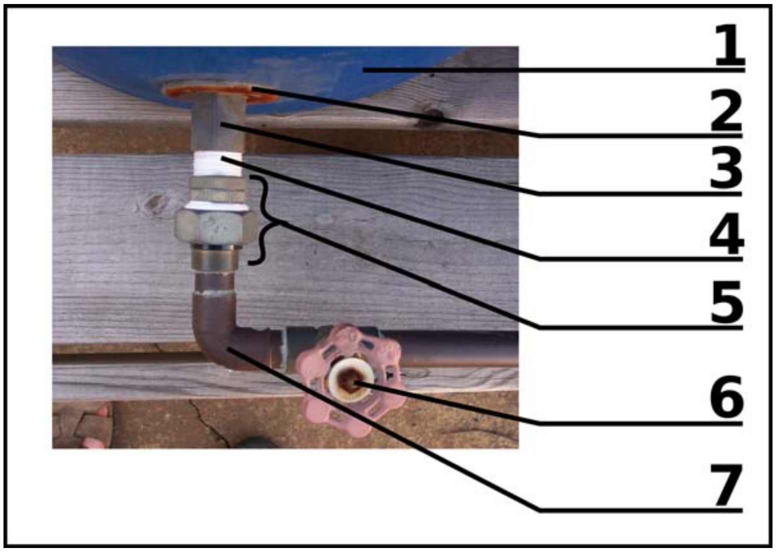

Figure 7: Detail of final plumbing showing different connector fitting to barrel

1 Rainbarrel
2 Zinc Washer
3 Threaded Hex Coupling
4 Brass Close Thread
5 Threaded Coupling
6 Ball Valve
7 90 ° Copper Elbow

There are two aspects to plumbing your barrels – plumbing them together and adding a stopcock to get water out of the barrels. In my design I combined the two into a single copper assembly which consists of two valves and the stopcock. The two valves allow for flexibility in using/draining the barrels but normally I leave them both wide open to allow for free flow of water from one tank to the other.

The plumbing assembly is attached to and through the barrels using the same technique as for the FFD: There is a close thread run through a hole in the tank. On either side of the thread I placed a large washer to distribute pressure, plenty of silicon sealant to waterproof the hole and tightened the whole thing together with hex couplings. This has remained watertight for the life of the barrels (almost three years and counting).

6.6. Operation

“Operating” the rainbarrels is fairly straightforward and requires little effort. Here’s a few things I abide by:

* I try to (but don’t always remember) drain the barrels a day or two before we get any significant amount of rain. This readies the system to absorb the maximum amount of runoff from a storm, “refreshes” the water in the barrels and minimizes the storm surge from my roof when it does rain.
* I regularly observe/adjust the spigot on the FFD. It does not seem to stay the same adjustment for long but, much like the barrels before a storm, I simply drain the FFD right after it rains. I believe the adjustment is needed due to temperature changes which cause expansion/contraction of the brass fitting.

6.7. Maintenance

Maintenance is pretty simple for the system I built. I clean the FFD about two times a year and clean the barrels once a year at the end of summer. I have had to repair the copper pipe two times now due to freezing of water in the pipes but it has been easy to repair.

7. What would I do differently?

* I chose to use copper pipe for the plumbing for a number of reasons including that I wanted to have fun, the strength of copper and aesthetics. If I were to do the project over again I would consider using PVC pipe instead of copper as ice has broken solder joints in two out of the three winters they have been through. To resolve this problem, I plan on adding heat tape in the future to prevent the complete freeze of the pipes.
* I built the stand as high as I could while keeping the top of the barrels below the height of the kitchen window. If I were to do it again, I might build the stand higher yet to increase the pressure when I use the hose.
* I made a mistake by using zinc washers in the barrels. The zinc is corroding and will eventually need to be replaced. When I do replace the zinc I will use either stainless steel, copper/brass or plastic to prevent the corrosion problem.

8. Resources

8.1. Local Material Suppliers

* **McCutcheon's** - http://www.mccutcheons.com/
  They're up in Frederick, MD but worth the trip. You can get barrels there (call ahead) and also various jams, jellies and other good stuff.

* **Fischers** - http://fischerhardware.com/
  The **best** hardware store in NOVA. Located in Springfield, you'd be surprised what you can find at Fischers.

* **Ferguson** - http://www.ferguson.com
  Good plumbing supplier.

* **Restore** - http://www.habitatnova.org/restore/
  You never know what you'll find at Restore. Make this the first stop on your rainbarrel shopping trip as you might find a lot of what you need very cheap.

* **Pet store** – I searched high and low and scoured the internet to find a 3" diameter plastic ball. I finally found what I needed at a pet store.

* **Pepsi Bottling Company** - 2611 Pepsi Pl., Hyattsville, MD
  The general number: (301) 322-7000 but your best bet is to contact Howard (301 322 7014). Barrels are $5 each. They tell me that there are two small holes in the top of each one (~3/4") and they only have one kind of barrel available. Barrels are available M-F until 3pm; be sure to call Howard before going so he knows you're coming.

* **Pepsi-Cola Bottling Co,** - 1650 Union Ave, Baltimore, MD
  Contact Charlie Dickerson at (410) 366-3500 x7785. They have the same deal as the Hyattsville facility - $5/barrel.

8.2. Web Resources

* **http://www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf**
  Texas Rainwater Harvesting Manual - This is what I envisioned when I set out to put together a tutorial. Why reinvent the wheel? Read this for a LOT of great information on all aspects of designing and building your own rainwater catchment system.

* **http://www2.ctahr.hawaii.edu/oc/freepubs/pdf/RM-12.pdf**
  Guidelines on Rainwater Catchment Systems for Hawaii – Similar to the Texas Rainwater Harvesting Manual, this is an excellent resource for understanding, designing and building your own system.

* **http://www.watertanks.com**
  Lots of products related to rainwater collection.

* **http://www.phys.ufl.edu/~liz/water.html**
  Older page which talks about cisterns but has good info/ideas for a FFD and an in-tank float among other things.

* **http://www.wvu.edu/~exten/infores/pubs/ageng/sw12.pdf**
  PDF Document detailing the planning and building of a cistern. Rainbarrels are essentially small cisterns and there is a lot of great information in this document.

* **http://www.therainwell.com/**
  Good source of information and where to buy unique or hard to find rainbarrel parts.

* **http://www.greenbuilder.com/sourcebook/Rainwater.html**
  Don't let the lack of formatting or organization deter you. There's some good information and, more importantly, good links on this page.

* **http://www.rainwatermanagement.com/products.php**
  Source of pre-built systems, information and ideas.

* **http://www.krylon.com/**
  Information on Krylon paints if you want to paint your plastic barrels.

* **http://www.jrsmith.com/**
  A great resource for fittings, ideas and information.

* **http://ericzander.com/Homework/Rainbarrel/index.htm**
  Website where I will maintain this tutorial and other resources.

8.3. Books

* **Ferrocement Water Tanks & Their Construction**
  by Simon B. Watt. I've read references to this book in several places so I am guessing it is a good one.