

## A Step by Step Guide

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# Building a Home Distillation Apparatus

## Foreword

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The pages that follow contain a step by step guide to building a relatively sophisticated still. It is directed at anyone who may want to know more about the subject, for hobbyists, tinkers, pure water enthusiasts, survivors, and perhaps amateur wine and beer makers.

The still involved in the chapters that follow is a unique distillation apparatus. At the time of this writing, there is only one like it. Designing and building this apparatus is the only subject of this manual and you will find that it confines itself to those areas. It does not enter into the domains of fermentation, recipes for making mash, beer, wine or any other spirits. These areas are covered in detail in other readily available books and numerous web sites.

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Building a Home Distillation Apparatus.

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## Introduction

### *About Attitudes and Regulation*

**S**o you're interested in building a still. In the US (and many other countries) I guess you know that doing that is just not the politically correct thing to do.

Even if you are just a curious person and simply want to know what's involved, you probably feel some reluctance about discussing the subject outside of your own trusted circles.

The reason you feel this way, most likely, is because a lot of laws have been passed over time that severely restrict the ways that you may refine products containing ethyl alcohol.

Most US residents are also quite familiar with the moonshine folklore, high-powered cars running shine over mountain back roads, and dodging the federal revenue agents. So much so that many may feel that they are doing something improper, or maybe even criminal by reading this.

Everyone should follow his or her own conscience in these matters. Personally, I believe that some of these laws are so poorly thought out and implemented that they border on being ridiculous.

A case in point. In the US, the government allows an individual to produce wine or beer for personal consumption by using a fermentation process to produce an alcoholic beverage.

The fermentation process however, produces a wine or beer containing chemicals that are actually poisonous for human consumption. Nevertheless, the government seems to think it is perfectly OK for an individual to ferment and drink the stuff, regardless of the impurities it may contain.



Unbelievably, the US government also makes it illegal for an individual to remove the poisons from the alcohol in the wine or beer by distillation. In other words, it is illegal for an individual to refine a legal beverage in their own home and, in the process, produce another perfectly legal beverage for their own consumption! Figure that one out.

Without much reflection, it is easy to see that such laws are flawed and without foundation in logic, justice, or the common good.

Fortunately, it is not illegal to express these opinions. That freedom also extends to writing about such things as alcohol distillation (legal or not), and the use and manufacture of equipment to effect this process in the home.

So, as long as your conscience allows, at least in the US, you are not doing anything wrong by reading this information. There is also nothing illegal about building a still.

Having said that, recognize that the only purpose of this document is to educate and inform those of you who are interested in this subject. It is not to be construed in any fashion as an encouragement to break the law. If you believe the law is incorrect, please take the time to contact your representatives in government, cast your vote at the polls, write newsletters to the media, and in general, try to make the changes in a legal and democratic manner.

And while it is hoped that the still will always be used for legitimate purposes, if you decide to distill ethyl alcohol then never forget that you are dealing with the law, and to twist an old barb:

**“If you can’t pay the bill then don’t use the still”**

Enough said. It’s time to get on with more practical things.

## Where To Start?

### *Information Sources*

It doesn't take long after making the decision to build a still to recognize that there are a lot of things to be considered. A visit to the library, and some reading about the distillation process is a good place to start. However living in a small rural town without a significant library can make things more difficult. It's even worse if the nearest big university is about 100 miles away.

If you find yourself in a similar condition you should consider starting with the Internet. Initial searches will turn up thousands of hits on the subjects of moonshining, distillation, stills, spirits, whiskey, reflux ratio, unit operations etc..

Unfortunately, there isn't a whole lot of really good information about building a first class personal still out there. Sure, there are lots of commercial distillers, beer and wine equipment suppliers, discussion groups, moonshining stories, book sellers, discussion groups, and lots of chemistry information on the web, but only a couple of quality publications on amateur distillation and still construction. There are some good ones though.

One of the first, and best, reference that I found was from a corporation in Sweden run by Gert Strand. It was the "Home Distillation Handbook", translated from Swedish to English and written under the pseudonym of Ola Norrman. It is available on line, for small fee in PDF format from [//http://partyman.sa](http://partyman.sa).

Partyman is a first class provider of liquor essences, fermentation, and fine German instrumentation equipment useful in alcoholic beverage measurements.



Ola Norrman's book takes you step by step through every procedure involved in the process of producing a variety of spirit drinks, including guidance in the construction of an appropriate still.

Another good source can be found in Dr. John Stone's book "[Making Gin and Vodka](#)". It can be ordered on <http://www.gin-vodka.com>. Dr. Stone concentrates on producing pure alcohol spirits (Vodka and Gin), but the book discusses in detail the construction of a multi-stage distillation apparatus, much like a scaled down commercial facility might use. It is very complete in describing every phase of producing and refining alcohol, and provides many first hand insights into this process.

For the more technically inclined, the web surfer should read M.T. Thams' [Introduction to Distillation](#) tutorial at:

<http://lorien.ncl.ac.uk/ming/distil/distil0.htm>.

For those of you who simply want a still, and not all the work of doing it yourself, you will enjoy the [Still Life](#) at <http://stillife.com>, and Ray Toms' Moonshine Supplies at <http://moonshine.co.nz/> .

The University at Akron offers an excellent slide presentation of distillation theory at: <http://ull.chemistry.uakron.edu/chemsep/distillation/>

For the engineering students among us, you might find Andrew Sloleys' distillation and petroleum refining homepage a good start. You will find it at: <http://asloley.home.mindspring.com>

And finally, for the best about the art, science, and folklore about distilling checkout Bourbon Street Bayou: <http://www.geocities.com/BourbonStreet/Bayou/2588/distill.htm>

These sites and books will give you a good starting background for those things you are about to undertake. Certainly there are many others that may be even more appropriate. But for the most part, they provide an excellent foundation for constructing a high quality apparatus that will deliver quality spirits in a safe manner.

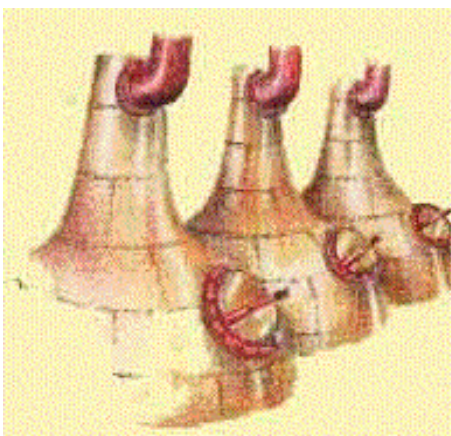
And so, armed with this information, and a bit of common sense, we can begin the task by addressing the most important question.



## What Kind of Still?

### *Pot Stills*

**P**ot stills were the earliest kind of stills. They simply had a pot to boil the fermented mash in, and an output tube that passed through something cooler (air or water etc.) which condensed the vapors coming from the pot.



The copper pot stills like the ones shown are reputed to have been in use for over 500 years to make some of the finest Irish Whiskey in the world. While the pot still is enormously inefficient, it is uniquely simple and easily adapted for home distillation of everything from essences to whiskey and moonshine.

From the Irish Whiskey Trail

Little has really changed in the design of the pot stills over the last 2000 years.

You won't find much difference between the moonshine still shown below and the alembic pots used years in Egyptian times to make perfumes.



From the John C. and Olive Campell Collection  
 Southern Historical Collection, University of North Carolina

The problem with pot stills is that they don't do a good job at separating out exactly what you want to distill as output. They are usually used to separate compounds whose boiling points differ by about 100° C. When beer is distilled, lots of things come out, some good, some bad. And because there are no fine controls on this kind of still, the output contains a lot of impurities.

Nevertheless, after each distillation, you always get a better output product from that which you started with. So each time you redistill the output in a pot still, it will come out a bit purer, but you lose a little each time you redistill. To make it really pure, you have to distill it so many times that you'll end up with almost no output.

Along those lines, If you are distilling fermented sugars with a pot still, unless you re-distill the output several times, you can get a massive hangover if you drink whatever comes out. Hangovers are caused by the impurities in the alcohol. In short, you've been poisoned (but just a little bit)!

Because of this limitation, it takes a lot longer to produce a reasonably pure finished product using pot stills. I'm told the finest Irish distilleries still use pot stills to make their whiskey. They take great pride in the fact that they triple distill the whiskey. The demand for this product was so great, that they built huge pot stills, some holding over 30,000 imperial gallons of beer.

So, while it is tempting to take the easy way out and build a simple pot still, it really wouldn't meet our goal of producing the very purest spirits, in the most efficient manner. To do that you've got to think about a reflux still.

## *Reflux Stills*



The pot still was the only distillation method known for almost 2000 years. But that all changed with the introduction of the reflux tower the late 19<sup>th</sup> century. That invention revolutionized the production of many valuable petroleum and chemical products that we commonly use today.

Basically, the reflux still is a structure that allows the distillate vapors from a boiler to rise up a column to the top where the vapors are condensed. The condensed liquid is then allowed to run back down through the rising vapors to a point where the temperatures become hot enough that it boils again. This process is called refluxing.

As this cycle continues, the mixture inside the tower is effectively re-distilled. In the process, the components of the mixture separate into discrete layers within the column based on their boiling points.

Industrial distillations are carried out in huge towers, where the refluxing is continued until the mixture is completely separated into layers. At that point the different components can be simultaneously drawn off the layers within the tower almost as fast as the mixture can be introduced into the column. This method is called continuous distillation.

While continuous distillation methods provide the volume output demanded by the petroleum industry, the practice is not well suited to our interests. We just want to separate on occasion, a single compound from a liquid mixture with a small scale still. That's called batch distillation.

Fortunately, the reflux column can be used with either batch or continuous distillation operations, and it can be scaled up or down to meet either industrial or home distillation needs.

How this scaling is done directly affects how we build our home still. So to do it right, we need to understand what is going on in the process.

The best place to start on that is to look into what happens when you boil something in a reflux column.

## Boiling Beer

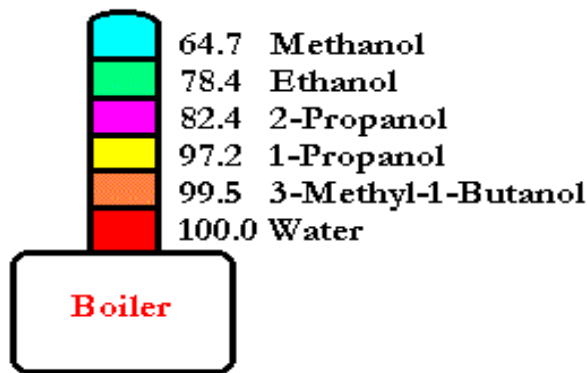
There is a lot of terminology surrounding the art of making Beer, Wine and Spirits. We are not going to get into most of these terms because they are not central to the construction of a still.

But to keep things straight in this manual, we'll be talking about Spirits as a product that is made by boiling Beer and condensing the vapors (distillation). Beer, in that context, is the result of fermenting Mash, and Mash is simply a mixture containing sugar.

Fermented mash (beer) is typically made up of ethyl alcohol and a lot of other things that most folks don't want in the distillate.

If you are going to use the still to process a batch of spirits then you first heat the beer enough to boil off most of the more volatile components (heads), before you collect the spirits.

What's really going on in the still when you boil the beer looks something like this:



The coolest part of the tower is at the top, and the warmest nearest the heat source at the bottom.

The beer components that have boiling points over 100° C will mostly remain in the boiler. For that matter, you won't let the temperature in the column get over 80° C. This will keep most of the undesirables (called

tails) out of the distillation output and in the boiler. You would also throw away all of the distillate that comes out before the temperature reaches 78° C. This part is called the heads, which contains methyl alcohol (a poison), and some other non-desirable congeners such as Ethyl Acetate.

So the important thing to remember about this process is that the mash you start with might be simple (sugar, water, yeast), but after fermentation, the beer contains all the ingredients shown above, and more.

It's also important to recognize that some of these compounds (e.g. methyl alcohol, 2-Propanol) have boiling points quite close to the ethyl alcohol you might be trying to distill out. That means you will have to be careful about controlling the column temperatures to make sure that you collect only pure spirits.

All these things considered then, the reflux still is by far the best choice. It will allow you produce a much better spirit than the pot stills.

Admittedly, this kind of still takes a bit more thought at the design stage, but really that's what we're talking about now.

So now it's time to go a little deeper into the issues that will come up in actually building a small-scale reflux distillation apparatus.

## Construction

**I**n this section we are going to mix how the still is built with why it's being built that way. And while this may be an annoyance to those who just want to get something working, it might also provide enough background to allow anyone to make fine adjustments to the design to better suit their needs. Even better, this extra information might prevent some colossal hangovers.

### *Components & Materials*

Selecting the right materials for our home distillation apparatus is very important.

Stainless steel is ideal because it cleans easily, looks nice, and has great resistance to the effects of boiling corrosive liquids. On the other hand, stainless steel is very difficult for the homebuilder to work with. This is especially true without special tools. There are few ready made fittings available for joining the parts, it is very expensive, and it is difficult to find a supplier willing to deal in small quantities with this material.

However, ready made stainless utensils may be easily adapted for use in the still. The boiler is a good example.

### *The Boiler*

Various sources have suggested that a good boiler can be easily constructed by converting used restaurant pots, stainless steel wash pails, bakers dough pans, used soda and beer kegs, old swimming pool filters and a few other such things into a boiler. These items are all good candidates for the purpose, but converting them into a boiler for a reflux column is *not* always easy. Sometimes they require considerable modification and specialized welding in order to provide proper connections to the column and a way to disassemble for cleaning.

You should give considerable thought to what fabrication will be required before you make your selection of boilers. It is very important that you be able to easily separate the boiler and column sections for cleaning. Construction is a lot easier if the boiling vessel has a tightly fitting, removable top.

You also need to make sure that you have enough room in the vessel to hold the batches you intend to distill, that it is sufficiently durable to withstand the boiling and charging processes, and that it will not taint the distillate with any objectionable metallic flavors or impurities.



The vessel that I found best for this purpose is a used stainless steel milk can. It is readily available, holds about 10 gallons, has a removable top, nice handles, and it shines like a silver chalice. You can actually grow to love the art in this vessel.

### ***The Top End***

It seems natural that a stainless steel boiler should have a stainless steel top end. It would not only look nice but it would also be easy to clean, rustproof, and extremely durable.

Unfortunately, dairy or medical grade stainless tubing and fittings are not easy to find and the parts are horrendously expensive. A small ½” stainless coupling costs as much as \$36.00. Regardless of these costs, you will find most of the suppliers will not want to deal with you on such small orders.

The automotive supply stores have stainless steel T409 automotive exhaust pipe. And while it is less expensive (about \$10.00/foot), it takes a lot of polishing to make it look good, and because there are no standard fittings available, this kind of tubing needs extensive MIG welding to fabricate it.

Glass is also nice, but it is also very costly, very fragile, and requires expensive custom glassblowing services to complete the fabrication.

So what all this actually comes down to is if you want to build this at home, plain old copper tubing is the best choice. It's easy to cut, braze, and silver solder. There are an endless number of standard fittings available at plumbing supply distributors, a wide variety of tubing sizes, it is quite inexpensive (around \$2.00-\$3.00/ft.) and it really looks beautiful when polished. Some even say it gives character to the flavor of the spirits too.



OK, it's decided. We are going to build a hybrid still with a stainless steel boiler, and a copper tubing top end.

The top end is composed of the reflux column, the cooling tubes, and the condenser assembly. At times in this manual we'll optimistically call the top end assembly a tower.

Construction starts with the condenser assembly first.

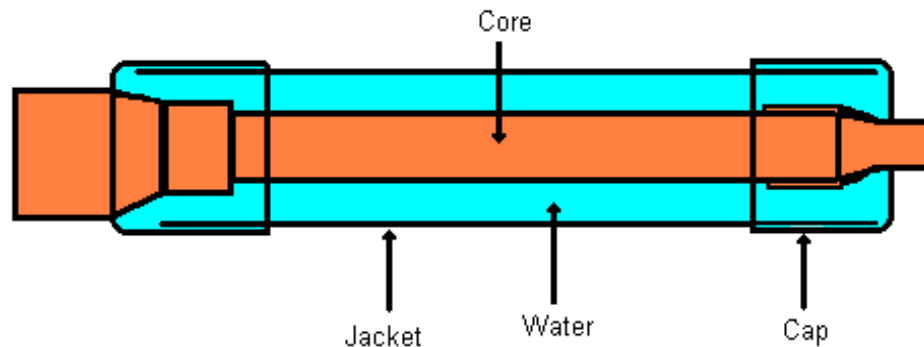


## Building The Condenser

**E**xcept for those in the electronic business, everyone knows what a condenser is. It's a device that cools down whatever vapors that flow through it to the point where the vapors condense into a liquid. That liquid is what the rest of the still is all about. In the still we are building, it is also the heart of the cooling system.

Condensers can be designed in many ways, but for a lot of reasons, as you'll see in the next paragraphs, a jacketed core condenser is particularly well suited for this still. With jacketed condensers, a circulating and cooling water supply runs between the jacket and the core. This condenses the liquids contained in the hot vapors coming from the column and going through the core.

Here's a sketch of what the insides of the condenser look like:



Simple as it might seem, there are a lot of considerations behind making a proper condenser for the kind of column we want to build.

Most low capacity distillation devices use a small capacity condenser. This is because they are designed for only one purpose: to drop the temperature of the distillation vapor to the point where the liquid separates out of the vapor. That usually does not require a great deal of cooling. Pot stills sometimes just use a coil of tubing that cools the vapor by just exposing it to the surrounding air temperature.

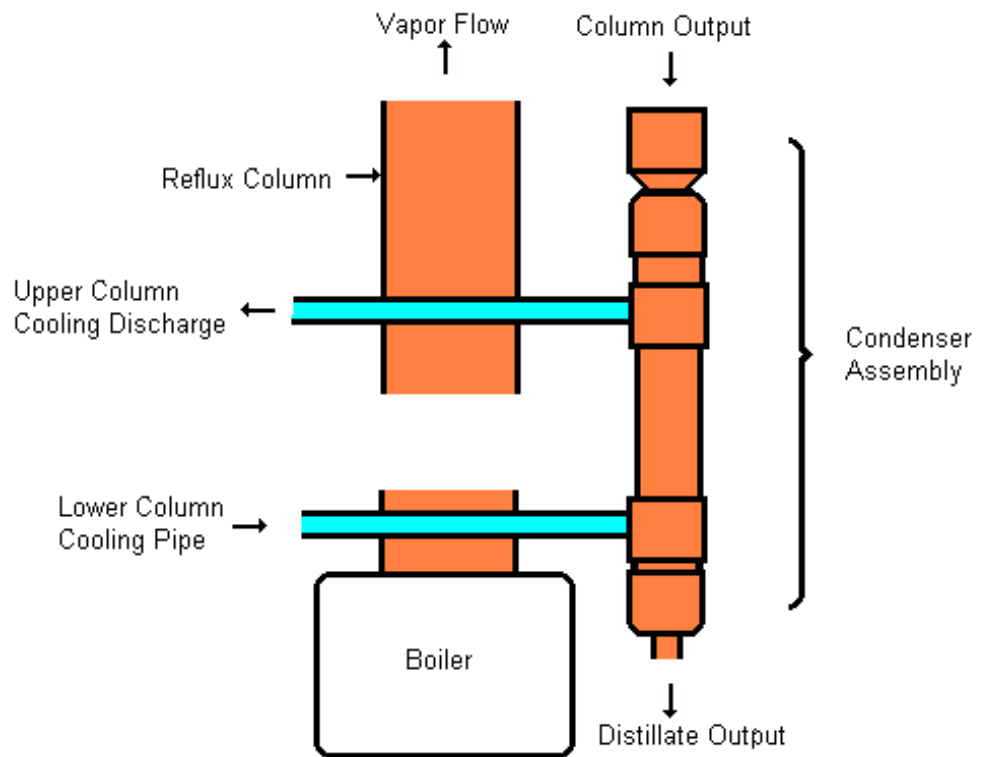
But keep in mind we are building a reflux still. That is a more sophisticated design. In the course of its operation, the reflux still produces a much higher quality of distillate than the pot stills because it effectively re-distills the mixture many times before it is drawn off from the still. That of course, requires much more cooling and much better temperature control than the simpler pot stills.

So, to accommodate these needs, we've designed this still with a much larger cooling capacity incorporated into the condenser. We've done that because we need not only the cooling required to condense the distillate vapors, but also to carefully regulate and control the temperatures *inside* the reflux tower.

To properly utilize the extra cooling capacity, we've made the water supply and drain lines from 1/2" copper pipe and run these cooling lines *through* the reflux column as part of the normal cooling circulation. The primary purpose of these lines is to control the amount of re-distillation (reflux) that occurs inside of the column.

In the sketch shown below you can see that the input cooling water is circulated first through the bottom of the column, then through the condenser, and finally back through the top of the column again.

The rather large surface area of the copper jacket of this condenser acts as a radiator. It dissipates the heat conducted both by the lower input cooling pipe and the heat absorbed from the column vapors by the water as it passes through the column on its way to the condenser.

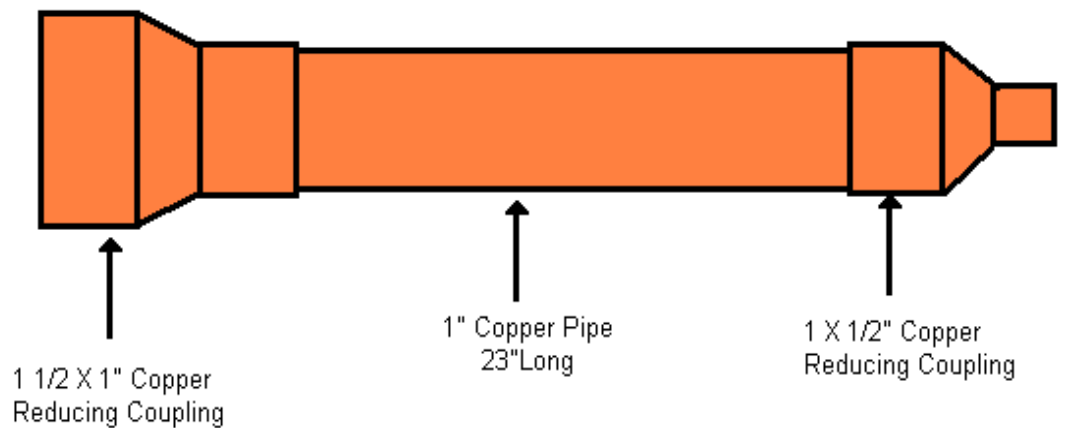


Those are the reasons why the big, jacketed condenser we are going to build for this job is better. Its also happens to be easier to fabricate and more efficient than those condensers which use a coiled tube contained within the distillate output pipe.

The first step in building the condenser is to fabricate the core assembly.

*The Condenser Core*

Here's a drawing of what we want to make first. It's the condenser core. It's made from only three pieces:



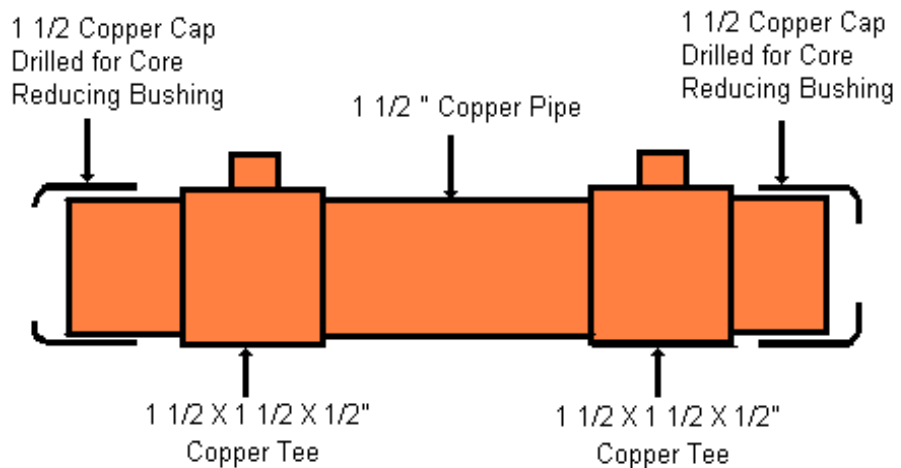
To make the core you begin by soldering together a 1 1/2" X 1" reducing coupling to a 23" length of 1" pipe. Be sure to clean the fittings and pipe with sandpaper or a stiff wire brush so it shines. Then brush on some flux to both pieces, and use lead-free solder. When you heat the joint enough with a torch, the solder will be sucked up into the joint. While the solder is still runny looking and shiny, wipe the joint with a clean rag. Makes a nice finish on the joint. Then solder a 1" X 1/2" reducing coupling on the other end in the same way. When you get done, it'll look like this:



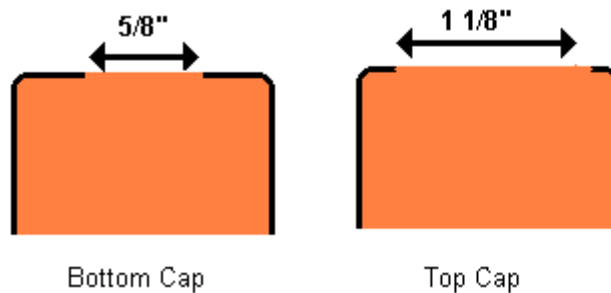
***The Condenser Jacket***

The next step is to build a jacket that fits closely around the core. That will allow a thin, fast moving, layer of water with a lot of surface area to circulate around the core, and quickly absorb the heat. In turn, it also allows the condensation rate (both internal and external) to react as quickly as possible to changes in the water flow.

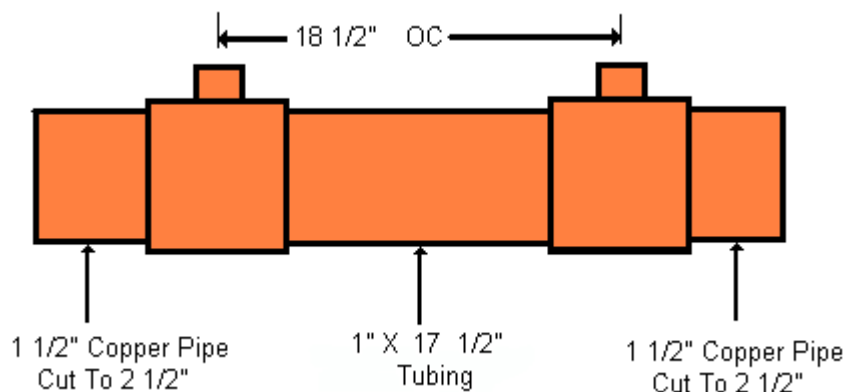
Since the column output is made of 1 1/2" piping, we have to reduce this down to 1" piping for the core (above), and then make the jacket out of 1 1/2" pipe. That will leave a 1/4" space surrounding the core for the water to circulate. To do this, we have to do some strange things to the end caps of the jacket, so that it will match the underlying core plumbing. Here's what's involved:



One cap has a 1 1/8" hole drilled in the end, the other cap, a 5/8" hole. The hardest part is to cut the right size holes in the caps so they will fit nicely with the core.

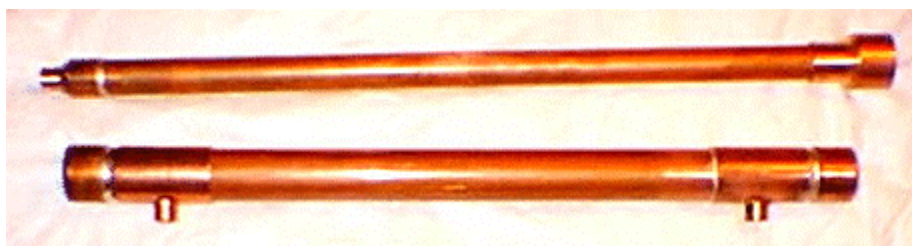


When the caps are done, you have to cut two nipples of 1 1/2" pipe each 2 1/2" long, and a piece 23 1/2" long for the main jacket. When you assemble the jacket, the 1/2" reducing tee outlets should be 18 1/2" on center. This is not a critical length, but later on you will see that it is important to insure that the cooling tube holes in the reflux column match this dimension.



The more important dimension is the overall jacket length. When the core is placed inside the assembly, it should fit snugly at both the top and bottom caps. You can adjust the length of either one of the nipple fittings (before you solder them) to make any fine adjustments.

Now you can complete the assembly by putting the core assembly through the holes in the jacket end caps, making sure the Tee's are centered along the length, and soldering all the joints. The core and jacket should look like this just before putting them together.

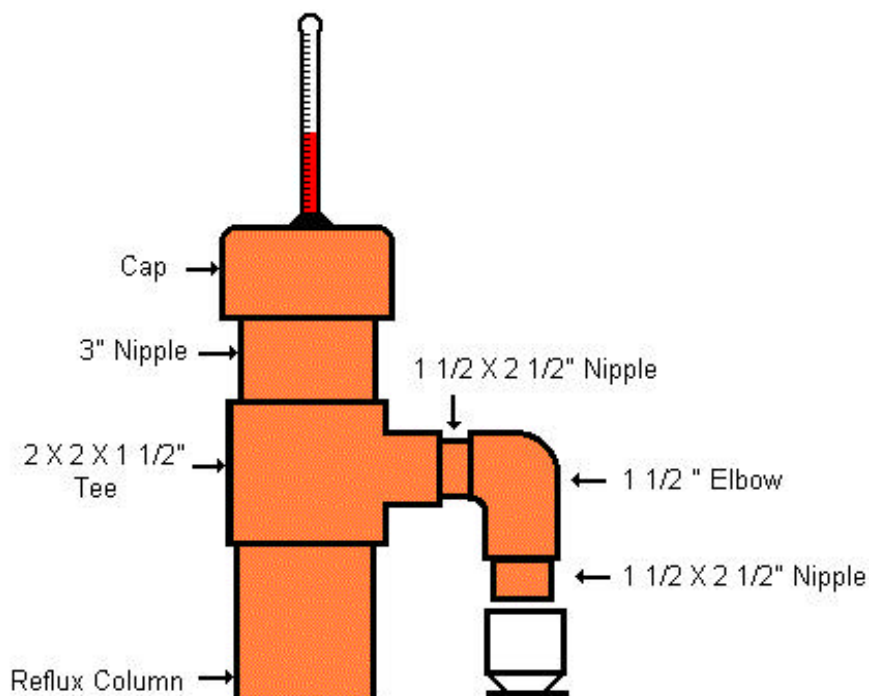


## Building the Reflux Column

The reflux column is the tube that runs straight up from the top of the boiler. The column is made from 2" copper tubing, is about three feet long, and has a thermometer mounted in the top cap. It is packed with Raschig rings (described later) to provide a large area condensation surface inside the column, and it has two cooling tubes that pass water through the vapors that rise through the column from the boiler. It also has a Tee connector at the top to accommodate an elbow connection to the condenser, and a screen at the bottom to keep the packing from falling out.

### *The Column Head*

The column head section consists of a cap, a thermometer, a 3" long nipple, and a 2 x 2 x 1 1/2" tee. It also includes a connection to the condenser assembly with two 1 1/2" x 1/2" nipples, and a 1 1/2" x 1/2" elbow. A drawing of the assembly is shown below:

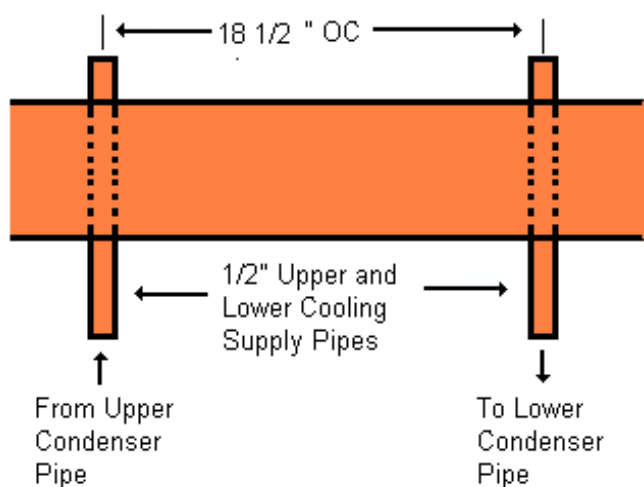


The cap is drilled in the center with a 3/8" hole to fit a rubber grommet and the thermometer stem. Not all stems have the same diameter, so you should make sure the hole fits your thermometer. The cap is *not* soldered to the column. This is to allow the column and packing to be back flushed and cleaned out by simply taking off the cap and hosing down the column.

### *The Column Body*

The column body is made of a 3 foot section of 2" copper pipe. It attaches to the 2 X 2 X 1 1/2" Column Head Tee on the top, and to the boiler (or flange) on the bottom end.

Two 5/8" holes are drilled on the center-line of the pipe, through both sides of the center section of the column. The two holes should be about 18 1/2" O.C., but more importantly, they should match the upper and lower cooling tubes coming from the condenser. You should use a drill guide (or drill press) to insure that the holes are squarely in the center of the tube, and on the same line along its length.



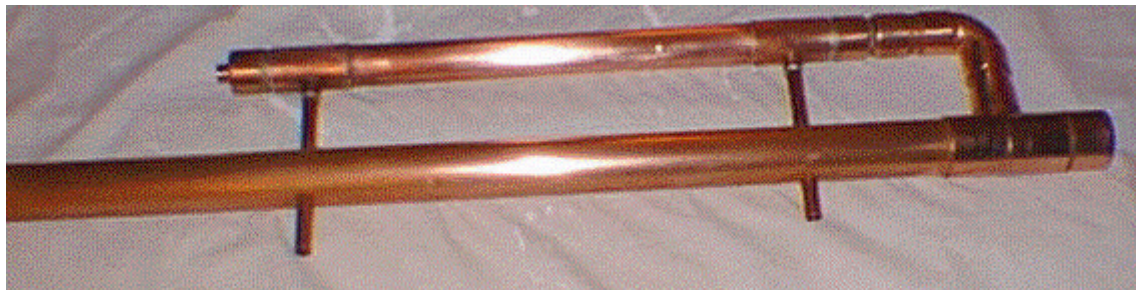
When the holes have been drilled, clean up the top end and solder the Tee fitting, nipple, and the middle section together. Then install the 1 1/2" nipples and elbow to the tee connection. Do *not* solder these yet. They must be left free for final fitting of the condenser assembly.



***The Tower Assembly***

Line up the two 1 ½ X 1 ½ X ½” tees on the condenser with the cooling tube holes in the column body, and install two

7” lengths of ½” tubing through the column and into the condenser tees. You should have a tower assembly now that looks like this.



Make sure everything fits OK and aligns well. When you’re satisfied, remove the cooling tubes and condenser. Clean up and solder the 1 ½” elbow and nipples to the column tee. Finally, re-install the cooling pipes to the condenser to assure its alignment, and solder the remaining joints.

***Mounting the Tower***

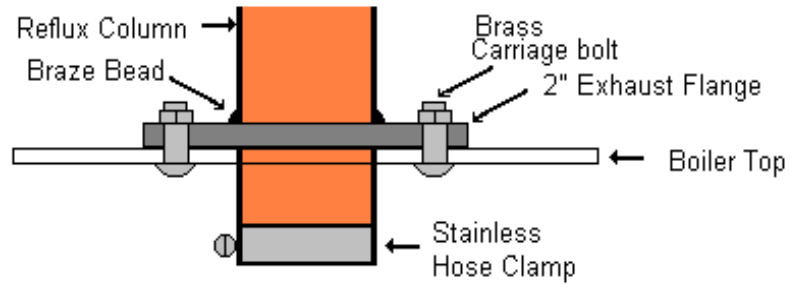
The next task is to install the mounting flange or coupling to the bottom of the column, and cover it with a screen. There are a number of ways to do this, and in many cases, it will

depend on what kind of boiler you have selected.

Attaching the column is much easier if the boiler has a removable top, but no matter how you decide to do it, make sure that you can easily detach the tower from the boiler for clean up.

The column should extend about an inch or two below the boiler cover so that brass screening can be used to cover the end. The screen keeps the tower packing (Raschig Rings) from falling into the boiler. A stainless steel hose clamp secures the screen to the bottom of the column.

A typical attachment under these conditions is shown below.



If your boiler doesn't have a removable top then you will not be able to use this method of assembling the column to the boiler.

The easiest alternative in that case is to have a short nipple of 2" copper tubing MIG welded to the top of the boiler. This will allow a union to be attached near the bottom of the column and allow the column to be removed at that point.

You will also have to install the screening at the bottom of the column in a different way so that the column pieces can be attached at the union joint. One approach is to solder a small mounting strap to the inside of the column, and attach a perforated sheet metal disk to the strap with a small sheet metal screw.

Because the boiler I selected has a removable top, there was no need to bolt and unbolt the column to clean it. You may do this though, to avoid MIG welding. I brought the cover and column down to a friend with a MIG welder. He cut the 2 1/8" hole in the cover, and welded the copper column to the stainless steel cap. It really looks pretty. I bought him a case of beer.



## *Column Packing*

To wrap the construction phase up, the column has to be packed with something for the vapors to condense on as they pass up the tower from the boiler. There are a lot of things you can use to pack the tower. Recommendations range from marbles, glass beads, copper or stainless scrubbing pads, to broken automotive safety glass and others.

Packing is a poor word to use for this material. It implies a dense filler. What we really want inside the column is something that won't pack, burn, melt, dissolve, or release impurities or poisons into the vapor in the column. We also want that material to have as large a surface area as possible, and at the same time offer as little resistance to the gas flow as possible. It should be easy to clean, and above all, it should not settle or pack down in the column.

And while that is a pretty tall order, there is a product that satisfies all these requirements. The product is called Raschig Rings. They are tiny (about 1/4" diameter) hollow cylinders made of glazed ceramic material. They are perfect for this kind of tower. They look like this.



From Partyman SA

In any event, fill the tower with your packing to just above the top cooling tube. Put the cover cap on, and attach the cooling hose couplings with stainless hose clamps.

At this point the real construction is over. Your still is complete except for a few finishing details, like heating and cooling issues. We'll cover that next.

## Heating Considerations

**N**ow that the construction of the still is complete, the last remaining consideration for operation is the heat source.

Initially you will have to decide whether to use electric or gas to provide the heat source to the boiler.

### *Electric Heating*

Electric immersion heaters are readily available for hot water heaters in either 1500 or 3000 watt sizes. But regulating the heat delivered to the boiler from these devices requires a very expensive voltage controller. The electric heaters also require a separate 120/240 volt source to operate, and respond very slowly to controls that would regulate the boiler temperatures. They also have to be mounted inside the boiler (a messy thing to clean) and the wires run to the outside (a hard thing to seal from leaks).

For safety's sake all electrical work should be done in accordance with the building and electrical codes, and is best handled by a licensed electrician.

External electric hot plates avoid the internal mounting problems, but they are less efficient, and in the US, generally limited to about 1600 watts on a 110 volt house circuit. That is inadequate for larger boiler sizes.

On the plus side, electric heating is better suited for indoor use. It is cleaner, safer (if wired in accordance with electrical codes), needs no venting, and provides less risk of alcohol fires or explosions.

### *LP Gas Heating*

Bottled LP gas, on the other hand, avoids many of the boiler fabrication and cleaning problems associated with electric heat.

Adjusting the heat level with Gas controls is much more flexible. The heat can easily be adjusted to any setting from off to maximum, unlike the typical Low, Medium, High settings on electrical switches.



A gas heat source will also react much more quickly to control changes than electric, and is capable of producing far more heat than electrical household circuits can supply.

Gas also makes the entire apparatus much more portable. That portability gives you the freedom to move the whole setup out to the garage, barn, utility shed, deck, backyard, or even the deep woods. That way you don't have to smell up the basement or garage (and the house) with the odors from whatever you might distill in the boiler.

A small 15,000 BTU cast iron outdoor cooking burner can be bought for under \$15.00 that does an excellent job. It will bring 7 ½ gallons of cold (4° C.) water to boil in less than an hour.

The downside is that gas heat, in a confined space and without proper ventilation, will deplete the oxygen in the air. It can also produce dangerous carbon monoxide if the burner is not adjusted properly. Lastly, gas heat is much more likely to start alcohol and combustible fires if great care is not taken.

## Putting It All Together

### *Shakedown*

A word of caution is necessary before you make the first trial run. Distillation may involve the use of high heat, electrical connections, open flames, boiling liquids, and perhaps explosive gas mixtures. All of these can cause serious personal injury, fires or even explosions if you do not take precautions and give a lot of thought to these things.

If, even after these warnings, you decide proceed with the distillation of highly flammable substances such as alcohol, remember that it is akin to boiling a pot of gasoline on top of your gas stove at home.

The test of the apparatus should be a trial run in which a gallon or two of water is distilled. The test will verify that the joints don't leak that there is sufficient heat input to do the job, and enough cooling control to control the distillation. It will also allow you to check the distillation rates and the warm up time.

To start the run, mount the boiler on top of the heat source, and fill it with a gallon of tap water. Then connect the cooling hoses on the column to the water supply and drain, and attach the column to the boiler. Do not allow the cooling water to circulate through the apparatus at this time.

Turn on the heat to its' highest setting and insert the thermometer in the top of the column. The bulb should be seated to the level of the upper column tee connection (where the vapors flow to the condenser).

In a short time (about 15 minutes) the water should be boiling to the point where vapor and liquid can be seen exiting the condenser, and the thermometer indicates that the boiling point temperature (100° C..) has been reached in the column. Note how long it took to boil so you can estimate the time for larger amounts.

Turn the heat down to a rolling boil, and slowly open the cooling water circulation valve just enough to stop any vapor from exiting the condenser. The distillate that runs from the condenser should be warm to the touch. This represents the maximum effective rate that the still can deliver under these circumstances.

At that point measure the time needed to collect exactly 250 ml of distillate. This should take about 7 or 8 minutes.

When that's done, slowly open the circulation valve until the distillate stops running altogether. Let the system continue in that state (no output) for about 15 minutes to verify its ability to operate under total reflux conditions.

When you've verified this point, it's time to shut the system down. You should always follow a sequence in these operations in order to avoid imploding the boiler and column. The shutdown sequence is:

- ⌚ First remove the thermometer cap from the top of the column (use gloves, it may be hot, and avoid burning yourself with the vapors coming out).
- ⌚ Next turn off the heat.
- ⌚ Finally shut off the cooling water circulation.

This is important, because if you are using plastic tubing to collect the distillate from the condenser, it could get kinked or obstructed in some way. That would seal off the apparatus from the air. If this happened while it was cooling down, a vacuum would be formed within the still as the vapors inside condense, and the air pressure outside could crush the unit.

When the unit has reached room temperature, disconnect the cooling hoses, back-flush the column with water then remove the top end from the boiler for cleaning.

Now that we know how to run the still, it might be a good idea to give some more thought of how to optimize the distillation.



### *Column Tuning*

Whenever you try to maximize the purity of the distillate in the least amount of time, you have to deal with the amount of refluxing needed.

In operation, we allow only a small part of the distillate output to be withdrawn in a unit of time. The remainder is re-cycled back into the column. This controls the amount of refluxing. The proportion of distillate returned to the column versus that which is withdrawn is called the Reflux Ratio.

In theory, the more reflux cycles that are allowed to take place the purer the output will be. In other words, high reflux ratios produce more refined products.

In practice though, you will find that as you increase the reflux ratio more and more, it produces less and less improvement in the purity of the output. You soon reach the point where the whole operation becomes counter productive in terms of the time and heating costs to produce the distillate.

It's also important to recognize that no matter how many reflux cycles are applied to the process, you will never be able to get a completely pure distillate.

Under the circumstances then, your goal in operating the still should be to produce a purer product than what you can buy commercially, and at the same time produce the product at the least cost.

All this then comes down to the big question:

**“What is the best reflux ratio to use in my still, and how do I regulate it?”**

The system we are building controls the reflux ratio by regulating the cooling flow inside the column. We calculate the reflux ratio by measuring the maximum distillation rate at a given heat level without cooling, and then regulate the cooling to provide an appropriate fraction of that rate.

Suppose, for instance, you can distill 1 liter/hour at a given heat setting without any cooling, and you want a reflux ratio of 3 to 1. Then you simply adjust the cooling flow (without changing the heat) to the point where only 250 ml of output is distilled in one hour. That means for each 1000 ml of distillate passed in a unit of time, 250ml is withdrawn, and 750 ml is refluxed. That gives a reflux ratio of 3:1.

Coming back to the key question “What’s the best reflux ratio to use?” It depends on the column design, what’s being distilled, an assessment of the output purity, and an evaluation of the costs involved in producing that purity.

It will take some experimentation on your part to get exactly what you want.

If you want to distill ethyl alcohol for instance, your best bet would be to start with a reflux ratio of 3:1 with this still. Commercial operations, I’ve been told, use ratios ranging from 1.8:1 to 5:1 for distilling this product.

Under normal conditions then, and using this ratio, you should be able to produce a crystal clear, totally odorless, 190 proof spirit from a 20% beer in a about 6 hours of distillation.

In any event, you have complete control over the refluxing with this still, and the only limitation you will face is the desired degree of refinement.

That is much more than can be said for most small scale stills.

***The Last Words***

Well it's done. We've started at scratch, learned a little along the way, maybe got involved enough to actually build the still, and maybe even went further.

For me, it's been a lot of fun, a great experience, and a continuing adventure. For those of you who have traveled the entire course, I hope you are pleased with the results. More than that, I hope you get involved enough to improve on this basic apparatus and let others know about it so that they too, may profit from your experiences.

Who knows, with enough interest from those of you reading this, perhaps some of the more insensible laws of the land can be changed. And if they can be changed simply because you get involved, then you will have made a great contribution by giving everyone a bit more freedom to pursue those interests that do no harm to their neighbors.

In any case, with the apparatus you have just constructed, you will be able to isolate, and perhaps enjoy, many of the refined compounds derived from your distillation apparatus. That, for many, is reward enough.

# Appendices

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## Material List

### **2" Copper Materials**

1 Tower Body 36" Long  
1 Cap Nipple 3" Long  
1 Tee Fitting 2 X 2 X 1½"  
1 Cap Fitting 2"

### **1½" Copper Materials**

4 Nipples 2½" Long  
1 Elbow 1½ X 1½"  
1 Reducing Coupling 1½ X 1"  
1 Condenser Jacket 17 1/4" Long  
2 1½ X 1½ X ½" Tee Fittings  
2 1½" Caps

### **1" Copper Materials**

1 1 X ½" Reducing Coupling  
1 Condenser Core 23" Long

### **½" Copper Materials**

2 Column Cooling Tubes 7" Long

## Tools

The distillation apparatus described in this book was built with the common hand tools found in the typical handyman garage (or apartment for that matter). They are separated into two categories in terms of ease of use and time saved.

### **Essential Tools**

Hacksaw

Measuring Tape

Electric Drill & Guide

3-4" Bench Vice

Compass

Metal Drill Bit Set

Round File

Propane/Mapp™ Gas Torch

Sand Cloth/Steel Wool

Lead Free Solder/Flux

### **Nice to Have Tools**

Pipe Cutters (1/2" - 2")

Drill Press

Workmate®Bench

5/8" and 1 1/8" Metal Hole Saw

Dremel® Tool or Die Grinder

Brazing Torch Set Up

Copper Joint Cleaning Brushes

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