Building an MQL Coolant System, Version 1.7

By R. G. Sparber

A bottle of cutting fluid and a brush can be used to lubricate a cutter and remove chips. This prevents the chips from being re-cut which can cause a bad finish or even break the cutter. It takes constant attention but does work. If manually milling, this approach isn't so bad. You have to be there anyway.

But if you are running Computer Numerical Control (CNC), this task soon gets old. The mind quickly gravitates to automatic means of doing the same job. This is a story of one such system.

I built a modified version of the Minimum Quantity Liquid (MQL) Coolant System designed by Brian Lamb. It is running a 5% solution of Tri-Cool™ mixed with water and is propelled by a stream of air at about 10 PSI.

Total cost not counting the air compressor can be as high as $165. With a well stocked junk box and skillful searching of the web, the cost would be much lower. Many people spent less than $50. This assumes they already have the Tri-Cool.

You can find Brian's article at
https://www.dropbox.com/s/wsggc0nmezotndf/MQL%20sprayer.pdf?dl=0

"Bloomingtonmike" has a video of Brian's design on YouTube
https://www.youtube.com/watch?v=bTRuDzdezbg

and here is a short video of my version in action https://youtu.be/Glx66D3FKVg

For a discussion on how coolant systems work, see the appendix.

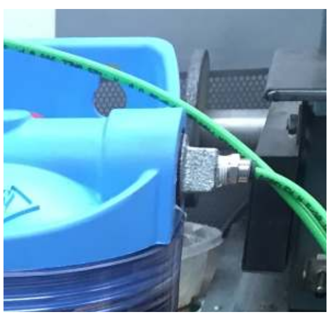
Time for a tour of the **M**inimum **Q**uantity **L**iquid Coolant System.

The MQL Coolant System

Compressed air at about 10 PSI is fed in from the left via a ball valve[2]. Most of this air flows out the T and into the green line.

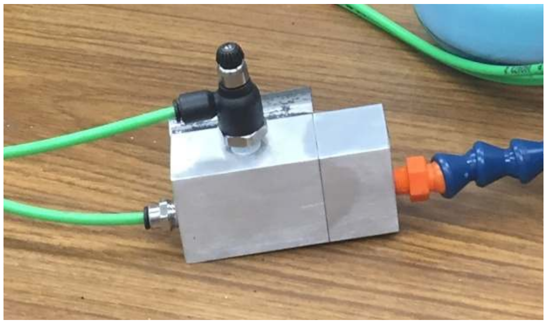
The rest of the air feeds into the coolant tank. This tank is just a whole house water filter housing.

The pressurized air in the tank drives the coolant up the tube[3].

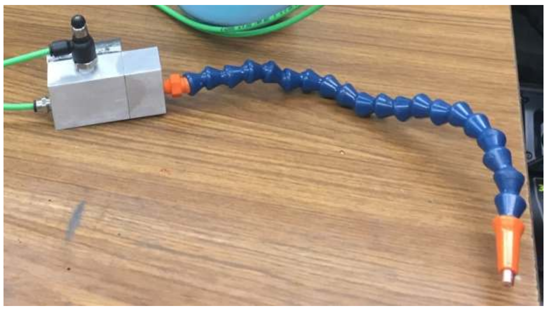


The tube passes through an air tight fitting and out the right side.

[2] I may later add a solenoid so g-code can be used to control the coolant flow.
[3] There is also a partial vacuum generated inside the mixing block (to be presented next).



The mixing block has two inputs. On the top is the liquid line. It feeds into a needle valve making it easy to control the flow of coolant. On the side is the air line. Holes drilled in the block channel the air past the liquid. Due to the Bernoulli's principle, coolant is drawn into the air stream.



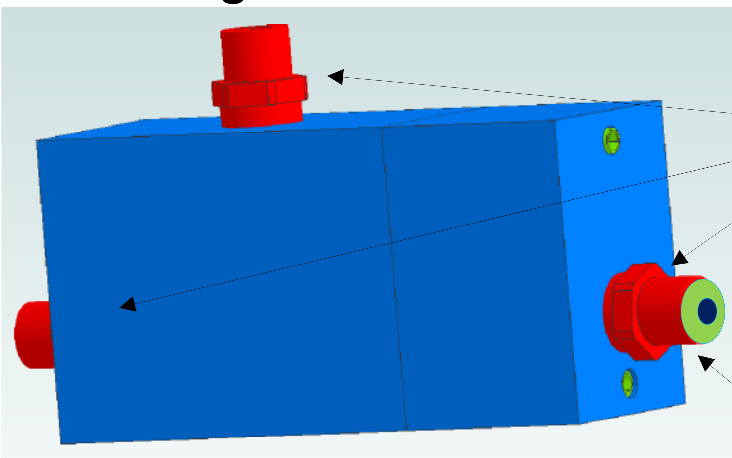
This mixture of coolant and air feeds through the blue ¼ inch Loc-Line™ and out the nozzle.

Note that the Loc-Line only provides mechanical support. The coolant/air mixture flows through a tube inside the Loc-Line.

This mixture can be adjusted from pure air to a very wet spray. How much liquid depends on the material being machined and the rate of removal.

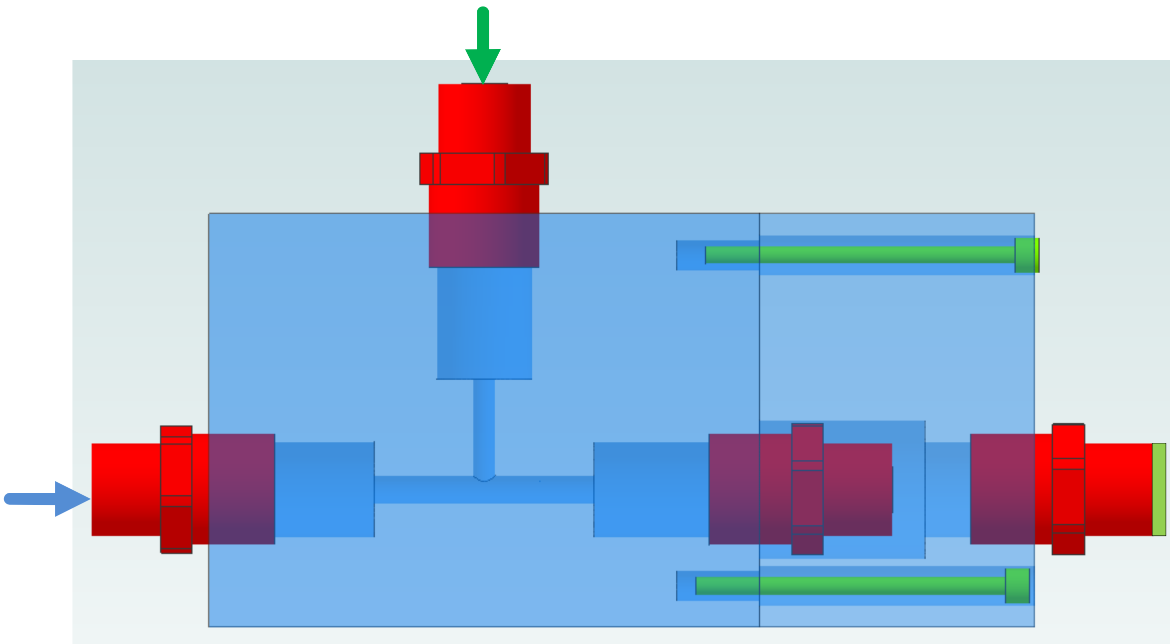
Most of the machining is on the mixing block. You will need a 1/8"-27 NPT tap.

The Mixing Block



This rendering of the mixing block shows the liquid inlet, air inlet, and output.

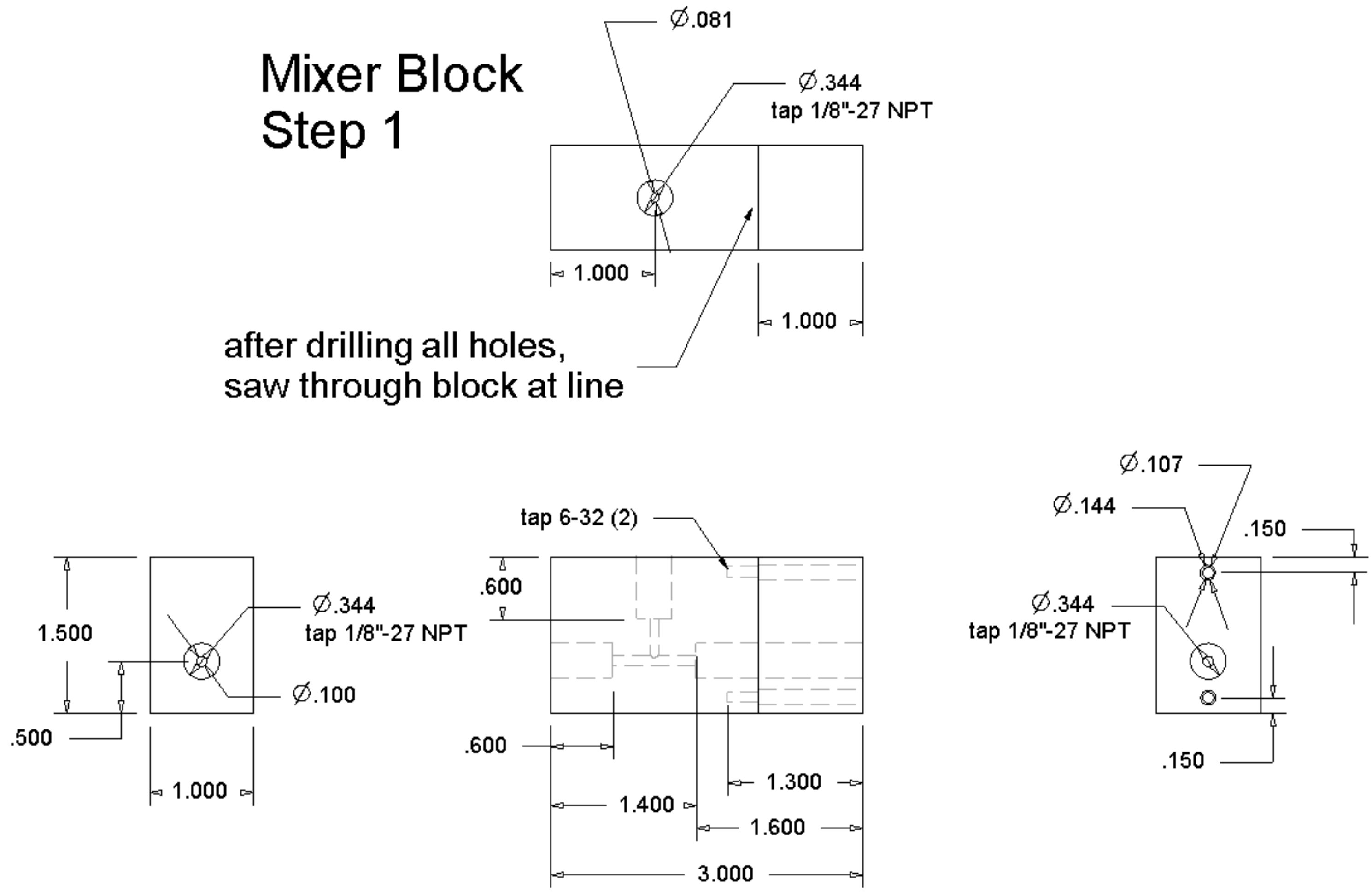
I did not draw the needle valve but it has the same thread as the liquid inlet. I also did not draw the Loc-Line but it too has the same thread.



With the block translucent, you can see the internal passageways. Air flows in from the left (blue arrow), liquid from the top (green arrow). They mix at the up-side-down T and flow out the coupler hidden inside the block. The coupler shown on the far right (with the green rectangle) is part of the Loc-Line assembly.

The horizontal passageway starts out on the left with a 0.344 inch diameter, then it reduces to 0.100 inches before returning to the 0.344 diameter. Next the diameter increases to 0.500 inches before returning to 0.344. You would be hard pressed to find a single drill bit that can cut this variable diameter hole. The trick is to drill a series of holes, slice the end of the block off, and drill another hole. Then bolt the block back together.

Machining the Mixing Block



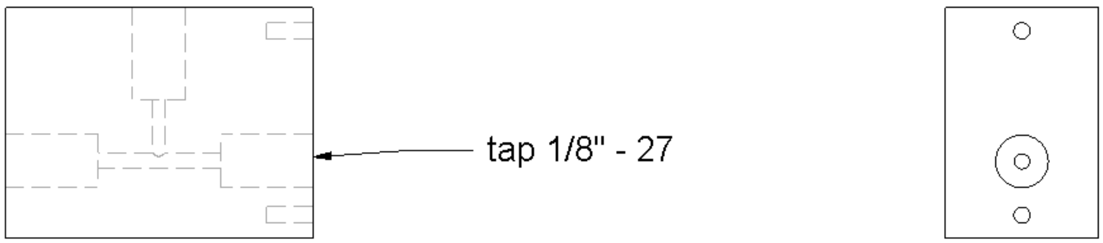
In step 1, I squared up a block of 6061 aluminum. Then I drilled the holes shown here. Although not shown in the drawing, I counterbored the 6-32 holes so the screw heads are recessed.

When done, I sawed 1 inch off the end of the block. Deburr but do not bevel the cut edges. Do not clean up the cut surfaces.

I was not able to cut the threads for the 6-32 holes until after I sawed off the block.

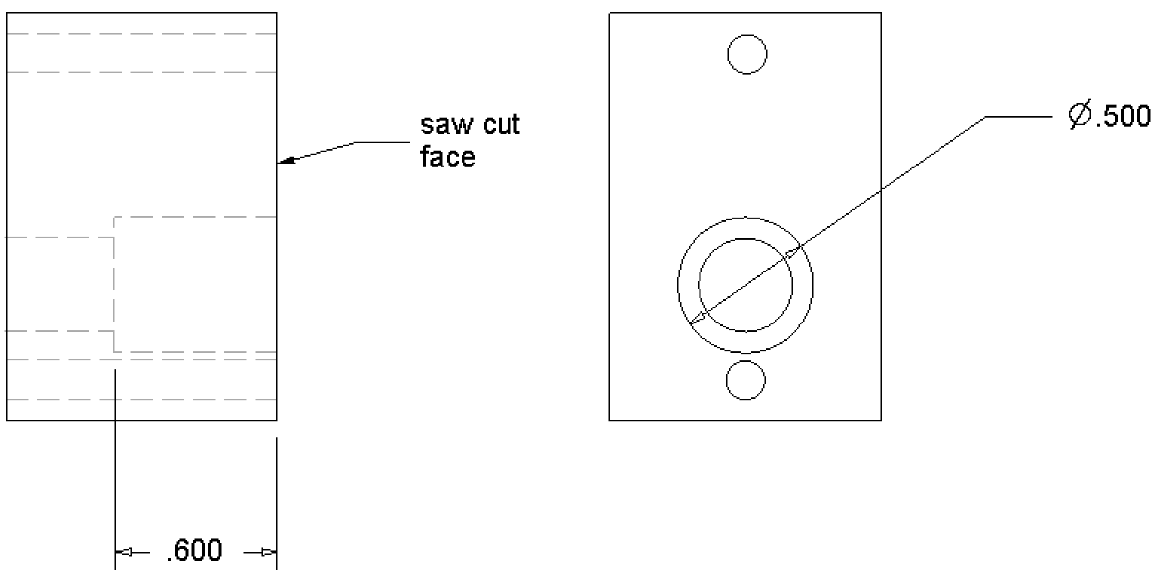
Note that I called for a tap hole of 0.344 inches. Check your tap as it might show a slightly different diameter. Note that the tap cuts a taper. Trial fit a coupler before moving on to the next hole.

Step 2



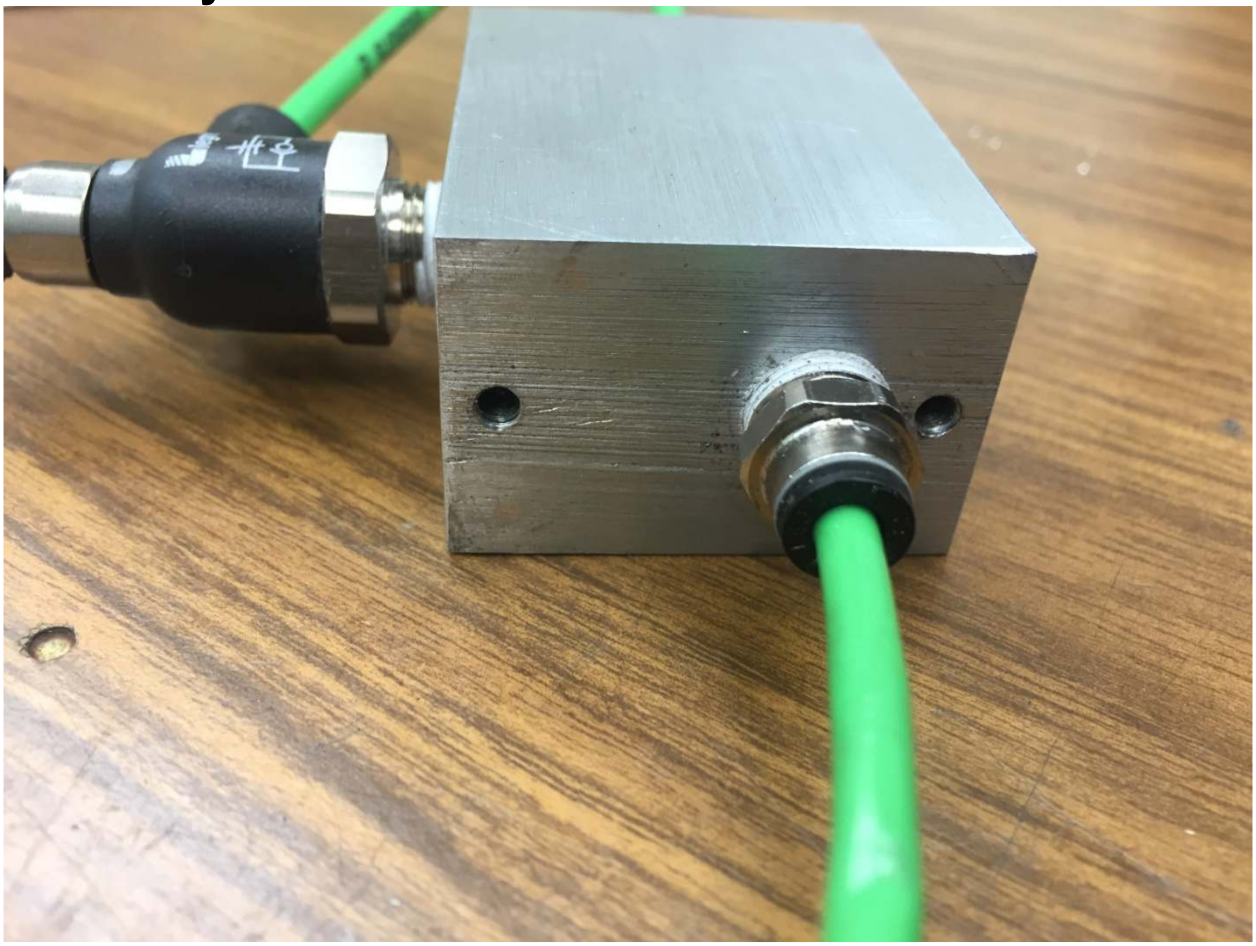
In step 2, I tapped the outlet hole in the larger block. The I trial fit a coupler but this time left it in.

Step 3



Next I drilled the recess in the smaller block to provide room for the hidden coupler. I trial fit the blocks together to be sure the smaller block does not hang up on the hidden coupler.

Assembly of the Mixer Block



Using Teflon™ tape[4] on all threads, I tightly screwed in the needle valve, air inlet, and mixture outlet couplers into the larger block.

[4] My couplers came with thread filler applied so I didn't need to apply tape to them.

I install the two 6-32 by 1.25 inch long SHCS bolts in the smaller block. Then I screwed in the Loc-Line. I turned the hex on the Loc-Line until the flat is parallel to the bottom face of the block. This will give you maximum access to the lower screw head.

The Nozzle and Flexible Arm

I put the 0.035 MIG tip in my lathe and face the end to remove the external threads. Then I used a #25 drill and went in about ¾ of the length of the tip. Using a 10-24 tap, I cut threads as deep as possible.

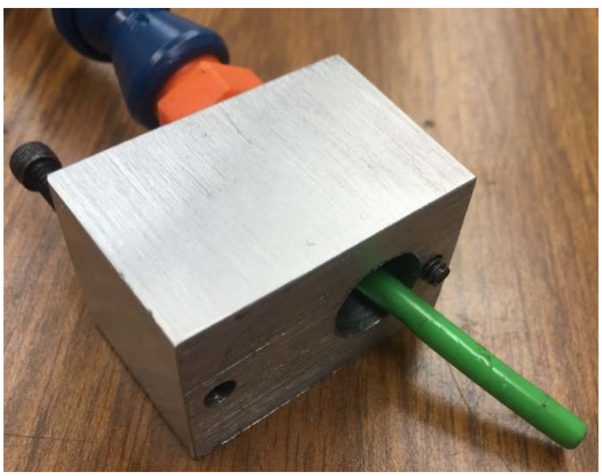
Next I coiled up a handful of tubing and hand feed a 10-24 nut onto the end for about ¼ inch. This formed a shallow thread and made it easier to turn the 10-24 die onto the end. Only need about ¼ inch of thread.

I wrapped Teflon tape around the end about one and a half turns. Finally, I screwed the MIG tip onto the tube. This will insure that no coolant leaks out the back of the tip.

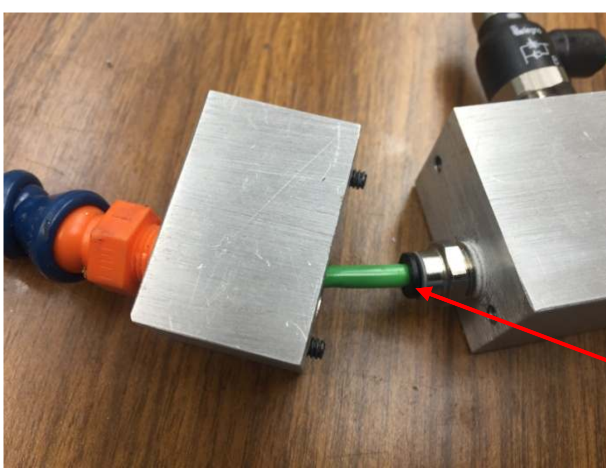
If you read Brian's article, you will see that I made one change that may affect performance. The length of the hole in the tip is much longer in Brian's design. This might change the spray pattern and possibly droplet size. I made this change by accident. Didn't read his text carefully enough. Fortunately, if necessary I can machine a new tip. So far, the error has not caused me trouble.

I needed to remove a small amount of plastic from the inside of the Loc-Line nozzle so the MIG tip can freely slide inside. A tapered reamer fed from the wide end of the nozzle did the job. Very little plastic must be removed.

Then I fished the entire tube through the Loc-Line so the MIG tip is about half way out of the nozzle.



Next I cut the tube off at the block end with about 1 inch exposed.



I pushed the tube all the way into the coupler. Then I slid the smaller block down until it contacts the larger block. The MIG tip rose out of the nozzle a bit. I measured from the end of the nozzle to the end of the MIG tip and subtracted 0.2 inches. This is how much I needed to remove from the tube at the coupler end. I released the tube from the coupler by pushing in on the ring while pulling the tube out.

After trimming off the end of the tube, I inserted it back into the coupler. I Slid the blocks together and tighten the two 6-32 SHCS bolts.

The MIG tip should stick out about 0.2 inches from the nozzle.

The Liquid Tank

I used wrought iron piping except where my junk drawer provided brass. I figured that the coolant does not rust the machine so it should not rust my pipes. Don't forget to use Teflon tape at all joints.

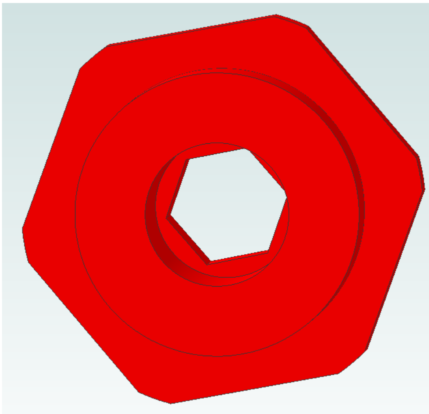
I brought all of the fittings that might work along with the gage and liquid tank to my local Ace Hardware™ store. In no time I had assembled what you see here.

Starting at the left is a quick coupler. My compressor feeds 10 PSI air in here. Next is a ball valve for easy shut off of flow. Then I have my pressure gage. I had a 0 to 160 PSI gage on hand but will be replacing it soon with a 0 to 30 PSI gage. Ideal pressure is around 10 PSI. I also plan to add a pressure regulator.

Next is the T which feeds my air line and the liquid tank. The tank is pressurized at the same PSI as the air line. This probably helps with the flow of liquid into the air stream within the mixing block but is not essential. It is likely the system would work fine if the intake to the tank was vented. However, this arrangement is mechanically very nice. All is supported as a single unit making it easy to move from machine to machine.

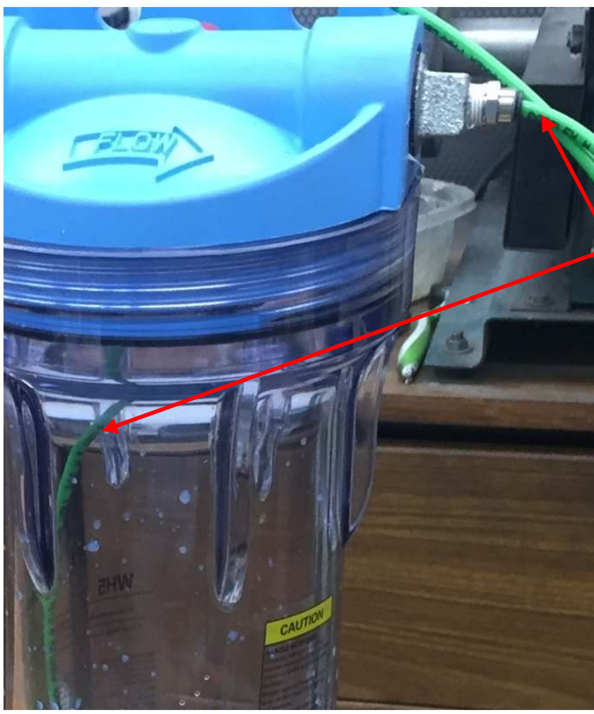
So far, all parts are stock from the hardware store. On the right is a standard plug which has been drilled and tapped 1/8"-27 NPT. There is plenty of metal in this plug so cutting the threads was easy and solid. Sure I could have built an adaptor from stock parts, but this was more compact and saved a little money.

Before installing the coupler into this plug, I modified it.



If you look down the bore of these couplers, you will see a section that grabs the tube. This section both locks the tube in place and forms an air tight seal. The adjacent section is a smaller diameter and has a hexagonal hole. As you push in the tube, this smaller diameter prevents further penetration.

I held the coupler in my lathe chuck so the hex section faced out. Then I carefully drilled in using a #21 drill until I removed all of the hex section. There is a small gap before reaching the tube lock section.

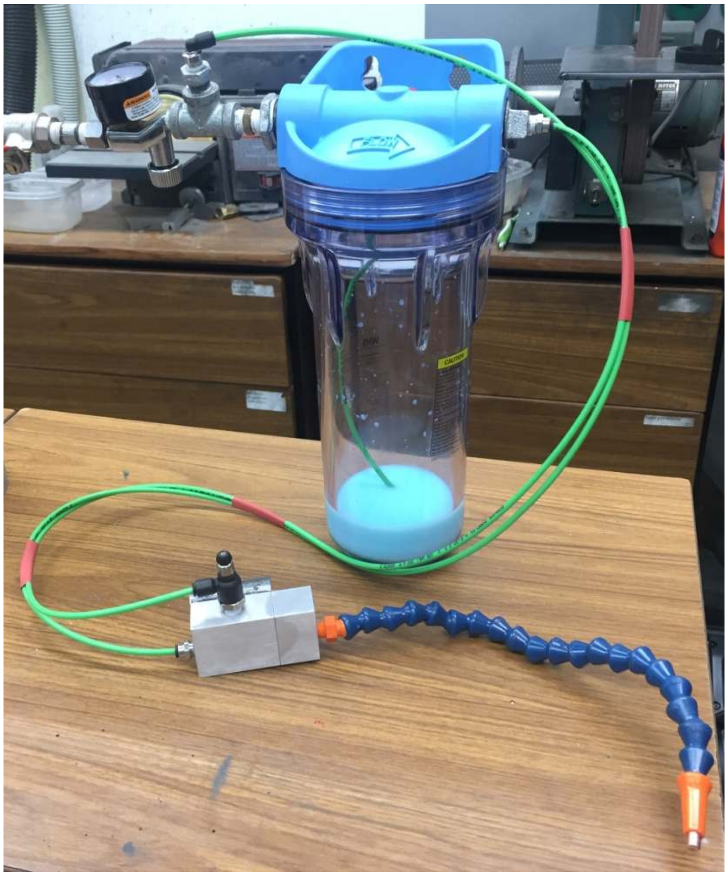


With the hex section gone, I was able to slide the tube through the coupler and into the tank.

Same tube.

You can see here that the tank is rather heavy duty. It was designed to survive fresh water line pressure. Yet our system should not be run much above 10 PSI. Some money could be saved by going with a lighter tank. If you chose to not pressurize the tank, an old milk jug could be used here.

Final Assembly



Time to attach the tubes. The liquid tube goes from the bottom of the tank, out the right coupler and over to the needle valve on top of the mixing block. The air tube goes from the T to the left of the tank to the coupler in the end of the mixing block. Those distances are approximately equal so I just cut my length of remaining tube in half. The tubes were first connected at the mixing block. I slid on 3 lengths of ¼ inch diameter heat shrink tubing but did not apply heat to them. Next I fed the liquid tube through the right coupler and down into the bottom of the tank. A little extra length spring loads the tube against the bottom of the tank.

With the liquid tube installed, I cut the air line to fit.

I plan to use this system on my mill/drill, lathe, horizontal/vertical bandsaw, and maybe even my drill press. That means it must be portable. For now, I have stuck double sided 3M™ foam tape on the mixer block and secured a strong magnet. I have a large magnet that hopefully will support the tank. Time will tell if this works.

While visiting Tim Coppage's shop, we discovered that his MQL system was clogged after not being used for a few months. The problem was solved by removing the needle valve coupler and running hot tap water through it for about 30 seconds.

Bill of Material (source verified 12/24/2015)

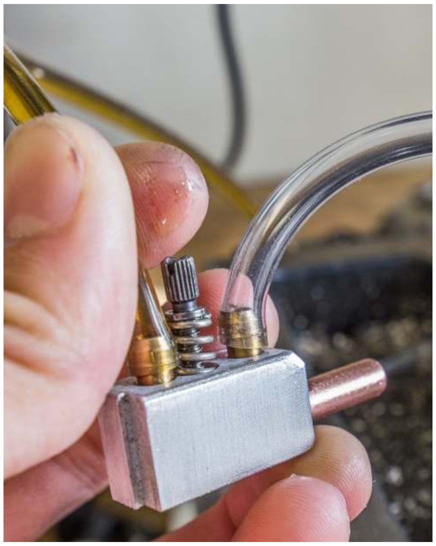
Quantity	Description	Possible Source	Current price[5]
1	Legris 1/8" NPT to 4mm hose 90º fitting	Enco 327-7605	$2.23
3	Legris 1/8" NPT to 4mm straight fitting	Enco 327-7587	3 x $1.81
6 feet	Parker Parflex 5/32" OD x .025 wall hose #003073 2	I was unable to find this product but the same size is available from other manufacturers.	About $15
1	Legris 1/8" NPT Compact meter, in flow control, # 7066 04 011	Amazon.com	$18.00
1	Pentek 158649 1/2” NPT 3G Slimline 10” Clear housing plus wrench to remove tank from top.	Google "Pentek 158649" for multiple sources. Big box hardware stores may also carry it.	$25.00
1	6061 aluminum block 1" x 1.5" x 3"		$2
2	6-32 x 1.25" SHCS		$1
1	¼" Loc-Line #40413	Amazon.com	$9.00
1	0.035 MIG tip	Hardware store	$1
n/a	Various plumbing fittings	Hardware store	$15
1	0-25 PSI gage plus regulator	eBay	$24
1 gallon	Tri-Cool Coolant concentrate[6]	Enco 296-2345	$44.27

With all parts bought, the cost would be around $165. If a friend gives you some Tri-Cool, we are down to $121. Happen to have the tank? Now we are at $96. A well stocked junk drawer would have the aluminum, screws, MIG tip, plumbing fittings, gage, and regulator. Now we are below $50.

[5] Does not including shipping or tax.
[6] This is enough concentrate to make 20 gallons of coolant!

An Alternate Design

Jason Rucks built a similar coolant system from all scrap parts.



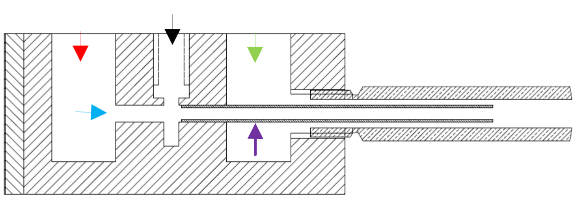
Jason used barbed hose fittings, clear plastic tubing, and a homemade needle valve. On the left end of the mixing block is a dovetail. This permits him to mount the mixing block on a DTI support.

Note that since the mixing block is so small, the nozzle is fitted directly to it.

Ten PSI air comes in through the left hose. Coolant is drawn in through the right hose and controlled by the needle valve in the middle.

The mixing block with nozzle is held by a DTI support on the left.

A section view of the mixing block shows the liquid intake on the left (red arrow).



It flows through a horizontal hole (blue arrow) that runs past the needle valve seat in the center (black arrow). A syringe needle (purple arrow) is pressed into the horizontal hole to channel the liquid from the needle valve into the nozzle. Air is fed into the chamber on the right (green arrow) and flows out the nozzle. The liquid is drawn out of the syringe needle by the venturi effect.

Acknowledgments

Thanks to Brian Lamb for the original design, Tim Coppage for both his insights and many of the key parts, and Dan Benoit for his insights and pointing me to Tim. Thanks to Malcolm Parker-Lisberg for his technical insights related to fluid dynamics and cooling systems. Thanks to John Herrmann for improving the clarity of this article. Thanks to Jason Rucks for sharing his unique and very low cost alternative design.

I welcome your comments and questions.

If you wish to be contacted each time I publish an article, email me with just "Article Alias" in the subject line.

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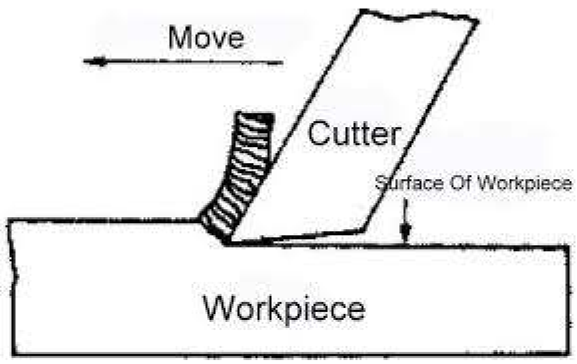
Appendix: What Is MQL?

Thanks to Malcolm Parker-Lisberg for helping me understand the action of lubrication and cooling. The following is my take on this subject. As other experts correct my understanding, I will evolve this text.



A web search for MQL turns up a lot of marketing platitudes but not much concrete information. The best that I can figure is that an MQL Coolant System has two goals: It blasts a low pressure stream of air at the chips to evacuate them while coating the cutter with a thin layer of lubricant[7]. The lubricant reduces friction caused by the cutting action. Less friction, less heat generating. But eliminate friction and the cutting action stops. A balance must be achieved where *excess* friction is eliminated.

There is also a buildup of heat. It must be removed in order to limit the temperature at the cutting edge. If the edge gets too hot, it will lose its hardness and become dull. That causes more friction and things just get worse. So although it is called a coolant system, it is a heat prevention, cooling, and chip evacuation system.

Focusing just on preventing heat, it appears to me that any method that gets the lubricant on the cutting edge would be just as effective. Apparently, spraying a fine mist puts too much liquid into the air and not enough gets on the cutter. By increasing the droplet size, less drifts away and more sticks to the cutter. The spray pattern should also matter since the goal is to just coat the cutter. Furthermore, the nozzle must be placed close to the cutter so some form of stiff yet flexible support is essential.

Then there is the matter of heat removal. With flood cooling, heat is removed by raising the temperature of the liquid as it flows around the cutter. With Mist cooling, heat is removed by changing the tiny particles of mostly water into a steam. Apparently the mix of mist and steam generates fog around the machine. Not healthy and rather messy.

[7] Although I use Tri-Cool, Malcolm recommends canola oil which is nontoxic as long as it is not turned into a mist. You do have to clean it off as it dries sticky.

With MQL, the particles of mostly water are larger than a mist. There would still be steam generated by the conversion of liquid water to steam but it would not be aggravated by mist. Furthermore, coolant is not lost by mist that just floats away.

So the advantage of MQL over mist is no fog generated. Both are capable of effectively removing heat. The air stream carrying the coolant helps to blow chips away from the cutter.