Arc - Automatic Reflux Control

The purpose of ARC is the automatically control the reflux ratio in the column without any electronics. That makes it a little easier to produce pure alcohol, the still regulates itself and you don't need to pay much attention to it. With good height of the column (something like a meter) and good packing you won't get any tails at all. The still will stop by itself at the end when the alcohol is gone in the boiler.

So the operation with ARC makes life easier:

- Remove heads as usual
- Change collecting vessel and let ARC take care of the rest.
- The purpose of this document is to explain how ARC works.

To understand the drawings you should get a basic understanding how a still works to begin with. Please take a look at Rikus building instructions for arc found in the photos area in new distillers while you look at the drawings here. It is always easier to get an understanding on how it works when you see real pictures of the thing.

Controlling temperature, the basics:

To make good tasting ethanol you need a good column and good packing. At the top all vapors are condensed and some of that liquid it is returned to the still, the reflux. The reflux is really important for a still, if you have none, the packing doesn't do anything, it doesn't matter how tall your still is or how advanced packing you use, if it doesn't get enough reflux you get poor quality and weak strength. The more reflux you let it have the better it separates. Best is full reflux, but at that point you are getting no product at all, so the drawback with high reflux ratio is poor speed.

How do you know your still have enough reflux ratio?

Watch the temperature at the top, if it's 78.1 C you have enough to get strong alcohol. But to make sure that you got high quality you need to make sure that the temperature a bit down in the column is close to 78 C as well. The best place to put a thermometer is a bit down in the packing if it's vodka production you want.

Another way to see why you need reflux ratio is to take a look at the boiler, in the boiler you have mash or whatever you distil. The vapor from the boiler feeds the column with alcohol and water. If you remove slowly at the top you can get 96% even though the boiler feeds the still will low strength alcohol. But if you open your production valve at the top much you will remove alcohol faster than the boiler will provide the column with new alcohol. You'll drain the column, and it won't take long before you get weak product.

As the run goes on, the alcohol level in the boiler will decrease, it means that the boiler will provide the column with alcohol at a decreasing rate. That means that you have to adjust your reflux ratio accordingly to make sure you have enough reflux ratio to get high strength. Most people simply set

the reflux ratio quite high from the beginning and change vessel for tails when the run is close to the end.

Instead of manually set the reflux ratio you can use some kind of device that checks the temperature a bit down in the packing. If it gets warm there it adjusts the reflux ratio to decrease the production rate and temperature goes back down. It's important to check the temperature a bit down and not at the top, because if you check at the top and the temperature is too high it's already too late, product is already getting bad. You need to make sure you have high strength a bit down in the packing as well to make sure the quality is good. If you measure a bit down you won't need to have as sensitive equipment, actually a thermostat is good enough.

So what's wrong with manually set reflux ratio?

Nothing, but you need to watch your still so you can remove tails in a separate vessel. If you don't you will spoil the good quality alcohol you did get earlier in the run.

With some kind of automatic system, you can skip that part, if the column is good you actually get high quality stuff to the last drop. And the still will stop by itself when there is no alcohol left in the boiler. It simplifies the distillation process.

Instead of using electronics and solenoid valve or whatever to regulate reflux ratio you can take benefit from the fact that high strength alcohol has a low boiling point. This is how ARC works. High strength alcohol is fed to a pipe; the pipe has contact with the column a bit down. If the pipe is hotter than the boiling point of the alcohol, the alcohol in the pipe will boil.

Explanation of the setup:

A boiler, 25 liters or whatever. Use a column 1" or more. I would recommend using at least one meter packing, the more the merrier. The top condenser can be whatever you like, cooling coil and so on. Then something to collect the condensate in the top, I recommend a SR head.

The green part in the drawing is the ARC. It's made of two pipes. The thick green line marked "1" in the drawing is a tube, 8-10 mm, product from the SR head enter this tube. It is soldered onto the column and the bottom of the tube is sealed. The length of the tube is about 40 cm. This pipe is from now on called the sensor tube.

A hole is drilled in that tube and a 6-8 mm tube marked "2" in the drawing is soldered in place, it is bent in a U bend to make a liquid lock. This pipe is from now on called product tube.

How it works:

To begin with, before the mash has started to boil, the packing and column are cold. When the mash starts to boil vapor enter the cold column. Some vapor will condense immediately and that condensate vaporize again when it's heated from the rising hot vapor coming from underneath. More and more of the column will be heated until finally the vapor enters the top condenser. Actually, the first vapor that reaches the top condenser is already 96%. If you would take a look

inside the column at this point you would see that at the very top you got 96%, just underneath the top the strength is lower and temperature is higher.

Now take a look at the sensor tube, it is soldered onto the column and the bottom part of it is a bit down on the column wall. Since it soldered onto the column it'll heat up along with that. The bottom part of the sensor tube is already over 78.15 C when the first vapor starts to condense in the condenser.

96% alcohol from top condenser runs down on the SR and that liquid goes down into the sensor tube. The sensor tube will quickly be filled with alcohol. But the bottom part of the tube is hot and that'll make the alcohol in the tube boil. When it does so the vapor will push out all liquid back into to SR head the same way it came in. The effect in the tube is similar to how a percolator works.

The only way the liquid can go is back into the column via the middle pipe in the SR head. Alcohol will enter the sensor tube over and over again and be pushed back all the time.

So the still is now at full reflux, no product comes out. When the still is at full reflux ethanol will accumulate in the column from the top and down, more and more ethanol will accumulate and when it does so the temperature in the column starts to drop from the top and down.

The sensor tube will also drop in temperature since it has the same temperature as the column (or close to), and eventually it'll be at about 78C.

What happens then?

Alcohol will try to get down in the sensor tube all the time, since the tube now has the same temperature as the alcohol it won't make the alcohol boil. Sensor tube fills up and product comes out via the product tube.

You get pretty high flow from the product pipe. Reflux ratio is zero. The accumulated alcohol in the column now gradually starts to come out as product. The temperature starts to rise from the bottom and up in the column. When the bottom of the sensor pipe gets hotter it'll make the alcohol boil again. Alcohol accumulates in the column and the cycle continues over and over.

Notice something important here. The sensor tube reacts to the temperature that is a bit down in the column. By doing so it reacts before the top strength has changed. So at the top the strength will always be at its maximum. The column part between the bottom of the tube and the top will be a buffer zone where strength it kept high, this part fine polish the spirits to ensure that you get high strength high quality spirits.

When you distil with this setup, you get high product rate to begin with, and as the run goes on the production rate will drop more and more. It takes longer time to accumulate alcohol in the column since the vapor from the boiler contains less alcohol.

At the end:

Finally you will be at the point when no more product comes out. The sensor pipe will pump alcohol back all the time. No more alcohol is left in the boiler (or very little).

One of the greatest benefits of this setup is that you get no tails and you get fine quality to the very end. To make that work it is essential that you use a tall column with good packing. At the end you will have two zones in the column, at the top and down to the bottom of the sensor pipe the strength will be 96% below that it'll be gradually less and at the bottom of the column the strength is close to zero.

Then it's time to turn it off. If you want to you can add a thermometer in the boiler. When it reaches 99 or so it's about time to turn it off. Not worth the time to force the last alcohol out of the mash, but that's up to you.

The top of the column will contain some high strength alcohol that is lost when you turn off the still, let that be. Don't try to remove it to squeeze out the last of the alcohol at the end. The amount buffered in the column isn't much at all. Since the top of the still never has bad quality the packing here never gets tainted with fusel oil and you wont have to clean your packing ever.

Some general advice on how to build it:

The column:

As I mentioned it has to be tall, make it as tall as you can, at least a meter with packing unless you use some really nice packing like heli-pak. Use good packing and pack it evenly if you use scrubbers. Please don't pack it too loose.

Use moderate heat, about a 1kw for a 2" still.

Insulate the column; it is very important that the sensor pipe is insulated. The product pipe should not be insulated.

The sensor pipe:

The further down the sensor pipe goes down on the column the better the quality becomes, you get a bigger buffer for 96%, downside with that is that speed of the still drops.

About 40 cm seems to be about right, but not much testing has been made yet. Also it depends on how good the packing is.

The taller the column part is that is below the sensor pipe, the faster the still becomes. Also it guarantees that the alcohol level in the boiler at the end is close to zero.

In the test I made I used an 8 mm pipe for the sensor pipe. Riku used 10 mm (I think)

A smaller pipe fills faster, it accumulates less liquid so it's easier to get a sharper cut for heads and the alcohol heats up faster, giving the setup better response time, and the ARC becomes more sensitive. But if it's too tiny air might have a trouble leaving the tube and the ARC malfunction. I'm not sure but I think 6 mm pipe will work. Maybe it'll trap air but I'm not sure, definitely worth a try.

Personally I think a smaller pipe works better than a bigger pipe, but I won't guarantee that, Rikus version worked better than mine even though he had larger pipe but it's hard to say why.

Instead of having the sensor pipe soldered on the outside you can have it on the inside on the column, that'll give it very good heat transfer. I haven't tested it myself, but another Swede has, he had trouble getting any product at all, maybe it became too sensitive to temperature change, or he had too poor packing. I'm not sure, but I think it'll work if the packing is good.

Another option is the solder the pipe in a spiral around the column, increases heat transfer giving it faster response time but accumulates more ethanol making it harder to separate heads.

Product pipe:

Make sure to have a U bend on the pipe, otherwise you will get vapor out of the tube. When the alcohol starts to boil in the sensor pipe the action is quite violent, a U bend will make sure that liquid is kept in product tube.

Are there any drawbacks with ARC?

Since you get some ethanol trapped in the sensor pipe and the product pipe it becomes more difficult to remove heads. You have to make a wider cut.

Since the still auto regulates itself you won't have the possibility to run it as a fast stripper. It'll produce 96% and regulate speed.

If you want to use your still as a fast stripper you need to make some modification. The ARC will force the still to produce 96%, so you have to add a separate needle valve to the SR head where you can remove alcohol fast. When you do so, the sensor pipe will be filled with low strength alcohol as well. This can be a problem next time you want to make a fine run and use the arc. The low strength alcohol is left in the pipe and disturbs the mechanism. Add a valve to the bottom of the sensor pipe so you can empty it.

Maybe you can use that valve alone for fast stripper runs, but I haven't tested so I can say for sure.

If you distil high strength alcohol (>30-40%) in the boiler the ARC never kicks in. The reason is that you won't get a sharp temperature difference in the column to begin with because the reflux ratio is so low to produce 96%. Low reflux ratio makes the still get a wider "temperature difference zone", eventually the strength in the top will drop and the strength a bit down in the column won't be much less so the ARC never reacts or it will kick in too late in the run.. The better heat transfer it is between the sensor pipe and column the higher strength you can redistill.

But there is a very simple solution to this problem. On the product pipe, add a needle valve. Regulate it so it reduces flow some, you can still use high speed but just make sure that it reduces flow some. I would recommend using a valve anyway since you want to remove heads slow to get them more concentrated. When you are done with heads removal you open the valve rather much and let the ARC make the fine adjustment.

Also by limiting the product flow you get less temperature fluctuation in the column. If you want to make pure alcohol of pretty bad 80% or so, you need to make sure you have some reflux ratio at the beginning anyway. The valve makes sure you have that and the ARC kicks in after a while when the strength in the boiler starts to drop.

Make sure to add the valve at the right place! On the picture you can see that the product pipe goes down first, and then makes a U turn upwards, on the pipe upwards after the turn is the place to add the valve. If you add it directly from sensor pipe the air in the pipe can't pass upwards to begin with and the system malfunctions. You can add the valve directly after sensor pipe if you add an extra tube for air to escape in.

Alternatives to ARC:

If you want to use electronics instead there are some alternatives that work in a similar way.

LM still with a solenoid valve, regulated by a thermostat. Put the thermostat on the column a bit down; set the valve onto the output. When the temp is too high a bit down the thermostat closes the valve.

Air cooled system with fan (cm system). Put a thermostat a bit down on the column, when the temp is too high it starts a fan that cools down extra on the reflux condenser, reflux ratio increase.

Power regulated cm, use a PID to regulate the temperature a bit down on the column, when the temp is too high, the PID lowers the power input.

Extra cooling water with cm, a thermostat regulates a solenoid valve that cools extra at the top of the still..

Well.. There are a lot of possibilities.

A few last words:

The ARC has only been tested by a few people (sep 2004) and there are some interesting variations available. We'll see, maybe there will be some interesting versions in the future.

Vodka_the_man on the distillers has made a drawing of a version using ARC on reflux instead of product. Not yet tested but it has potential.

Riku is a fast developer and I wouldn't be surprised if he comes up with a better version, or optimized version. Or maybe someone else will.

Anyway, the one in this document works fine and is pretty simple. And don't forget to watch Rikus pictures in the photos department of new_distillers if you want to build one.

Hope you like the idea, when I came up with it I though "hmm.. can this really work?"

When I tested it and saw that it did I was actually pretty surprised myself. To me that showed again that there are still a lot of things to discover in our hobby distillation world. So don't ever think that all is already made. Keep on thinking!