June 4, 2020

K40 Beginner Insights: Q and A for people who have bought or are about to buy a K40 (entries are links)

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Should I buy a K40 at all?

You really owe it to yourself to answer this question clearly and concisely.

The reality is that a K40 laser engraver is not a consumer-level appliance. It is a somewhat-specialized business/industrial tool. It requires that you set up a special place for it to sit and work. It requires some adaptation of the work place where it will sit so it can be fed electricity, cooling water, and exhaust possibly-dangerous fumes. It requires regular and somewhat technical maintenance and cleaning. It requires that internal parts be replaced periodically. It may be electrically and optically dangerous unless you read and follow safety procedures. It can and has started fires that burned buildings. In the most common shipped configuration, it is electrically dangerous and needs internal rewiring for safety reasons.
If and only if you are willing to do the necessary technical learning, technical repairs and adjustments, ongoing periodic parts replacement, and careful, by-the-book operations, you ought to think long and hard about whether you really want a K40, or would rather make things some other way. If you are willing to go learn how to do it right, good. If you don't want to learn to operate and repair it correctly, you are at risk of not only wasting your money, but also hurting yourself.

As alternatives, there are people who will use their K40 or other laser to cut out things from your files for a modest fee, and Maker Spaces that have a laser to use. There are no K40 laser repair shops that I know of, so there's no equivalent of taking the car to the garage or calling the AC repair service. Consider your options. Back to top

What Can a K40 do?

A K40 can engrave by burning on any material that absorbs the invisible infrared laser beam. There is a list of these materials below and a more complete list in the appendixes. It can do this over an approximately 12” by 8” area as it comes from the factory. It can be modified to work a bigger area. It can cut through thin (less than a few millimeters, less than 1/8-1/4”) materials that absorb the beam. These materials have to be flat, because focusing the beam into a tiny spot is needed to engrave or cut. The K40 cannot cut or effectively engrave metals, although it can burn paint and dyes off the top of metals. Back to top

What materials can a K40 engrave and/or cut? What materials should be avoided and why?

In general, materials that absorb the deep infra-red beam (10um) that the CO_2 laser puts out are most affected. Materials that reflect it are not very affected, and the reflected beam can be dangerous to eyes and skin, as well as damaging the laser lens. **Organics such as paper, wood, and organic fibers** absorb strongly and can be cut and engraved. **Glass** absorbs, and can be etched easily, although the K40 will not cut glass. **Stones** generally absorb and can be etched. Bare metals generally reflect and can't be cut. Marking bare metals needs special coatings. **Plastic or paint coated metals** can be marked, but this amounts to burning off the coating under the laser. Anodized and dyed aluminum can be marked fairly easily; this amounts to burning the dye out of the anodized layer. **Plastics** can in general be melted or burned by the K40, but the results depend heavily on the exact materials. **Acrylic** cuts easily and nicely, some plastics only melt and discolor. Plastics and adhesives in composite materials may give off toxic or corrosive gasses. Plastics containing chlorine (poly-vinyl-**chloride**...) emit hydrochloric acid when being lasered, and this will eat the lining of your nose, throat and lungs. It also rusts and corrodes the inside of your laser even if you're properly exhausting fumes.

There is an appendix at the end with many materials and their engraving and cutting ease, and any warnings I've run into. Back to top

Where should I buy my K40? Which vendor? Ebay? Amazon? Other vendor?

There are many "manufacturers" of K40 style lasers. In fact, the term "K40" is best understood as a style of CNC laser rather than a model number. In general, the actual manufacturer of any given K40 is in general unknown. They are sold on ebay, and increasingly on Amazon by either trading companies who did not manufacture them, or importers who buy wholesale lots from either one of the original manufacturers or from trading companies, then do a variable amount of cleanup, alignment, testing and so on.

Often, the total amount of care and quality in a machine is reflected in the price. K40 makers have been in a race to the bottom on price for some years now, so there is always a fight to be the cheapest on ebay, and sometimes on Amazon. The more care and effort expended in pre-testing and setting up a K40, the more you can expect it to cost. And advertising is, after all, advertising.

There are some people who report receiving a K40 which could be used right out of the box with only the minimum necessary set up of cooling water, exhaust air and checking for safety and water leaks. There are also people who receive dented boxes, cracked laser tubes, units with alignment and focus problems, loose belts, or simply non-functioning electronics. Most often, the cheapest ones can be expected to have more problems. Of course there are very high price bad ones too. It's a difficult and opaque issue. At the end, you pays your money and takes your chances. Back to top

How much does a K40 laser engraver cost?

Sellers in the US$400 – US$450 range are beginning to provide the "just works" pretested and aligned version more often as measured by posting in forums. In the US$350 to US$400 range, you're taking more chances on getting a not-as-well made and/or tested one. Back to top

Some of them look different. Which version/type should I buy?

First of all, the paint colors mean nothing whatsoever. There is **nothing** you can determine from the colors other than whether you like the colors or not. Saying "the blue one" or "the orange one" means nothing.

What does make a difference is getting one with an analog meter, not the digital display version. The analog meter version tells you more useful information about what power the tube is using. A common upgrade for the digital meter version is to add on an analog meter somehow.

There is a rising tide of **"mini-K40" machines**. This is a smaller unit, which may suit your needs as the original K40 style is BIG. It eats up a lot of workbench space. The "Mini" version solves this by a slight repackaging to get smaller height and less width. It is virtually certain that the shorter, lower power laser tube in the Mini is cheaper to manufacture, as is a smaller case.

And shorter is lower power in laser tubes. In CO2 gas lasers, all other things being roughly equal, power is proportional to length. The original K40 uses a 700mm to 720mm long tube, and claims 40 watts. It is best thought of as a 30-35W tube. You can't stuff a higher power laser tube into the width of the K40. It would be longer than the box is wide. Some "K40" boxes were made with a hole on the right/control side to accommodate a higher power (and therefore longer) 50W tube inside a bolt-on metal shield. **The Mini has a 600mm long tube, probably 20-25 "real" watts**, advertised as a 30W tube if you buy a tube, and maybe advertised as 40W in the ebay advertising.

Some people have reported ordering a full size K40, and receiving a full-size K40 case, but the laser tube inside was only 600mm long. The manufacturer/seller was making more profit by substituting in a cheaper, lower power laser tube. **If you intend to buy a K40, make sure it comes with the longer tube. If you want the slightly-smaller K40 Mini to save some space or money, fine.** **Back to top**

What is a K40 Mini?

It's a smaller, but lower power version of the K40. Where the K40 struggles to output a 40W beam, the Mini struggles to output a 30W beam from its shorter tube. See "Some of them look different". Back to top

Get the M2 Nano controller version unless you plan to replace the controller.

Some early K40 style lasers came with a "Moshi" controller and used "MoshiDraw" software. These are both judged to be difficult to use and get good results with. Most current ones have the "M2 Nano" style controllers. The controller board has "M2 Nano" labeling on the control board. These can be used with the maker-supplied (and probably cracked, illegal) CorelDraw and CorelLaser software. However, the M2 Nano controller can be used with the free "k40 whisperer" software. This gets more user comments about being easier to use and more reliable. So if you have a choice, get the M2 Nano controller.

If you have a dead M2 Nano, you can buy a new one from Cloudray for US$25.00. Or you can put in one of the alternate controllers. Back to top

Get the analog meter version, not the digital numeric display version.

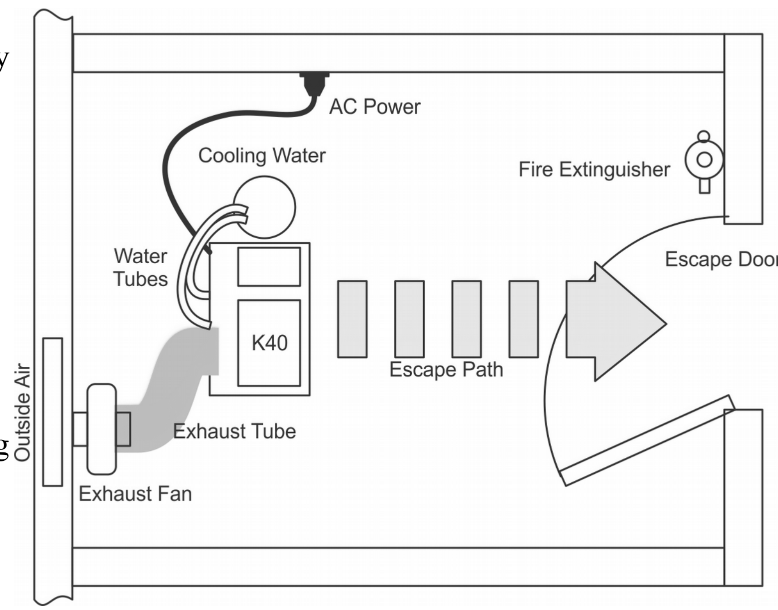
The digital version looks nice, but it tells you only 0-100 %. It's not clear 0-100% of what. It has something to do with beam power, and K40 laser hackers have worked out the fine level of detail of what it does, but pretty much all of them can let you set power to anything up to 100%. This is a problem, as any laser tube current over about 15-20ma can cause ever-faster damage to the laser tube. Setting it to 100% may wear out the tube in a very short time.

The analog meter version tells you directly what current is going through the tube, and you can set it to something meaningful. Most people get good, long life on the laser tube (assuming nothing else kills it) by keeping the tube current under 15ma. The analog meter tells you directly if you're setting fast-tube-death currents. **Get the analog meter.**

If you have a digital version already, get a US$5-$10 analog meter and install it. There are many online how-tos for this. Back to top

Where will you put your K40?

Another not-obvious item is a place to put it. The K40 style laser is an industrial/business tool and it has special needs for where it is set up to work. The thing is big; it eats most of a normal desktop all by itself, and that is without the cooling water setup and the air exhaust tubing and fan. Equally important is that the exhaust tubing really needs to be metal, not the floppy plastic that comes with the K40, and it really ought to be as short as possible to minimize leaks of stinky, possibly-dangerous fumes. You really also need a place to put your fire extinguisher that is nearby but not so close that you could not get to it if the K40 is engulfed in flames.



Here is a sketch of some things to think about when setting up your K40 laser. They were not obvious to me when I first got mine, and only came to me over time and reading. This may not be a complete set of considerations, and may have errors, but you ought to at least think about these things when setting up.

You're probably going to put your K40 indoors, in a room of some kind. It is technically possible to put the K40 and cooling water setup on some kind of rolling cart and roll it outdoors, but that's way beyond these considerations.

Choose a room with at least one wall and ideally a window that vents to the outside air. This lets you exhaust stinky and dangerous fumes outdoors. In a garage or workshop of some kind, you might be able to cut a vent-sized hole to the outside, but most people will have to fit the exhaust into a window somehow.

The exhaust fan should be at the outside wall, so the fan sucks fumes out, not blows them out into the room from the machine. If you do this, small exhaust tube leaks will not matter much.

The K40 should be near enough to the exhaust fan to make the metal vent tubing easy to run, and smooth, without a lot of bends and kinks. Closer is better.

The cooling water should be near enough to the K40 to not run very long tubes. Long tubes work, but they're a leak exposure, and let room air heat your nice, chilled water on the way to and from the laser.

The AC power for the laser should not be hidden behind the laser. This is fire consideration. If the K40 breaks out in flames, you really, really want to be able to yank that cord out of the wall. A safety switch on the laser itself is good, but you may not have time. For extra points, make that AC power plug be somewhere along your escape path. For super extra points, put a red mushroom-head emergency power off switch right next to the door and the fire extinguisher.

The escape path is important. It should not be blocked, and should be short and direct. The fire extinguisher should be on your escape path, at least a few feet away from the possibly-flaming laser. The time you spend running for the fire extinguisher is time for your brain to weigh whether fight (the extinguisher) or flight (just keep running) is the smartest option. Back to top

Is the K40 complete as shipped or do I need to add things to make it work?

NO. The K40 is not complete as shipped. You need to add, at a minimum a cooling water reservoir; this can be as simple as a 5 gallon (20L) plastic pail, a 5+ gallon insulated cooler, something like that. It is highly advisable to add:

- A remote-sensor thermometer (~ US$10, ebay, amazon, etc.) to be able to see the temperature of your cooling water. Running with cooling water over about 20C/68F will shorten the life of your US$100 laser tube.
- Metal vent tube for the exhaust fan. The supplied tube is essentially useless and will spread flames if a fire starts inside the machine. Home improvement stores, hardware stores, HVAC and hot water tank suppliers generally carry a 100mm/4" flexible ribbed aluminum vent tube that is much better than the stock plastic tube.
- That power strip thing above is a really good idea if similar things exist in your country.

If you buy the lowest price unit, you are at risk of getting a unit with some dents and dings, bad alignment, incorrect focus. Some people report that they just did the minimal amount of setup (setting up cooling water and pump, setting up the exhaust fan and tube, running water tubes, etc.) and their unit turns out good engraving and cutting on thin materials. About the only way to get a "good one" is to see what the most current comments on the various K40 laser forums say about which vendor is doing good ones recently. I prefer to both consult that repository of information and learn to do the various setup and adjustment procedures.

The K40 needs additional setup in its work location; at least a cooling water reservoir, a direct vent of the fumes to the outside and a fire extinguisher. These are not provided with the K40.

As for making it better than stock, there are a number of things that people have done to make their K40 lasers more usable, more convenient, and ideally, more reliable. See "Enhancements and modifications" below. Back to top

Is the exhaust fan that comes with it OK? Do I need a different one?

The exhaust fan that ships with the K40 style lasers is somewhere between marginal and useless. It's a bathroom exhaust fan that might, possibly be OK for a little while – but only if you're willing to take chance on breathing foul smelling and possibly toxic burning fumes.

DO NOT turn it on without the ventilation hooked up. The vapors and particles the laser beam makes in burning most targets are toxic to you and in some cases the machine itself. Do not even try to run this thing in a room without specific ventilation. That exhaust fan and flexible tubing that came with the machine are minimal, but they may be enough to keep you from poisoning yourself and/or your family. Don't run the machine without something sucking air out of the back of the machine. Ventilate to the outdoors: blow that stuff out a window. In most cases, it stinks even if it's not immediately deadly. Back to top

Is the exhaust vent tube that comes with it OK? Do I need a different one?

You need a different one. You need an all-metal vent tube at least the same size as the vent fan you use, generally about 100mm/4" diameter. There are flexible aluminum vent hoses for household dryers at most home improvement stores. Get one and use it, at a minimum.

The supplied exhaust tube is plastic, and will either melt if temperatures get too high, or may burn in the event of a fire inside the enclosure. If it's a fire, this lets flames out into your work area while the fan helps spread the flames. Back to top

Is the water pump that comes with the K40 OK, or do I need a different/better one?

You're fine with the supplied pump. It's actually OK. The amount of water flow through the laser tube needs to be at least 0.5 to 1.0 liters per minute. The supplied pump can do this.

TEST your pump. It's easy. Set up your cooling water reservoir and hook up the tubes and such. Then instead of running the return water tube back into the cooling water reservoir, drop its end into a 2-4 liter (½ to 1 gallon) bottle, jar, pan, or other receiver, and plug the pump into the wall all by itself. Run it for one minute, and see if you got your ½ to 1 liter/quart. If you did, you have enough water flow. If you didn't get this much flow, you would be endangering your ($100!) laser tube by running it with poor water flow. The stock pump passes this test if it's working correctly.

The pump has only one tube fitting as it is submersible – you dunk the whole pump into the cooling water bucket. The water comes out that hose fitting and is sucked into the body of the pump. Submersible pumps are designed to do this safely, and run in aquariums 24/7/365.

There is a minor dispute about whether the submerged pump can heat your cooling water. Yes, it can, a little. However, the heating is trivial compared to the heat coming in from the laser, so if you're adequately cooling the laser, the pump isn't an issue. External pumps work fine, but are generally more expensive and offer the opportunity for more tubing and more leaks. If you're the kind of person that wants to fully trick out your laser and can deal with the extra plumbing, sure, go for it. But it's not necessary.

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Do I need to use that Ground Plug on the Back of the K40?

Maybe – but you have clear and present safety exposures if you have to use it. The grounding terminal is a poor attempt to make the K40 usable in countries and places that only have two-prong AC power without a safety ground. Most buyers of a K40 have modern, three prong AC outlets, and the machine is perfectly well grounded by the AC wiring. If your AC mains electrical supply has three prongs, one of which is a "safety ground", and the grounding inside the machine is either OK as it arrives or has been fixed, then no, you do not have to use the ground plug/socket on the back of the machine. Most of the industrialized world has electrical plugs that are this way.

The outside ground terminal has a good use, but it's not what the makers had in mind. It's a good place to **do the ground wiring inside the machine**. It’s a good place to tie the AC safety ground wire to the metal case.

It is likely that the original designers put that plug there in case the buyer is in a country or region that has electrical plugs that only have two prongs. There cannot be a safety ground wire in a two-wire AC cord, and you are exposed to electrical shocks by any electrical equipment, and by the K40 in general. In this case, you could use the ground plug on the back to connect your K40 case to an earth ground.

If you decide that you must use the ground plug on the back for safety grounding, you still have to be sure that the ground socket connects to the case by sanding the paint off the case where the ground plug/socket bolts into the case, much like the diagram for grounding in “More On Electrical Safety”.

One other thing I can think of that is good about that terminal is that it makes it easy to attach a bare copper wire there and run that wire into the cooling water reservoir to ground the water. This eliminates an arc from the 20,000 volt laser power supply to the cooling water as a hazard. Some people have reported a tingling sensation touching the cooling water. This is fixed by grounding the water.

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What other things need added or changed?

If you have added a good exhaust fan, metal exhaust tubing, a fire extinguisher, a cooling water reservoir, and a remote sensing thermometer (see “Is the K40 complete as shipped?), you can more or less safely engrave and possibly cut thin materials other than metals. If you plan to do much of this, you ought to consider adding or changing:

- air assist
- a small visible laser pointer for positioning the start point for new jobs
- some way to cool your cooling water for long jobs; see cooling

There are a lot of upgrades (meaning to make the machine work more or better) that are noted elsewhere. But some things that might well be added to the base machine include:

- an analog current meter if your K40 did not come with one
- a stock of emptied and refilled soda bottles frozen to ice is really handy for keeping your cooling water in the right range and is mostly free Back to top

Is the K40 safe to use as it comes? What needs changed or updated for safety?

No. It is not safe as it comes out of the shipping crate. See the section titled “More on Electrical Safety” below for more on what needs done. It has these safety exposures in its original state:

1. The AC mains wiring and grounding wiring inside the controls section must be checked for safety. In general the safety ground wiring inside does not effectively ground the outer case. This is only one wiring failure away from putting deadly voltage onto the shell of the machine or into the cooling water.
2. Fire: there is a very real danger of starting fires with the K40 laser. Never operate it without a fire extinguisher nearby. See “Fire danger!” below.

3. Burned fingers/hands/eyes: The K40 as it comes out of the shipping box will let you run the laser with any of the covers open. There is no protective interlock to keep this from happening. People regularly post pictures of the second or third degree burns on their hands they got by reaching inside the laser while they pressed the "test" button. There are a lot of "welcome to the club" replies. This is silly. Would you align your table saw blade while the saw was plugged in? And if you cut one of your fingers to the bone (or off!!) with your table saw, would you be proud of it? The thing that would keep this from happening is cover interlocks.

4. Interlocks are switches which disable the laser when a cover is opened. You can set this up with adhesive-backed burglar-alarm type switches and a little wiring. There are many tutorials on the net telling you how to set up interlocks. Do it. Don't be proud of a laser burn.

   The K40 style machines come with labeling that they are "CE" and FDA approved / registered / compliant. This is clearly wrong. The grounding scheme would invalidate it from CE marking, for one thing. The FDA marking is intended to say that it's safe for the laser classes recommended by the USA Food and Drug Administration. It is not.

   The K40 style lasers all produce so much laser power that they're in the most dangerous Class 4 category per the FDA's rating scheme. Class 4 lasers require a complete enclosure that prevents even accidentally reflected laser light from escaping the enclosure, and also requires safety interlocks to stop the laser firing if the enclosure is opened.

   The "accidental escape" is arguable; ask the people with burned tables and work benches from that hole in the bottom. But there is no hint of an enclosure interlock. Back to top

Fire danger!

The K40 and all other high power lasers are burning tools. They do what they do by burning things. If the high temperatures and airflow manage to start a self-supporting flame inside the box, this can – and has – expanded to open flames engulfing the entire machine, with the real possibility of burning down the building.

For just how much trouble you can get into, take a look at Appendix 3 of K40 fires from people that have had them.

All you can do is:

- use air assist; this can often "blow out" smaller flames at the focus point before they build into self-sustaining flames
- keep the inside of the machine clean; the more scraps of previous work present in the bottom of the box, the more chance that a poorly focused beam can heat them to ignition
- get and keep a fire extinguisher nearby, and watch your burn jobs so you can put out any flames that happen to start.

Your new/prospective laser is NOT a complete solution that you can simply open the box and run. To get it to be that cheap, the manufacturers (and there are several or many) cut a lot of corners. One big range of corner cutting was in the original objectives. The K40 was originally designed strictly for engraving or cutting rubber stamps. Very few users have desires that limited, so the expectations you probably have are higher than the machine was designed for. You're going to have to work at it.
I personally would never plug my K40 into the wall power without having a five pound CO2 fire extinguisher ready in case there is a fire. But then I value my family, myself, and my house, in that

order. The cheapest CO2 fire extinguishers cost US$80 and up at the time of this writing. $100 is a better estimate. Replacing your K40 will cost $400, replacing the upgrades another $100-$300. Hospital stays for smoke inhalation get rapidly more expensive and we know what hospitals and funerals cost.
I have seen some university web sites where they post instructions and cautions to students that use their CNC laser labs in which they advise/require the students to keep a plastic spray bottle of water beside the laser while lasing. They are instructed to spray water on any “minor” flames if they appear. I have a horror of spraying water into a working electrical machine, but then maybe this would work OK. I have not tried it. Back to top

Is there any special setup I need to do when I first set it up?

Maybe. If you were lucky and got a well-prepared machine that was carefully set up by the seller, you have only the beginner setups below. You may not have to align the moving parts of the mechanical stuff and may not have to align the mirrors and lens.

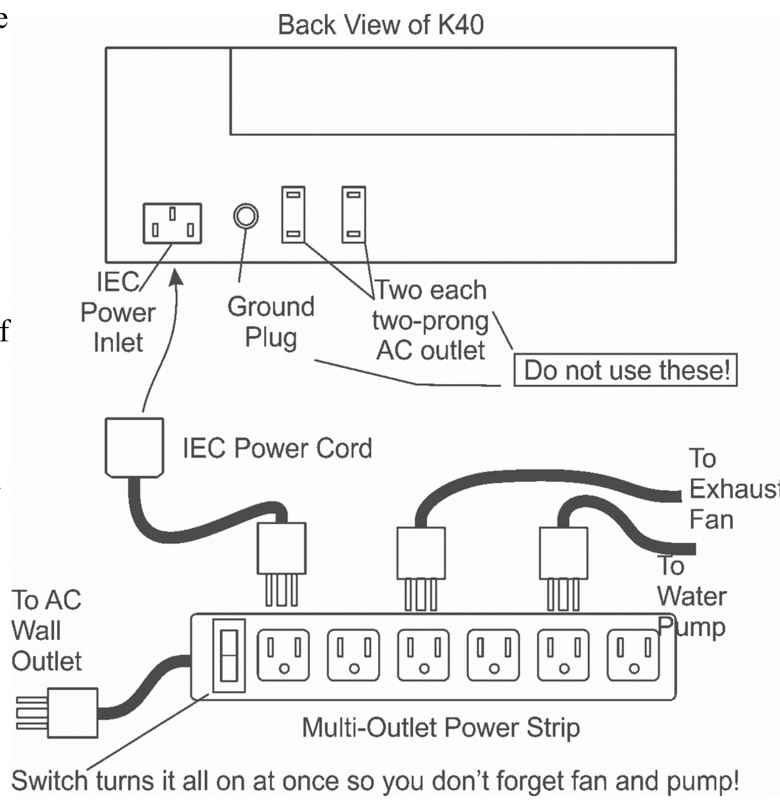
If you bought a bottom-dollar machine, count on having to align at least the focus and mirrors, and possibly-probably the mechanical movement. Back to top

Set Up and Adjustments

You will probably have to do adjustments on the machine you get it to work right. Even if you got lucky and your machine’s supplier went the extra distance to send you a well-prepared and well-set up unit, you will eventually have to tinker with mirror adjustment and focus.

This includes focusing the lens on the bed accurately, adjusting the mirrors to actually hit the middles of the three mirrors, or even adjusting the squareness of the X and Y axes. Some buyers are lucky and get machines that work well to start with, but these are the exceptions. Get ahead of the game and be prepared to learn how to do these adjustments yourself. You will need to do this some day to keep your laser running.

If you bought a K40 to save money over the US$3k to US$15k that US CNC laser suppliers charge, it is unlikely that you can afford to pay someone else to adjust and maintain your machine, even if you could find someone willing to do so.



Here is one suggested way to plug in the K40, exhaust fan, and water pump. The grounding plug and two-wire outlets on the back of the machine are safety hazards unless you are an electrical expert. See what to do in “electrical safety” or better yet, use a multi-outlet power strip to turn on the laser, fan and water pump all at the same time. You could also plug your air assist pump into this as well. Back to top

Cooling Water: Distilled, RO, Deionized, Tap?

You CAN use tap water, but this MAY make your laser susceptible to arcing and tube damage inside the tube. This is because the laser tube runs on 10,000 to 20,000 volts of electricity. The more conductive the water, the more electricity that can leak out into the water. This puts more stress on your power supply and can lead to early power supply failure.

Water is actually an electrical insulator, but anything dissolved in the water makes it conductive. Tap water may be nearly anything at all, depending on where you get your tap water. Most tap water contains from some to a lot of dissolved solids and other crud that make it more conductive; this stuff can also deposit out on the glass inside the laser tube or support algae growth inside the plumbing tubes or laser tube.

Distilled, RO (reverse osmosis), and deionized water are all much less conductive than tap water in general, and are relatively cheap in most places. Tap water is a crap shoot. As an oddity, in my area, I find distilled water for US$1 per gallon in the baby food section of most grocery stores.

Keep it clean, use distilled, Reverse Osmosis (RO) or “deionized” water (DI). If you can’t get those, put out a clean container and catch rain water. This will not be as pure as distilled, RO or DI, as it picks up stuff during its fall through the air, but it’s probably better than tap water.

Putting additives into the water may directly make the water more conductive. Don’t use any additives unless you have to, and then only tiny amounts. Additives include RV anti-freeze, dishwashing detergent, algacide, and other things.

Cooling water reservoir

Do not, even for an instant, fire the laser without the tube full of cooling water. Really, do not fire it for an instant without water circulating. It can permanently damage your $100-$150 laser tube and maybe the $75 power supply.

Dunk the attached pump into the water, and connect the supplied tubing to the ports on the back of the laser. One tube connects to the output of the pump, the other tube returns water to the reservoir. Before you plug the laser proper in, set up the water tank, pump and tubing, and do a test run by plugging the pump into the wall power socket. Any water leaking out may have damaged your laser or electrocuted you if you haven't already fixed the electrical safety grounding fixes above. Note that the pump supplied with the laser will not pump water any more than about 5-6 feet high, so the pump really ought to be level with or no more than three feet or so below the laser tube. Back to top

Bubbles in the tube: why they’re bad and getting rid of them

When you start pumping water into an empty tube, you’re likely to have some bubbles that refuse to come out. In addition to looking sloppy, these are bad for the laser. Here’s why.

A bubble is a pocket of gas between the cooling water and the glass it’s intended to cool. So the glass under the bubble can get hotter than the glass around it. Like most materials, glass expands when it gets hot. Glass is actually a little flexible, but not much. If part of the glass expands more than the rest it can cause cracks.

A crack from the cooling water tube into the gas chamber pollutes the gasses and the laser tube is now dead. A crack in the separately-glued-on mirror cavities can crack the cement that holds them on. Just the uneven expansion of the glass in the mirror cavities from bubbles there can move the mirror off enough to make it have less power.

So get those bubbles out. Some ways to do that are to:

- Rotate the laser tube so the water outlet is up. This lets the bubbles have a path to the outside.
- Run the pump a long time. Some people run it 24/7/365. This may help.
- Tilt the whole machine to let the bubbles run uphill to the water outlet. This can and should be done with the pump running but the AC power to the whole machine disconnected for safety reasons.
- Tiny bubbles may form on the electrodes on the ends. This is normal, as most water contains dissolved gasses. Watch and see if the tiny bubbles become a big one, and if they do, de-bubble as above.
- Some people say to put a tiny amount of dishwashing detergent into the cooling water. This may or may not be good, as it has the potential to make the water more conductive. See Cooling Water: Distilled, RO, Deionized, Tap?

My K40 won't cut / loses power / is getting weaker

Straight talk first – the K40 is NOT an appliance/tool like most people think. It does NOT automatically project a 40W cutting beam. There are many things that will make it not cut/burn well, and you're going to have to keep working through the possible causes to find out why.

Here's a list of possible causes.

- Sadly, your new K40 may always have been weak. These are not the best quality tubes. CO2 laser tubes vary a lot in quality, so the manufacturers test their newly-made tubes and sort them for best to worst. A weak tube that does make a laser beam, but only a weak one may not be scrapped, it may be sold to a cheap-machine maker. K40 laser makers are by definition cheap-machine makers, so guess where the weaker tubes often wind up. However, there are a lot of other things that COULD be the problem, so you'll have to put some work into it to find out what's really wrong, further down in the list. Don't automatically assume that you have a weak tube.
- New laser won't cause a burn on a target at mirror 1: It's hosed. Decid whether you want to return it for a refund or try to repair it. These aren't perfect machines by any means, but they ought to do SOMETHING when they're new.
- Improper focus: you want the beam focus point (see Focus Set Up). For cutting, the tightest-focus spot should be in the middle of the thickness of the material. For engraving, the tightest focus spot (that is, finest dot/line size) should be exactly on the surface. For just burning your fingers and leaving a scar, anywhere in the beam will do, but the focus spot will make the worst burn.
- Bed and rail alignment is off: The whole point of the front-back and left-right movement rails is to get the laser head to move in a perfectly flat path in all directions. The whole point of bed height and alignment is to get the distance from the laser head to the material to be the perfect height for focus over the entire area the head can move. If either one of these is wrong, the focus can not be correct, and the result is that the beam seems to have less power in the places

where the focus height is not perfect. See Appendix 5. Ramp test (and misaligned bed height)

- Laser seems to get weaker over the same burning session: check your cooling water temperature. If the temperature of the cooling water rises, the laser beam power gets weaker. Also, the tube heats up internally over minutes and hours, and will simply be weaker because the insides where the water can't get are hotter.
- Laser gets weaker over days and weeks: CO2 gas lasers do slowly get weaker and wear out over time. This can happen even if you're not using the tube – the gasses can slowly leak out or decay so it gets weaker. You can make this worse by running the tube with too-hot cooling water; or by running the laser tube at too-high beam current. Too high current can degrade the gases either slowly over time, or suddenly. Note that all laser tubes have a finite life that you can only make worse by misusing it.
- Laser just stops sending out a beam: stick a mirror alignment target on mirror 1, the first mirror the beam hits. If the laser makes an arc inside the tube when you press the "test" button, but no burn appears on the target, no beam is coming out. This can be a dead tube, or it can be a power supply problem.
- Running the tube with current too high: There is a consensus that you shouldn't run the laser with higher current than about 15ma for longest useful tube life. If you have the digital model, you have no idea what the nice percent numbers mean in terms of tube current. That's one reason that you really, really ought to have a beam current meter in your K40. If it is the digital model, PUT AN ANALOG METER IN IT. Then at least you can know how you're killing your tube.
- No laser beam, as above, and a crackling sound: the high voltage wire to the tube is arcing to the case. The tube is not getting power, so it doesn't lase. Fix the arc problem.
- Arc inside the tube changes from the purplish-pink glow of a new tube to a mostly white arc: the tube is dead. The color of the arc changes depending on the gas mix in the tube. White indicates that the gas mixture has died. Get a new tube.

Cooling your cooling water

Unless your air temperature when running the laser is below about 12C or so, you will need to cool your cooling water. The cooling water gets the heat out of the laser tube and into the reservoir, it doesn't destroy the heat. So you have to cool the cooling water. Here are some ways that work:

- A multi-gallon (many-liter) reservoir that heats up only very slowly; the more volume of water the longer it will take to heat up. If you do this, you had better put a remote reading thermometer into the water so you know when it gets too hot.
- Radiator: circulate the cooling water through a radiator of some kind that transfers the heat to the surrounding air. This only works if the surrounding air is cooler than the target 64F-68F (18C – 20C) temperature for the cooling water. This applies to all kinds of radiators, including CPU radiators, car radiators, whatever. The CW3000 "cooler" is a radiator in a box, with a fan. It is NOT an active cooler, so it has this same problem.
- Active cooler: The deluxe version is the CW-5000/ CW-5200 cooler, intended for exactly this kind of work. These are expensive. A perhaps cheaper option is a used aquarium cooler. These

can often be found for ~US$100 or less, used. Whatever active cooler you use, it must be able to keep up with the heat output of the laser, or your water will heat up, just more slowly than it would otherwise. If the active cooler can't pump as much heat as the laser puts out, it won't keep up with the laser's heating.

- McGuyver active cooler: You can put a CPU radiator in front of a window air conditioner and circulate the cooling water through it with a second pump. For a big enough radiator, this ought to work out fine. I have not tried it, but it seems reasonable.
- Cheap and cheerful: Use a 5 gallon/20+ liter reservoir and freeze water in used plastic drink bottles. Dump in a frozen bottle when the cooling reservoir gets up to near the top temperature. A 1 liter bottle of ice is good for 15 minutes or so of full power running, longer for lower power. This lets you store up the active cooling of your refrigerator for use all at once when you need it.
- Use a big, already cold reservoir of water and let it heat up over the run. If the reservoir is big enough, the reservoir won't overheat during the run. Putting a multi-gallon/many liter jug inside a mini refrigerator could maybe be made to work.

Here are some ways that MIGHT work, and might not, depending on your local air temperature and how long/what power you run your laser:

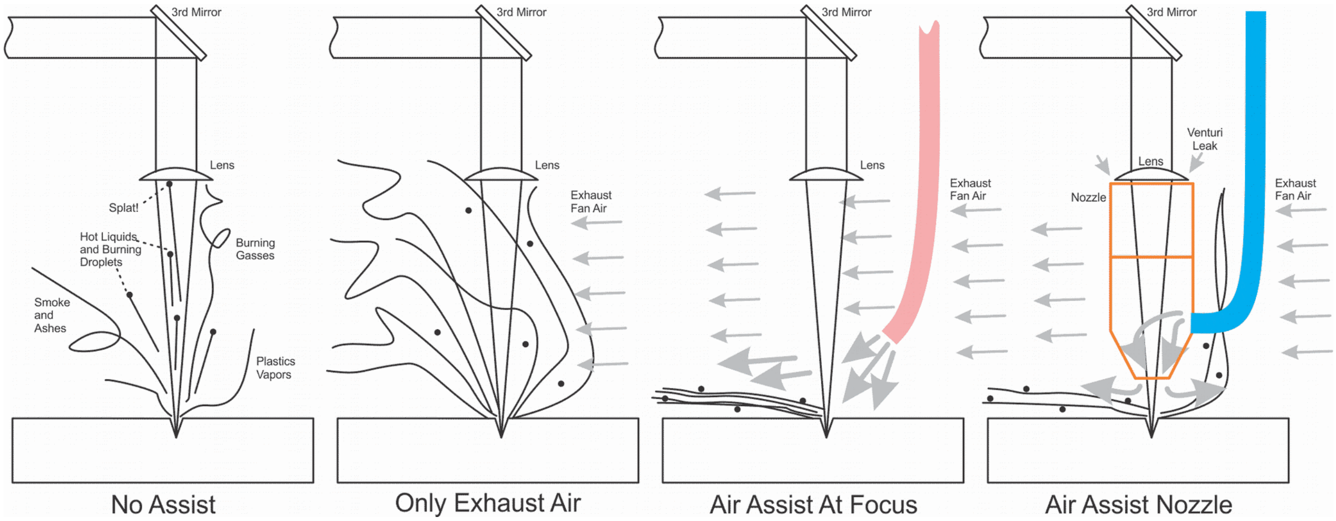
- Cannibalized drinking fountain cooler: in general these don't have enough long term cooling capacity. May work OK if you don't run for long periods or if you rig some way for them to cool a large insulated reservoir for a long time.
- Bottled water cooler: Same issues as the drinking fountain cooler.
- Running tap water through the laser constantly: this has the same issues as tap water in general stressing the power supply, but if your water is cold enough, could work. It's wasteful of water, at a minimum.

Unless you have a big, already cold reservoir of cooling water – 50 gallons of water already between 15C to 20C – you will need to cool the cooling water somehow. The simplest way for getting started is to use a five gallon / 20 liter plastic bucket full of distilled water and drop into it rinsed and refilled plastic soda/juice bottles that you have frozen. A 1 quart / ½ liter bottle frozen will absorb the heat from a K40 operating for about 15 minutes before it's all melted. Then remove that now-thawed bottle and drop in another frozen bottle.

For the more sophisticated methods and how this was figured out, see Appendix 4. Back to top

Air assist

There is strong agreement among experienced K40 owners that the first addition you need is air assist. This is a jet of air blown right at the focus point. Air assist does at least a couple of good things. One is to forcefully clear away smoke and globules of debris from the cutting/engraving spot and make better cuts. Another is to actually blow out tiny flames at the focus spot, reducing fire risk. Here's what air assist does:



The super high heat at the laser focus spot converts the target material to evaporated fumes, smoke fumes, burning particles, ashes and so on. This stuff comes flying out and wafting out of the crater the laser digs. If you don't have air assist or an exhaust (leftmost picture) then this stuff goes wherever it wants to, including blocking part of the incoming beam light power and condensing on the lens, again cutting power and heating the lens. This shortens the time til you need a new lens.

Using an exhaust fan (second picture from left) moves most of the fumes, smoke, and particles out the back of the machine, more or less gently depending on how strongly the exhaust fan sucks air out of the case. This helps, but does not eliminate the burn residue dirtying up the lens, mirrors, etc.

Air assist with a separate tube (third picture from left) helps by forcefully pushing the detritus from the burning spot out of the burn crater. This not only helps keep the lens and mirror cleaner by shoving the residues toward the exhaust fan, it also actually gets into the burn crater and shoves the residue out of the crater spot. This makes the burning/cutting much more effective and increases the burning/cutting power of the laser without needing any more power in the beam. It's a double win.

Finally, some people do air assist with an air assist nozzle (rightmost picture). This shoves air into a closed nozzle under the lens and out through a small spot that the focused beam also uses. The idea is that the air is all forced to blow right into the burn spot. That probably helps the cutting/burning a lot. But it introduces some issues. The air exits the nozzle hole and spreads out in all directions, not just toward the exhaust vent at the back of the machine. It is possible for some amount of the burning residue to get sucked back into the top of the nozzle and deposited on the top of the lens. Some nozzles are better than others. Epilog, the US$15,000 CNC lasers, uses an external tube, not a nozzle. Think about that.

Air assist is usually done by buying a biggish-capability aquarium air pump ($30-$100) to supply the air, and then routing a tube along the X-Y framing to the moving head so it can blow through either an after-market focus cone on the moving head, or a metal tube aimed at the focus spot. The picture shows one of the common of this type pump. This particular one is on Amazon for US$39 at the time of writing. Even smaller US$10-US$20 pumps are thought to be an advantage. You can go deluxe with the Zeny airbrush compressor with the small air tank for about US$70, and get into airbrushing at the same time.

The air from the pump is conveyed to the laser cutting head through a plastic tube which needs to end at the cutting head, and there is some mechanical work involved in getting the air tube to follow the head without impeding its motion while cutting.

Generally, there is some kind of metal tube that conveys the stream of air right down to the focus/cutting spot. Many K40s use a length of small metal tubing (4mm copper tubing, small automotive brake tubing, both cheap and widely available) bent to point the air at the spot. The high-dollar Epilog CNC lasers use the bent-tube method.

Another way is to put a metal or plastic air assist head on the lens holder. The air assist head adapter can be 3-D printed or bought. The 3-D printed versions get comments like "after a while, my cone started to melt", so your mileage may vary. There is a lot of forum commentary on how to do air assist. Go do your homework when you get to this.

It may be useful to put an aquarium air valve in the air tubing line so you can tune the amount of air to the material being cut, the cutting speed, power and so on. This can get complicated, but offers the possibility of really clean cutting. Back to top

Engraving/Cutting Bed

The K40 style lasers were originally designed to engrave patterns and pictures on thin sheets, or to make rubber stamps by engraving rubber sheets. That is – the bed was not designed to adapt to the kinds of materials most K40 owners want. The stock bed is set up with a spring arrangement to hold small sheets. Unless your work uses thin sheets like the original design, and doesn't vary in thickness much, you'll likely want a different bed. The deluxe beds have height adjustment so you can move the material up and down so the (fixed height) focus spot is right on the material. This is a big deal, as a poor focus is one of the most reported problems with bad engraving or cutting performance. Changeable height beds make moving the material to the correct focus height easy.

Added Power Supply

The K40's stock power supply is adequate, just barely, for K40 operations. If you add stuff on, like LED strips for interior lights, LED pointers and so on, consider spending US$26 (Jameco) for a MeanWell RT-85D power supply. This has three outputs: 24V, 12V and 5V. These are sufficient for running the motors in the K40, replacing the 24V from the original power supply, and the logic 5V, as well as LED and other power. It takes a load off the just-barely-enough stock PS. Back to top

Do-s and Don't-s

Do:

- Do set up your cooling water reservoir, pump, and water tubing before even plugging the laser power cord into the wall.
- Do test the reservoir, pump and tubing for leaks before even plugging the laser into the wall. The pump can be plugged into the wall all by itself.
- Do check for water leakage inside the laser tube compartment before running the laser.
- Do use an analog meter to check tube current. Add an analog current meter of 0-30ma range to do power checking.

- Do study online sources for how to adjust and set up your laser. You may need to do it. This includes:
  - how to adjust focus
  - how to adjust mirrors for proper light path
  - how to adjust the X-Y axes to be perpendicular
  - how to tension belts
- Do learn, at some point before you need them, sources for and prices of spare parts like mirrors, lenses, belts, power supplies, and so on. Someday you'll need them. See "Spare parts and replacements" below.

Don't:

- Don't ever fire the laser, even for a second, without water in the tube. You risk instant damage the tube to some degree – all the way up to instantly fatally – by blipping the laser on with no water in the tube. Set up a cooling water tank and circulating pump before ever turning on the laser, even for an instant.
- Don't ever fire the laser, even for a second, without cooling water flowing through the tube. It can overheat quickly if the water is not flowing.
- Do not rely on the digital display as an indicator of laser power.
- Don't run the laser with the lid open, or with the laser compartment or controls compartment open. The laser and controls compartment are dangerous electrically. They contain either exposed AC mains voltage than can electrocute you, or 10,000 to 20,000 volts DC that can not only electrocute you, it can jump out of exposed wires you are not even touching.

  The laser compartment and main bed get watts of laser light. This can blind you instantly, even from a merely "shiny" reflection. This is the reason the FDA requires case interlocks to disable lasers when the case is opened. Some people are so fascinated by watching the laser burn things that they leave the lid open all the time. Mostly they get away with it. Do you want to take the chance that one day you'll accidentally scar both corneas at the same time? Back to top

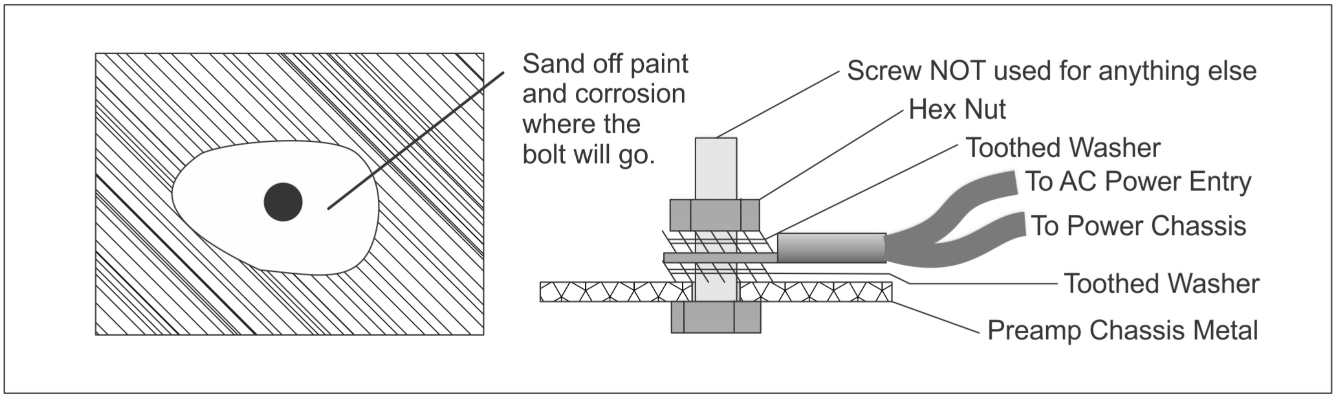
More On Electrical Safety

Grounding

Electrical grounding works by setting up a solid, continuous path to earth ground from all the user-touchable metal parts to a metal conductor buried in the ground. That way, any electrical leakage or short that "energizes" some metal part you can touch is "shorted" to ground. This usually pops a breaker or blows a fuse, but it prevents you from being electrocuted. Modern electrical codes require three (or more) prong electrical outlets, one contact of which is this earth safety ground. In most countries, using this third wire ground to ground your machine through the AC power cord is all you need to do, other than perhaps checking to see that your outlets themselves are correctly grounded.

Electrical Outlets and Inlets

The electrical outlets on the back of the K40 are in general not only useless, they're a positive electrical danger. The wiring is often not well done and may come loose, and in most K40s they are two-wire outlets, so anything you do manage to plug into them cannot be grounded. That's what that ground terminal on the back panel is probably for, maybe. However, that ground terminal is often insulated from the chassis by plastic washers and/or paint, making it misleadingly dangerous.



The picture below is how I reworked the ground lug inside my K40.

I have professionally designed AC powered equipment since the mid 1970s, so electrical safety is near and dear to my heart. So are the legal implications of electrical safety. I must make this disclaimer: This is based on the advice I got from a real, no-fooling safety engineer that did safety inspections of industrial equipment for certification. That being said, I do not know if his advice is enough to ensure safety, and I can not and do not recommend that you use this for your machine. I merely present it for your consideration. If you do it this way it is at your own risk, and you take all responsibility for your safety doing it this way. I trust this for my safety, but you must decide on your own about your safety.

I hate disclaimers, but they're necessary.

Along the same lines, including the same disclaimers, here's how I solved the (in my opinion) unsafe wiring inside the box, in general.

New electrical outlets on back: If you plan to use the electrical outlets, they need replaced with three-wire outlets. I used Qualtek 739W-X2/32 that I bought from Mouser Electronics. They cost me US$1.28 each. They required me to cut and file a rectangular hole in the back of the K40 for each one. This has to be the correct size, so some skill in placing and filing the holes to the proper shape was needed.

Note that it's easier to just not use them, and to use a multi-outlet power strip to turn on laser, fan and water pump all at the same time.

Replace the AC line cord entry with an IEC style entry module if yours did not come with one already. The "IEC style" modules are like the power cords and inlet on most PC style computers.

Rewire AC mains wiring to power supply or supplies.

Wire fixed electrical outlets.

Replace the two electrical outlets in the back of the box with proper snap-in or bolt-on outlets for your country's electrical system.

Rewire the electrical grounds inside the box. Make a proper grounding stud. Properly crimp terminals for safety grounding the electrical outlets and power supply. Back to top

Cooling Water Ground

It's really smarter to put a safety-grounded conductor into the cooling water. This way, leakage current that somehow manages to get into the water path is reduced to a safe potential by the grounding conductor. This is the only good use I've come up with for the external ground terminal: run a bare wire from that terminal into your cooling water.

I only bring this up because I have seen some forum posts from people who report slight electrical shocks when putting their hands in the cooling water. It would be a really ugly surprise to be electrocuted by touching the cooling water in the reservoir. Using non-conductive (i.e. distilled) cooling water makes such a shock less likely. A leak of the cooling water inside the enclosure can short to either the AC mains voltages or the 10kV to 20kV that the laser tube runs on. Either of these are bad news to the human body. Back to top

Software Considerations

The earliest control cards with the K40 style machines was a "Moshi" and it came with only its own special "Moshi Draw software". This is generally agreed to be useless. The later lasers used a "M2 Nano" controller that was packaged with the Corel stuff above. There is a free alternate program called "K40 Whisperer" that works with the M2Nano controller. It frees you from the poor software that is bundled with the machine, at no more cost. You can buy more expensive control cards (up to hundreds of dollars) and fancier control software that may enable you to do fancier burns. As you learn the machine, you can figure out how much you want to spend.

The CorelDraw supplied with the K40 is probably a hacked/cracked version of the commercial Corel Draw package. The Corel Laser supplied with the K40 is not a Corel product, it's a separate add-on. Corel Laser requires the USB dongle supplied with the machine to operate. You can buy additional dongles, but they're expensive, about US$30-$50 last time I looked. The dongle is an active USB processor/encryptor and cannot be copied or hacked in any simple way. So the K40 uses more advanced piracy protection for their add-on driver, and gives you a pirated Corel Draw package.

Which materials can you cut/engrave safely?

There are certain materials you should not burn in your laser. PVC (polyvinyl chloride) releases hydrochloric acid as it burns. Many other materials involving chlorine in the chemical makeup do too. Some materials release HCN (that's "hydrogen cyanide"!) gas as they burn. Wood, leather, and acrylics are fine, but check before burning others. In general, people on forums have reported success (and no health issues!) from working on:

- Wood and wood products like plywood, masonite, and similar. Variable results are reported depending on what adhesives are used to make up the wood products.
- Paper, cardboard, etc.
- Fabrics and felt
- Acrylic (plexiglas, perspex, etc.)
- Leather (which may require special dance steps like wetting, etc.)
- Glass – your K40 will most likely engrave but not cut through ordinary glass
- ABS to some degree. My friend with the Epilog cuts acrylic all the time, but he has a good vent system. ABS is reputed to give off hydrogen cyanide (HCN) when lased. Don't try this until

you have a GOOD vent system, and then don't vent it into your neighbor's window.
- Coatings on metals; the K40 doesn't have the power to cut metals. It ...might… cut thin aluminum foils. Maybe. But it's dandy at engraving away coatings like aluminum anodizing, paints and other such.
- Marking compounds on metals. There are several spread-on compounds that are catalyzed/burned by the laser so they leave a permanent mark on metals when lased. Cermark is one brand name, but some people report good results with molybdenum greases. Back to top

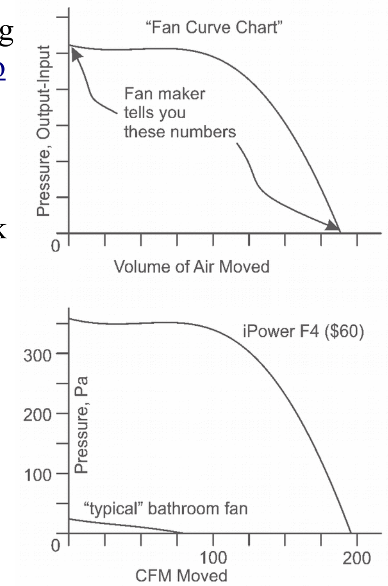
Enhancements and modifications

Air Assist

Air assist is an enhancement that is nearly a necessity.. Back to top

Laser pointer positioning

Using one or two cheap laser pointer modules is a good way to always know where the beam will hit without actually firing it. A clever way to do this is to use two line-focus lasers in a cross hairs arrangement. The lines can be set up to cross directly under the focus spot no matter what height the lens is from the work. A single spot laser pointing in from the side can only be in the right position at one height. Back to top



Adjustable bed height

The fixed position bed for holding materials to burn is dreadful in the stock machine. If you ever get your focus set up for the bed properly, the focus will be correct only if you use the exact-same thickness stock after that. If you change material thicknesses, you will have to re-focus. Adjustable bed heights let you move the material to the focus.

Exhaust Fan Upgrade

This gets mildly complicated. The included fan is a not-very-good bathroom exhaust fan. It has limited air volume moved (cubic feet per minute, CFM) and very limited ability to produce a pressure difference across the fan – that is, how hard it blows or sucks air.

To understand this, we need to look at a "fan curve". This is just a chart of how much air a fan moves as you change how restricted its airflow path is. We all know that if you close off a vacuum cleaner, you get nearly zero air flow, but lots of suction. Without the restriction, a vacuum moves much more air, and has less, but still some suction. If we measure the suction and airflow for a fan at many steps of restriction, we can make a fan curve.

A general fan curve is the top figure. At zero air flow, you get highest suction. At zero suction, you get the greatest air flow. The manufacturer of course tells you the big numbers, but doesn't always tell you about that curve in the middle.

What you as the use probably wants is to operate your fan at the highest combination of air flow and suction, at that kind of knee in the middle. You want some pressure to get the air moves past the resistance of the vent tubing and to suck air in through the K40. You want medium air flow – not zero, and not a loud hurricane.

I could not find fan curves for the included exhaust fan, and only one for a 4” centrifugal duct blower that's often used for K40 upgrades. I stuck in a “typical” bathroom fan curve. We can expect the stock K40 fan to be worse than this. There is a difference you can drive a truck through.

What I took from this thinking is that you can make much more air flow through the K40 with only a modest amount of money spent for an improved exhaust fan – under that $60, and probably well under that price.

A possible radical choice is a bounce house blower. These can sometimes be cheap or free. They will move dramatically more air than even the iPower example. Back to top

Added Power Supply

The K40’s stock power supply is adequate, just barely, for K40 operations. If you add stuff on (like LED strips for viewing the lasing through the window while engraving, or for better visibility to set up stock to work on) it may cause issues because the power supply is just barely able to put out the power.

There is a cheap alternative that will let you add on many more electrical mods. I bought a Mean Well RT-85D power supply for US$25.79 from Jameco Electronics. This supply provides 24Vdc at 2A, 12Vdc at 1A, and 5Vdc at 6A. This is plenty to provide all of the +24V the K40 needs for its X-Y motors, vastly more +5V than it needs for the logic and controls, and also gives you 1A of 12V for anything else, like maybe those LED strips. It takes the 24V and 5V loading off the stock power supply entirely, and so the stock power supply is not running so near the edge of the power cliff. There are probably other 2- and 3-output power supplies that would do much the same. A 24V and 12V supply would do most of this, and maybe be cheaper. Back to top

Good general K40 tech notes

I very much like DonKJr’s blog for no-nonsense tech info on the K40. See http://donsthings.blogspot.com/2016/11/the-k40-total-conversion.html
It’s sometimes difficult to find things, but reading it all will make you much more knowledgeable about your K40. Don sells kits of parts for useful hacks. I have not bought any of these, but I like the free tech information. Seriously, about 2/3 of the beginner’s mystification could be cleared up by just reading this blog.

http://donsthings.blogspot.com/2016/11/the-k40-total-conversion.html
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Spare parts, replacements

- Laser tube

  The laser tube in the K40 is what industry calls a “wear item”, and it will wear out in the normal and proper use of the machine. Glass CO2 lasers are often rated for a life of ~5000 power-on hours. When they are misused by running them with too much current (power) they wear out faster. When they are poorly cooled, they wear out faster. When they are just abused by letting their cooling water freeze inside, or get full of thick algae, or miss-wired, they can fail completely. General wear-out causes a long, slow loss of cutting power.

  The tubes in K40s are not first-quality tubes in general, because of the intense pressure on the sellers to offer the lowest price. You can get replacements from some online vendors. I have seen reports of good results, including “Wow! This is great! It never cut/engraved like this with the original tube!” Some vendors that come to mind from forum posts include Ten High, Cloud

Ray, and Lightobjects.

You're looking for a 700mm to 720mm max length and 50mm diameter. That's the biggest that will all fit inside the enclosure. This limits you to 35-40W rated tubes. Your original tube was probably only producing 25-30W max, and possibly much less, as the OEM tubes were generally not the first, best quality tubes. Here are some links I found on a quick search. They are in no particular order.

- https://www.lightobject.com/Laser-Tubes/SPT-35W-CO2-Sealed-Laser-Tube-for-Small-K40-Laser-Engraving-Machine
- https://www.amazon.com/TEN-HIGH-AC110V-engraving-cutting-machine/dp/B00BKWOS1E
- https://www.amazon.com/SenTECH-Engraving-Cutting-Machine-Discounts/dp/B07RX5V42F/ref=sr_1_2?keywords=glass+laser+tube+40w&qid=1573619022&s=home-garden&sr=1-2-catcorr
- https://www.cloudraylaser.com/collections/cloudray-laser-tube/products/35-45w-720mm-co2-laser-upgraded-metal-head-tube-cr35?variant=12782294270003
- https://www.cloudraylaser.com/products/cloudray-tongli-700mm-40w-co2-laser-tube-glass-pipe-for-co2-laser-engraving-cutting-machine-tl-tlc700-50?variant=12816467296307

If you have the "Mini" version, you're going to have to find a vendor for the 600mm long shorter laser tube. Start with the vendors above and see if they carry it.

- power supply

  There are many replacement power supplies. I hope to expand this section.

- lenses

  The stock lenses are 12mm diameter zinc selenide (ZnSe) material and have a yellow-orange cast to my eye. Zinc selenide is toxic and fairly fragile, so always handle your lens with care when cleaning it.

  CO2 laser lenses can also be made from GaAs (gallium arsenide) and Ge (germanium). These more esoteric lenses may appeal to you. Read up on them before spending a lot of money on therm.

- Mirrors

  Common mirror materials are Si (silicon) with gold plating, polished copper, molybdenum, and perhaps others. If I understand what I read, the gold plated silicon has the possibility of being the absolute best reflectance, but may also degrade quickly, and may also be poorly made. Copper is not often seen in K40s. Molybdenum (MO) mirrors are solid polished metal, and probably the toughest and most reliable, even though they are slightly less reflective. MO seems to be the most resistant to damage and/or poor cleaning technique.

  One reference I read said that the coating or reflective surface of the mirrors – may – degrade over a fairly short time, leading to a 25-50% power loss through the mirrors absorbing the heat.

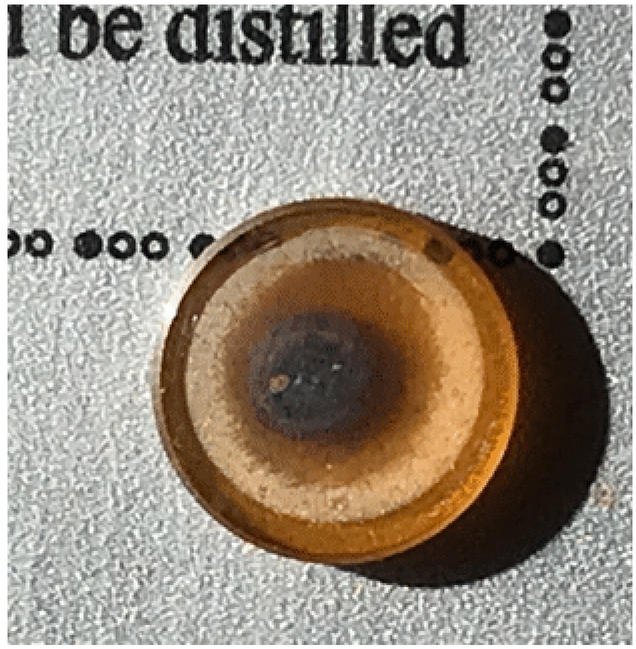
- belts

  The belts are NOT the common hobby-CNC GT2 toothed belts. I still need to track down what they are – I've never replaced mine, and I need to follow my own advice and get a spare set before mine fail. [Back to top](#)

Regular Maintenance

The K40 contains some parts that will break or wear out, and some that need regular care. I'll just mention some obvious ones and add to them as I think of more.

- Lens and mirror cleaning

  Your lenses either pass or reflect the entire power of the laser beam. This is fine as long as very little of the power in the beam stays inside the lens or makes it past the shiny surface to the inside of the mirror. A layer of dirt, condensed oils and plastic vapor, smoke particles and such can absorb a lot of the power and transfer it to the lens or mirror.

  This picture is a bad example. And that is AFTER I cleaned it with acetone. I got my K40 used, and I suspect that the seller thought he was taking me for a sucker. It simply cannot have been working well for him. Don't let this happen to your lens or mirrors.

- Lenses can fracture or spall off a piece of the lens, which of course ruins its ability to focus laser light, and makes it fail even more. What happens to the mirrors depends on what they're made of. Some mirrors are silicon crystal (semiconductor wafer stuff) coated with a whiff of condensed gold vapor and some kind of coating over the gold. These are the cheapest, and also the most likely to break if dirty and then overheated. Molybdenum metal mirrors are much more durable and only mildly more expensive. A good thing to do is to replace any unsatisfactory mirror with MO (molybdenum) mirrors.

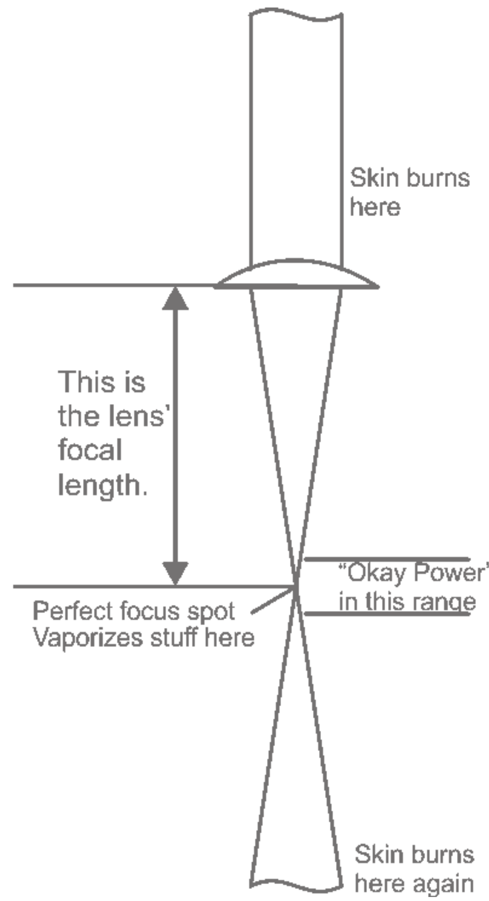
  The actual cleaning is tricky if done right. Most of the commercial laser sites I've read recommend cleaning the mirrors with acetone – not water, not alcohol – and lens papers, not cotton swabs. I first used alcohol and swabs on mine until I read better. The best thing is probably to do a web search for laser optics cleaning procedures that are (a) recommended by professionals and (b) something you can actually accomplish.

  The worst cleaning is no cleaning at all.

- Focus Set Up

  You have to adjust the bed of the machine to hold the material you're cutting or engraving to nearly exactly the focus length of the lens. Here's why.

Your laser beam emerges from the tube about 5-7mm diameter (¼ inch, more or less), is reflected by three mirrors, and then focused by the lens down to a small spot. In a perfect world, the beam would be perfectly round in shape and “Gaussian” as well as “single mode”. These are not perfect lasers, so the beams are not perfectly round nor “Gaussian” nor “single mode”, so they will not focus to a supremely tiny focus spot.



This is only work knowing because it means that your focused laser burning spot will only get so small, and no smaller. If you’re getting 30W of laser light out of the tube, you will lose a few percent in the mirrors before the lens. Even then, if you accidentally get your finger or other body part into the beam, the 30W of laser light will instantly give you second or third degree burns in the roughly quarter-inch size of the beam. The lens can focus all that ~30W onto a spot maybe 0.010”/0.25mm diameter. The power to burn things at any point in the beam is dependent on how much power is in the area of the beam that hits. Since the area of a circle is proportional to the square of the radius, the same power that hits a ¼ inch diameter in the unfocused beam is concentrated into a spot (0.01/0.125) squared smaller, so the power per unit area goes up by 156 times. The power at the beam focus from a 30W laser is ~3000W in that tiny spot if everything is just right.

The spot power is close to this much for a short distance above and below the true focal spot. Depending on the material, there may be enough “depth of focus” to cut through a material in one pass. How thick the laser can cut through depends on the power density (power per unit area) the material needs to burn/cut it.

The “Okay Power” range is not very thick. If your material is higher or lower than the tight, small spot region, it will be scorched or partially cut, but won’t cut through. The spot size is bigger both higher and lower than the perfect focus spot, so resolution suffers from poor focus too. For the K40, the OK power zone is probably no more than 6-7mm thick.

The classical way to test focus is to set up some material purposely slanted so the laser hits it at different distances from the lens. If you do this right, you can lase multiple lines and pick the thinnest line. That’s very near the true focus length. Then you set up your bed so new sheets of material are close to this perfect distance.

The “perfect focus distance” is the lens focal distance. K40s ship with 50.8mm (2.0”) focus length lenses. You can get 38.5mm (~1.5”) lenses, which have a shorter focus length and so a narrower “Okay Power” range. Some people like to use this for engraving. Back to top

Appendix 1. Materials

This material was gathered from the web in the recommendations of either laser manufacturers for use with their CO2 lasers, or from user groups, maker spaces, or university advice/rules/cautions to student users. It is certainly not complete, and may contain errors, but it's better than asking a fresh new question about "Can I cut/engrave XXX material in the K40?" every time. Please help enlarge and refine this list. Back to top

The materials are grouped by classes:

- I = inorganic, or mineral but not metals
- M = metals
- O = organics
- P = plastics; yes, I know most plastics are technically organic, but for lasers, they're special

Material	Class	Engrave	Cut	Cautions	Why/Notes
Organics					
Cardboard, corrugated	o	Y	Y	Flames!	
Cloth	o	Y	Y		
Cork	o	Y	Y		
Cork (composite)	o	Y	Y	caution	Adhesives may cause poor results
Fabric (natural, not poly)	o	Y	Y		Synthetics are woven plastics.
Felt/cloth/cotton/hemp	o	Y	Y		Wool felt stinks
Leather	o	Y	Y	Stinks!!	No, really, it stinks horribly
Leather/Suede	o	Y	Y	Stinks!!	Note: artificial leather is PVC or PU
Matte Board	o	Y	Y		
MDF/Engineered woods	o	Y	Y	caution	Adhesives may cause poor results
Mother of Pearl	o	Y	Y		
Paper	o	Y	Y		
Paper, card stock	o	Y	Y		
Pressboard/chipboard	o	Y	Y		
Woods (general)	o	Y	Y		
Solid Wood		Y	Y		
Plywood/Composite woods		Y	Y	caution	Adhesives may cause poor results
Wood Veneer	o	Y	Y		
Plastics					
Acrylic/Lucite/Plexiglas/ PMMA	p	Y	Y		Good results usually. Can give nice polished edges.
Coroplast ('corrugated plastic')	p	Y	Y	Flames!	Reputed to catch fire easily.
Delrin (POM)	p	Y	Y		
Depron foam	p	Y	Y		
Gator foam	p	Y	Y		
Kapton tape (Polyimide)	p	Y	Y		
Mylar (PET)	p	Y	Y		
Nylon	p	Y	Y		
Polycarbonate (Lexan)	P	~	~	Poor results	Melts and discolors, not clean

PETG (polyethylene terephthalate glycol)	p	Y	Y		
Solid Styrene	p	Y	Y	Flames!	Catches fire easily
Teflon (PTFE)	p	Y	Y		
Thin Polycarbonate/Lexan Sheeting (<1mm)	p	Y	Y		Works better than thicker
PVC ("vinyl")	P	Y	Y	Toxic	Toxic/corrosive HCl released , eats machines and lungs
Polyurethane	P	Y	Y	Toxic	Releases hydrogen cyanide (HCN)
Inorganics					
Carbon fiber mats/weave	I	N	Y	~	Non-epoxied mat, weave only
Ceramic (e.g. decorative tile)	I	Y	N		
Corian	I	Y	N		Corian is powdered stone in resin
Fiberglass	I	Y	N		
Glass	I	Y	N		
Magnetic Sheet	I	?	Y		
Marble	I	Y	N		
Marble, Stone, Soap stone, Granite, Onyx.	I	Y	N		
Melamine	I	Y	Y		
Rubber	I	Y	Y	Varies	Some rubbers have chlorine, like vinyl
PCB (fiberglass, FR4, etc.)	I	?	~		Varied reports
Bare Metals in general	m	N	N		
Aluminum	m	N	N		
Anodized Aluminum	m	~	N		Laser can burn out the dye
Brass	m	N	N		
Stainless Steel	m	N	N		
Titanium	m	N	N		
Painted/coated metals	m	Y	N		Laser can burn away the coating/paint

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Appendix 2. Material Sources

Most cities have suppliers of plastic sheet, wood products and paper products. Use the internet and search for what’s local to you, or for a mail order supplier. I could do a list, but it would be enormous and always out of date. Back to top

Appendix 3. More about K40 cooling

- **Why do they need to be cooled at all?**
  The US$100-$150 laser tube can die in as little as a few seconds without cooling.
  =>> If you don't cool them enough, they quit working in a short time.<<==
- **How much cooling is enough?**
  >> Enough cooling to keep your cooling water bucket under 20C/68F and enough pumping to keep about one liter of water per minute flowing through your laser tube. <<
- No, I meant can I use the pump that comes with the laser and a bucket of water?
  >> Maybe. It depends on the pump and the bucket of water. And your hose path. <<
  Always, always place the end of the return hose under the water surface in the water bucket.
- **Can I use tap water for cooling?** I’ve seen people using tap water, distilled water, and special recipes for cooling water. What works?
  You can use >some< tap waters. Distilled water is better. Some additive recipes are OK, others are counter productive.
- OK, **how can I keep the cooling water reservoir cool enough**?
  >> Most K40 users will need to refrigerate the water somehow. <<
  - Ignore cooling the bucket, just circulate the water at whatever temperature.
  - Run tap water into the bucket
  - Re-purpose an office water-bottle style cooler.
  - Re-purpose a miniature refrigerator.
  - Use Peltier/electrothermal panels.
  - Use a computer CPU water-cooling radiator
  - Use a CW-3000 water radiator; note, a CW-3000 is NOT a cooler, it's a radiator, and it cannot get your cooling water as cold as the room air temperature.
  - Use a CW-5200; this is a real, active chiller and CAN cool your water down to the recommended temps even if the room air is hotter.
  - Use an aquarium water chiller; this is a real, active chiller and CAN cool your water down to the recommended temps even if the room air is hotter.
  - Scavenge a used window air conditioner; this is a real, active chiller and CAN cool your water down to the recommended temps even if the room air is hotter.
  - Live in a cold climate.
- **Why is there a minimum temperature for the cooling water?** Why can't I run cooling water

at 15C? 10C?
Doing this flirts with causing thermal expansion/contraction cracks in the glass.

- **How much heat does a K40 generate?**
The K40 has to get rid of 160W to 200W of waste heat
- **How much water and at what temperature do you have to circulate?**
Move about liter of water per minute through the K40 tube, and cool it to between 18C (64F) and 20C (68F) in the cooling tank.
- **Can the little aquarium pump that came with the K40 pump enough water?**
Probably, if you don’t arrange your plumbing to prevent it from doing so. Always make sure your return hose end goes under the water level in the coolant bucket.
- **You have to cool the water in your bucket, too**, as well as running the water through the laser.
- **Use the largest practical cooling water tank.** Most people seem to use four to five gallons and that works well.

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Appendix 4. Horror stories: Fire!

Here are some saved pictures and comments in the discussion that may help you decide whether to get a fire extinguisher and watch every burn job like a hawk. Thinking about this and being prepared might save your K40, your house, or in extrema, your life.

The posts and photos that follow are graphic illustrations of what can happen with your K40 in only a few minutes. They show why you should

(1) Never, ever leave the K40 or any CNC laser running without you watching it 100% of the time.

(2) Some people have reported good results on small flames with a plastic spray bottle of water kept beside the machine. This requires you to be waiting beside the machine, not having "stepped away from the machine for a moment".

(3) Have a fire extinguisher close to hand; the right fire extinguisher is a CO2 extinguisher, not a home-improvement-store "ABC" powder type. Both will extinguish a fire, but once the fire is out, the CO2 simply vanishes from the machine into the air.

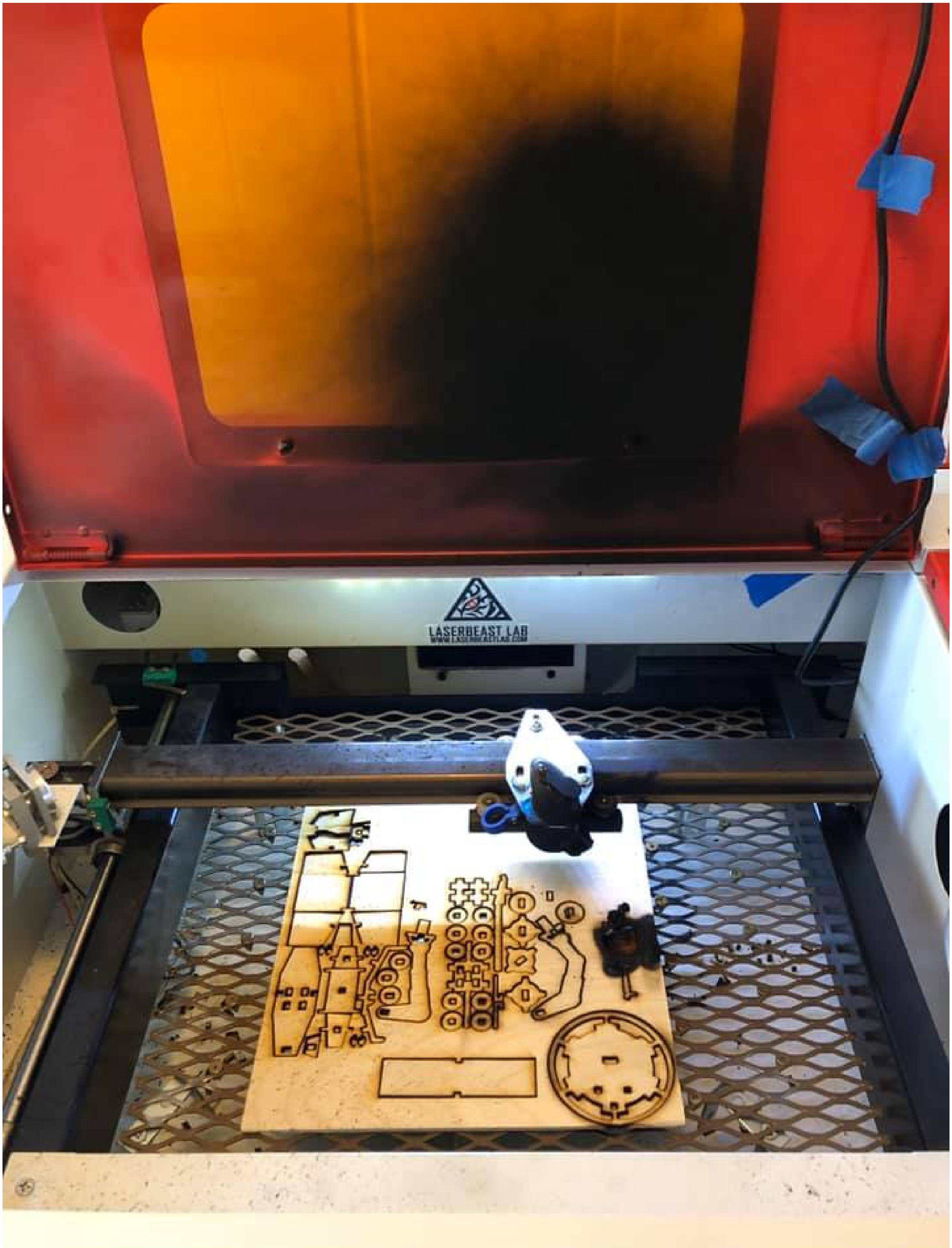
But people who have used powder on their lasers say that the powder gets into everything, sticks to surfaces, is nearly impossible to remove, and may well be corrosive. The fire may not kill your laser, but a powder fire extinguisher may well make it impossible to salvage the machine. On the other hand, you get to keep your house and life. ACK! Use CO2.

(4) Be prepared to handle the situation when (not if) a fire starts inside the machine. Be ready to kill all the electricity to the machine with some kind of cutoff switch, even if you just pull the cord of the outlet strip that runs the machine out of the wall. Be sure you can reach the electrical cord to yank it even if the machine has an internal fire. Place your fire extinguisher nearby, but not so close that a flaming laser would keep you from grabbing the extinguisher. Have an exit strategy. Don't let a flaming laser keep you from exiting the room if it gets out of hand.

You really, really can burn down your house by getting too comfortable with the machine running all by itself.

What follows are posts and pictures, used by permission, from people who have had laser fires, in order of increasing severity. Sure, K40s don't catch fire very often. But as these folks will tell you, it only takes once. Back to top

23 Feb 2020 Anybody want a slightly used K40? One careful owner.
I NEVER walk away while it's cutting........Until today ?☹



Nobody hurt thank God. Massive flames from such a little thing and my God those covers smell when

they're burning! Lucky I had the extinguisher to hand. Was only cutting 3mm birch ply. Last 2 of the order as well. Typical

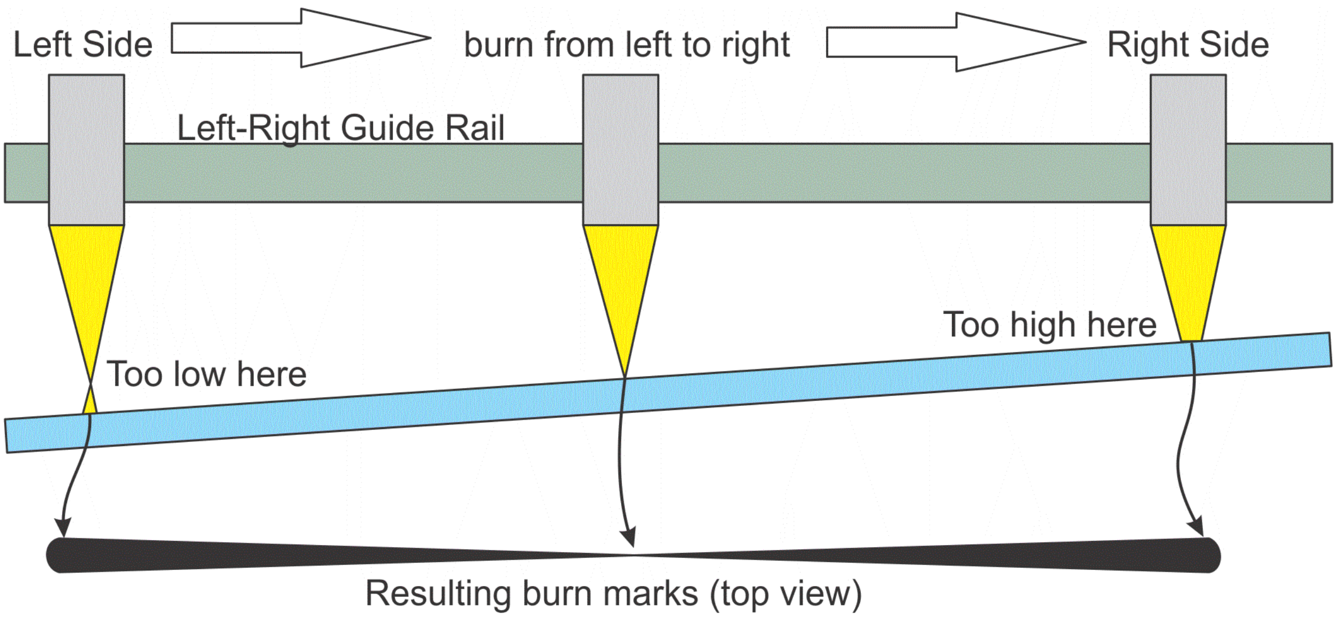
Another discussion participant posted in response:
I quickly nipped to the house for a pee all gone in 8 minutes

All in all around 16k in loss on this ******* lol
[this prompted the question]
how does that happen in 8 minutes 0o
[the reply?]
a fire in a small enclosed wooden space. We called the fire brigade it took them 8 minutes to get to us by that time it was all over.

Appendix 5. Ramp test (and misaligned bed height)

It is critical to get and keep your laser lens and the material being burned at exactly the right distance apart. One problem is finding out what that perfect height is, and another is keeping that height correct at all places on the material being burned. If the distance is not right, the beam appears to "lose power".

Imagine that your K40 has a glass front panel, and you can look into the front and see the laser head move from left to right along the guide rail. Also imagine that the material/bed is too low on the left side and too high on the right side. As it moves from left to right, it passes through the perfect height somewhere in the middle. The picture below is exaggerated, but it gets the point across.



The resulting burn marks as seen from the top look like the black area in the picture. On the left side, the material is too low, so the beam has passed through the focus point and spread back out, resulting in a wider and lower power burn when it hits the material. On the right, the beam has not yet come to a focus, so it's still too wide, and produces a wide burn mark. The beam's power is spread out over a wider area, and does not burn the material as intensely. In the middle at the perfect height, all of the beam's power is concentrated on a single spot, and you get both the best cutting and the tiniest spots and lines for engraving.

The problem of finding the perfect height in the first place can be solved by a "ramp test". You can do this by putting in a sheet of material that is deliberately higher on one side than the other and doing a burn. The position of the thinnest burn mark is the perfect height, and you can measure that. This lets you adjust your bed so it's possible to set the perfect height all over and get good burns.

That works backwards too. If your laser is not cutting well, seems to have too little power, it may be that your bed is too high or too low. If your laser seems to burn OK in some spots but not others, your bed may not be parallel to the movement of the laser head all over it. That same too-low/just right/too high burn pattern can happen from front to back or diagonally too!

Appendix 6. K40 cooling, in depth: Warning! Engineering and Math here (well, OK, not much)

The electrical arc that excites the CO2 to lase also rips up some of the CO2 into carbon monoxide and oxygen. These two poison the ability of the remaining CO_2 to lase. Laser tube designers can set up the tube so that the CO and O_2 will recombine into CO_2. Getting a long life out of a sealed CO_2 laser tube is a delicate balance of using it without running it so hot that the gasses are permanently poisoned. For a specific laser tube, driving it hard (high power/current) and letting it get too hot internally hastens its eventual death.

The K40 manual doesn't say much about how much water to circulate. Other makers of same-size replacement laser tubes indicate that you need ½ to 1 liter per minute. This is pretty modest circulation, and the aquarium style pump that comes with the laser is probably capable of this, as long as you don't make them pump the water too high above the pump. Aquarium pumps can generally not pump any water higher than a few feet upwards.

Always, always place the end of the return hose under the water surface in the water bucket. This creates a siphon effect which makes your pump work much better.

The common five gallon bucket of water is a fine solution if you can keep the water down to the recommended temperature range. Four to five gallons (16-20 liters) of water make a fine coolant reservoir. But you also need to contrive to keep that water cool. The more water in your reservoir, the longer it will take to heat up.

If you don't refrigerate the bucket of water somehow, the water will eventually be the same temperature as the air around it. If that air around the water bucket is down at 18-20C, you're good if you let the bucket cool down to air temperature between laser runs and don't run the laser for hours, then you're probably OK. If you live someplace hot, where “room temperature” is over 20C/68F, the water starts above the recommended temperature. I live in a place where the outdoor temperature is regularly 38C.

You can use >some< tap waters. Some tap waters have high mineral content or chemicals that make them less desirable for cooling a laser. You obviously don’t want mineral deposits on the glass tubes inside your laser. That could ruin cooling in spots, and lead to glass failure. Also, tap water is highly conductive, which may itself be a problem. I’ve read a couple of places that the conductivity of the water may encourage internal arcing. One place even supposed that early laser tube failures could come from high conductivity encouraging arcing. Tap water is usable, but I consider it to be a field expedient, what you do when you can’t get the right stuff in a hurry.

More research is clearly needed on that topic, but I have a simple and pragmatic view. Distilled water is available locally in my grocery stores in the baby food section for about US$1 per gallon. I can’t think of a good reason NOT to use distilled water over the long term.

If you don’t have distilled water easily available, you can make distilled water with a tray of wet stuff, a bottle, a pane of glass and some time spent building. This is the classic solar distiller. Try typing “diy solar distiller” into a search engine. There are many, many DIY solar distiller links on the web, some as simple as two used soft drink bottles. Here’s a decent starting place: http://diy-alternative-energy.com/build-a-solar-water-distiller/ The important part for most solar distillers is a pane of glass. You can make the rest out of repurposed/salvaged things.

I classify the magic coolant recipes I’ve found into three groups: those intended to get rid of bubbles, those intended to prevent freezing and those intended to prevent algae growth.

Algae growth is a problem, as it interferes with water flow directly, deposits on the glass, prevents heat transfer, and on and on. Algae (green gook) growth is bad. There are aquarium additives that kill algae, and some that seem to not make your high-resistance distilled water more conductive. A few drops of the right stuff in several gallons seems to be enough. Bleach may work, but do your homework on this before going to bleach.

Anti-freeze is problematic. The best thing in my mind is to not let your laser sit where it will freeze. That may not be possible for you, but do your homework on anti-freezes before you pick one. These can easily cause problems with conductivity.

Anti-bubble potions get a lot of press in the laser community. I have yet to find one mentioned where someone didn't come along and say "I tried that and it didn't work." I don't yet know what to think about bubble potions. I have this idea that it may be possible to deal with bubbles more constructively by pulling a modest vacuum on the cooling water bucket to enlarge the bubbles in the tube and hoses and sweep them out. More experimentation is needed.

Net: Some additive recipes are OK, others are counter productive.

Most K40 users will need to refrigerate the water somehow. The quick, certain way to keep the cooling water tank cool enough is to use ice to cool it. One reasonable way to do this is to save half-liter or liter plastic beverage bottles, fill them with water, and freeze them in a refrigerator. ½ Liter/16oz of ice melting in a water bucket will absorb enough heat to run the K40 at maximum power for about 15 minutes without the water bucket heating up. There are other ways:

- Ignore cooling the bucket, just circulate the water at whatever temperature. This works anywhere from sometimes to mostly. However, there is a steady flow of posted complaints about how quickly laser tubes wore out. Most people who simply use a bucket with no special attention to temperature probably don't run long lasing jobs, and it takes a long time to heat 5 gallons of water. I call this technique "you bet your tube".
- Run tap water into the bucket and let it overflow into a drain. In many places, the city tap water is 68F/20C or colder for much of the year. It's wasteful of water, but it works. Water quality is a problem, as city tap water often contains lots of dissolved minerals and other things you'd really prefer not to put in your laser tube.
- Re-purpose an office water-bottle style cooler. These can often be had for between US$50 and free. They can work, but have issues. In general, the problems come down to how fast the units can remove heat. The manufacturers' documents on water coolers are remarkably un-enlightening. I did a pretty solid search on the web and found no manufacturer's literature that said how many watt-seconds or BTUs per hour that they would move. The literature only says that it will "cool" thus-and-such water in this time. That would be great, but nowhere do they say what temperature the incoming water was before cooling, and what temperature "cool" is. This makes it impossible to figure the heat moving capability. Some people use them, though. Maybe there are extra large capacity coolers that are big enough. I can't find info on that though.
- Re-purpose a miniature refrigerator. The manufacturers' literature that I could find indicates that they are limited to about 20W to 100W of heat removal per second, so they're probably not able to keep up with the K40 running continuously. However, if you can put your 5 gallon water bucket inside them and cool that water overnight or for some hours, the water in effect stores up the cooling and can run the laser for a longer time before overheating.
- Use Peltier/electrothermal panels. Sounds good: put air on one side, your cooling water on the other side, and pump electricity through them. The cold (water) side gets cold, the hot (air) side gets hot, and heat is pumped from the cold side to the hot side. They actually do work this way, but the practical matters of how big/many panels are needed to pump enough heat fast enough, and the kinds of fans and pumps needed to move air and water around, and the big aluminum finned heat sinks for the air side make this a difficult thing to do. Like office coolers and mini-fridges, anything you do for cooling will help. But Peltiers have a hard time keeping up with the

heat output of a K40 at any kind of reasonable price and effort. And they take a modestly large electrical power supply to drive them to do the cooling. The laser power supply itself doesn't have enough spare power to run Peltiers suitable for enough cooling.

- Use a computer CPU water-cooling radiator placed over an air conditioning cold-air outlet. Most ACs in good condition produce cold air at about 62F (16C) and if you get enough water flow and air flow and the radiator is big enough, the AC will keep the water cold. I admire this solution, but have not tried it myself. The trick will be getting enough water flow in the radiator, a big enough radiator, and enough cooling air flow from the AC.
- Use a CW-3000 water chiller. There are lots of these on ebay for US$150 and up, marketed for cooling lasers. Only problem is they are not chillers. They are radiators that blow room temperature air over your cooling water. If your water is accidentally cooler than room temperature they will actual HEAT your cooling water. In my opinion, they're a waste of money. Be aware that these are often counterfeited/copied.
- Use a CW-5200 or other water chiller that has actual compressor based refrigeration and is rated for cooling water. Great solution, one of these will take care of the full cooling load of a K40. But they cost US$500 or so. Be aware that these are often counterfeited/copied/cloned.
- Use an aquarium water chiller. Good idea, but expensive. Bought new, about US$500 and up. May be a fine solution if you can get one used for cheap. Like the CW-5200 and its ilk, these will reliably handle the heating load if they're running right.
- Scavenge a used window air conditioner. Outstanding choice for being cheap and for having enough cooling capacity. The smallest window ACs have several times the cooling capacity needed by a K40. The trouble is getting that "cold" from the evaporator coil that gets cold and into your water. There are DIY descriptions of how to hack one of these and bend the evaporator coil over into water, or build a water tank around it. Ultimately, this is a huge amount of work. Maybe combining this with the CPU radiator would work.
- Live in a cold climate. Good idea, makes cooling easy. Room temperature is likely to be down in the 18-20C range anyway, so the laser is happy with just a radiator. But you will have to worry about the cooling water freezing. This is an unpleasant end for a laser tube. And if you don't already live a cold place, moving might be more expensive than a CW-5200.

There is a minimum temperature for the cooling water. The innermost glass tube contains the lasing material at a power density twice (or more) the density of the actual external beam and also contains the 10,000C electrical arc that excites the gas to lase. It's really hot inside that tube. The next tube out contains the reserve gas, where the tired (Lase-y?) gas from the inner tube goes to rest. The outermost tube contains the cooling water. It's job is to keep the middle reserve gas tube cool enough for the CO and O2 wastes from the lasing gases to recombine into CO2 to live to lase again. With very hot gasses and glass on the inside, and cold water on the outside, all meeting at the ends which make the tube supports, the temperature differences get critical.

The Technical Explanations for All the Above

It's a universal truth that the amount of energy and matter you put into something will equal the amount of energy and mass coming out. This gets complicated by burning fuels and by nuclear processes, but for something like a K40 laser where we put in electricity and get out light (that laser beam) and heat, it is simple. Pretty much, all the electrical power you put in has to come out of it as heat or light.

So if you put in the 300W or so of electricity these things take to run, and get out 40W of light in the laser beam, all the rest of the electricity eventually heats up the machine. The whole point of running cooling water through it is to carry heat away so that the machine doesn’t heat up inside until something dies.

==>> This is the ultimate goal of cooling: carry away as much heat as is generated. <<==

How much heat is generated?

The fast majority of the heat is generated in that laser tube. Most gas lasers convert 1% to 2% of the electricity to laser beam. CO2 lasers are remarkable in that they can convert electricity to laser beam power at up to 20% efficiency.

But turning that around the other way, CO2 lasers need because about 80% of the electricity you shove through the tube is converted to heat. Only 20% (if you're lucky and things are tweaked in properly) comes out as beam power. You have to get rid of the 80% that's waste heat. If you don't the gases overheat, chemically combine, eat molecules off the glass, melt the glass, and in general stop being useful.

If you put out 40W of laser light, and that’s 20% of the total power into the tube, then the total power into the tube must be 200W and the remainder after 40W leaves as laser light is 160W. There is a lot of room to quibble with that number, because K40’s say they put out 40w, but the reality is probably more like 30, max. However, K40’s lowest-bidder laser tubes are also unlikely to hit the magic 20% efficiency, either. So the waste heat is probably a bigger proportion of the total. Until I can find better numbers, I think the K40 has to get rid of 160W to 200W of waste heat in the cooling water.

How much water and at what temperature do you have to circulate?

The makers of the K40 lasers don’t say. They just send that little aquarium pump. But researching other laser tube maker’s recommendations, you can find some numbers. The clearest recommendations came from a respected maker of replacement tubes. For their 80W-100W laser tubes, the same glass-tube style, they recommend cooling water at 18C to 20C and 2 liters per minute of flow. I based my guesses for the K40 tube around that.

I reasoned that the gasses would be similar inside, and that the glass tubes, electrodes, and end mirrors would be very similar, so the temperature recommendation should be the same. I also reasoned that a tube rated for around half the output power ought to generate about half the heat, and so could make do with half the water flow, about 1 liter per minute.

This is a very thin basis for a guess, but it’s about the best info I could find. And it seems to give reasonable estimates for other things. In the absence of better reference numbers, flow about liter of water per minute through the K40 tube, and cool it to between 18C (64F) and 20C (68F) in the cooling tank.

Can the little aquarium pump that came with the K40 pump enough water?

Probably, if you don’t arrange your plumbing to prevent it from doing so. Small aquarium pumps do come rated for substantial flow rates, but they cannot produce much pressure to force water against flow resistances. A large and hidden pressure resistance for small pumps is the height the water has to be pumped to.

If the stock pump is roughly level with the laser machine, it’s probably OK. Putting the laser up on a work bench a couple of feet above the coolant bucket means the pump has to pump the water both through the hose resistance of the machine and also up a couple of feet of height. It doesn't sound like much, but that 2-3 feet of height may be nearly all of the pressure the pump can produce, so not much is left over to move water through the laser. Many aquarium pumps flatly specify that they can't pump water any higher than four to five feet, period. At that height, their pumping stops entirely. Below that, most of their effort is expended pushing the water up, not running it through the machine.

There is a trick here, though. If the pump can just manage to get the water up into the tube and get water running out the outlet hose, and you put the end of the outlet hose under the cooling water level, the suction of the water falling from the laser coolant bucket pulls the water behind it, and reduces the pressure on the pump, which now doesn't "see" the pumping height. The moral of the story is: always make sure your return hose end goes under the water level in the coolant bucket.

How much cooling water is needed? Is one/two/four/five gallons enough?

Now it gets complicated. The short answer is that the less "reserve" coolant you have in your cooling bucket, the better and faster you have to cool the water bucket.

And very sneakily, you probably just noticed that you have to cool the water in your bucket, too, as well as running the water through your laser. There are at least two things that have to be cooled.

Ultimately, the laser is cooled by either the air in the room around the water bucket, except for a few unusual cases. The cooling water is a fast and easy way to move the waste heat out of the laser tube to keep the tube from dying. But if the cooling water gets too hot, it doesn't cool the laser enough and the laser dies more or less slowly. So the cooling water has to get cooled, too.

But water stores more heat per unit weight than any common substance. It's a great heat reservoir. The more water you have in your cooling bucket, the longer it will take to heat the water up, and the longer you can run the laser without overheating. If you think about it, the oceans are a bucket, although a very large one. Imagine that your pump is pumping water out of the ocean, through the laser, and back into the ocean. How long would it take to heat up the ocean?

Correspondingly, the smaller the reserve water tank, the faster the laser will heat it up. If you have only one gallon (about four liters) of water in your cooling tank, it will heat up five times as fast as if you had five gallons of water to heat. So use the largest practical cooling water tank. Most people seem to use four to five gallons and that works well.

Now it gets picky. To keep your laser cooling water down under 20C, you will have to work out how to cool the water, and how fast.

Water is a great way to store heat. There are two common ways to express a certain amount of heat/energy, the Joule and the BTU. A Joule is one watt for one second. We can substitute the term "watt*second" for Joule. A BTU (British Thermal Unit) is the amount of heat needed to raise the temperature of one pound of water by one degree Farenheit. As always, you have to convert the units to make sense of metric and Imperial measurements.

Back at stored heat, water has a specific heat of 4.186 Joules/gram*C. If the K40 is making 160W of water heat, it does that every second, so it makes 160 watt-seconds or Joules per second. That amount of heat would raise one gram of water (1/1000 of a liter) by 160/4.186 = 38C on top of whatever temperature the gram of water already was. And it would rise another 38C the next second. If you had a total of 1 liter (1kg) of water to cool the laser, it would heat at 1/1000 that rate, or 0.038C per second, and 2.28C per minute. But we can use a lot more water. Let's say we have 4 liters (~ 1 gallon) of water to heat. The 160W raises it by 160/(4000*4.186) = 0.00956 C every second. If our water started out at 20C, in one minute it would heat up by 0.573C, and it would do that every minute we ran the laser.

Using four times as much water, 4 gallons (~16 liters) cuts the heating rate by four to 0.14333C per minute. So – the more cooling water reserved, the longer you can run your laser without cooling the water itself. If we have 4 gallons (16L) of tank water and 1 liter in the tube, the output of the tube would heat a (roughly) 17 liter mass of water by about 0.135C/ minute. Ten minutes is 1.35C, and an hour is 8.1C. A big water reservoir heats slowly.

Most of the foggy recommendations I've seen say that your cooling water should not get above that 20C number. If you start with 20C (68F) water, and four gallons of it, it gets to 21.43C in ten minutes, 22.86C in 20 minutes, and 24.3C in 30 minutes. If instead, you had started at 30C (86F, which we get all the time here), you'd have water at 34.3 C in 30 minutes. This is danger territory for tube life.

A lot of people simply use an un-cooled bucket of water at whatever temperature the air sits. The heating numbers show how they get away with this. If they do a short (30 minutes) lasing session, their water only heats up a bit over 4C, and the tube does not die immediately. But it does shorten the tube's life at the far end, the bit of its life you can't see yet.

If you only use the laser for short (~10-15 minutes) sessions, and will never use it for much of the 1000 to 5000 hours it is capable of, you may not need to cool your cooling water bucket.

If you want long tube life, and plan to use up all the hours it has in it, then you need to cool the cooling water. Plan to try to keep the cooling water down to 20C. There are many ways to do this, as noted before. But the simplest, cheapest way to do it is to freeze plastic soft drink bottles re-filled with water. A 16 oz/ 0.5L bottle has enough "cold" stored in the frozen ice to eat up the total heat output of a K40 for about 15 minutes as it thaws. So dunking one of these in you coolant bucket until you get the bucket down to 20C, and dropping in another every 15 minutes of lasing is a pretty good – and cheap! - way of cooling your laser's water. The other means mentioned earlier work to the degree that they can remove 160W per second from the cooling water.

Thoughts about ice

As amazing as water is, water changing state from fluid to solid (ice) and from fluid to gas (steam) is even more amazing. It takes energy to change ice at 0C into water at 0C. A lot of energy. Water takes 4.186Watt-second/gram*C to heat. Changing ice at 0C to water at the same temperature, 0C, takes 334 W*S/g*C. And that is from 0C to 0C – a constant temperature. Your laser puts out 160 W*s per second, or 9600 W*s per minute. That melts 28 grams of ice. A half-liter of water is 500g. Melting that takes 500*334 = 167,000 W*s. So your laser's 9600 W*S/min needs 167000/9600 = 17.39 minutes.

Ice is readily made and stored in modern refrigerators. You can put your refrigerator to work making ice and keep all those little bottles of 15 minutes of laser cooling just sitting there, waiting for you to need them.

What about using thermoelectric/Peltier coolers?

I have looked at Peltier/thermoelectric devices for cooling and didn't think I could use them well. Thermoelectric devices are tricky. they work best at low temperature differentials, and have a Coefficient Of Performance that as a practical matter peaks out at about 1.2 (if I read the charts and graphs correctly) for a device working at about 0.3 of its maximum current.

Uh...Right? So what does that mean? Well, If you pick a small temperature differential (that is, cooled thing to external temperature difference) under about 20C, you can actually get a Peltier to pump out as much heat as you put into it to do the pumping, perhaps a bit more. That is, you spend as much electricity to do the pumping as you move heat energy from the cold to the hot side. The hot side has to get rid of both the moved heat and the electricity you put into the cooler to do the moving, so you have to remove twice as much heat from the hot side as you pump out of the cold side.

So at a temperature difference of 20C, if you run the Peltier at about 1/3 of its max current, you pump just a hair more power out of the cooled thing than you spend doing the pumping. So to get rid of the 160-200W from a K40, and to bring that down to 10-20C under room temperature air, you would spend about the same amount of power doing the pumping as you remove from the laser; you put in 160-200W of electricity, 160-200W of heat gets pulled out of the water being cooled, and you have to supply heat sinks/radiators that will reject 320-400W of heat from the Peltier itself. The technical thermodynamic term for this state of affairs is AAAAACK!!

Worse, since the Peltiers are most efficient when running at about 1/3 of their rated power/current, you need Peltiers rated at a Voltage X Current of 900 to 1200W so you can run them efficiently. That gets expensive. So do the heat sinks. I can see that you're already looking at fan cooling the Peltiers. Good. You'll need it. When I looked at this I was thinking I'd circulate water on the hot side of the Peltiers and run this through some water-to-air radiators and fans to keep the high side temperature down. The radiator will have to be hotter than the surrounding air to transfer heat into it, so that's another step which can poison the efficiency of Peltiers.

As I said, I wish you good luck. I thought the design task was beyond my ability to do well.

Why the tubes wear out and die

From Sam's Laser FAQ:

> [In] Commercial sealed CO2 lasers […] you can't just take an axial flow CO2 design, seal it up, and expect the laser to work for more than a few minutes. The discharge process breaks down the CO2 to produce CO and O2 which quickly poison the lasing process. There ARE a number of solutions to this problem including the addition of other gases like H2 or H20 (water vapor) to the gas mix to react with the CO and O2 to regenerate CO2 or the use of a high temperature (300 °C) cathode to act as a catalyst to stimulate recombination.

The K40's sealed CO2 gas mix gets hot when you run the 20kV arc through it that powers the lasing. CO2 gas mix is generally CO2, helium, and nitrogen. The helium and nitrogen are not passive bystanders. The nitrogen is actually driven by the arc discharge, and emits photons that are the perfect size to pump the CO2 just right to lase. Helium has a high thermal conductivity; it's in there to help conduct the waste heat out of the nitrogen and CO2. The CO2 is ripped into CO and O2 by the driving energy, and this stuff will not lase like CO2 will, so it “poisons” the tube's ability to put out laser power. The only reason this stuff lases for more than a few moments is that if left alone, it will mostly recombine into CO2.

Early CO2 lasers simply ran a flow of fresh CO2 gas mix through a laser tube and exhaust the “poisoned” gas to the atmosphere. The super high power industrial lasers still do, because the high temperatures of the arc that puts energy into the CO2 to lase and the inefficiencies of the conversion to optical power out cause a lot of waste heat. Lasers in general are notorious for how poorly they convert electricity to laser beam. Very high gas temperatures apparently prevent the CO2 from lasing at all and even “normal” operation degrades the gas somewhat.

Heat considered as air in a balloon, and why neither air nor steel is as good as water

A short analogy for heat transfer: the balloon.

Imagine that heat is represented by air, temperature by pressure, and an object being heated is a balloon.

If you push air into the balloon, its pressure goes up. How much its pressure goes up depends on how much air you push into the balloon. More air, more pressure, until something breaks. If you have air pushed into the balloon, you can let some out by opening the balloon a bit and the stored air exits, reducing pressure.

If you have two balloons, you can inflate one to a high pressure, and one to a low pressure. If you then connect both balloons, the air will always go from the high pressure balloon to the low pressure balloon.

Heat, like air in balloons, always flows from a place with high temperature (like pressure) to a place with lower temperature. It never voluntarily flows the other way. If you want it to flow “uphill” to a place with higher temperature, you have to use a heat pump to force it to flow were it doesn't naturally want to go.

Temperature, like pressure, is a measure of how much heat is contained in how big a balloon. For tiny balloons, a single puff of air by mouth may be enough to get it inflated. But a larger one, like a several-foot-diameter weather balloon would not have significantly large pressure after many exhalations into it. Physical materials behave like this. The more mass (weight) of material you have, the more heat it takes to raise its temperature. And materials, just like balloons, vary as to how “stretchy” they are – how much heat it takes to raise their temperature per degree. A small kiddie balloon is easy to inflate by blowing into it. A car tire's inner tube is essentially not inflatable by mouth – it takes too much pressure to stretch it. This property of needing various amounts of heat to raise the temperature of materials is called the specific heat of the material.

It turns out to be simple to calculate how much heat will raise an object's temperature. The physics folks say:

$$Q = c * m * dT$$

where Q is the amount of heat, m is the mass of the object, dT is the change in temperature, and c is the specific heat of the material. Water has the highest specific heat of any common material, and is non-toxic so it makes a good coolant.

The specific heat of water is 4.186 Joules per gram-degree C. So if you want to heat 1kg of water by 10C, you have to put in $Q = 4.186 * 1000g * 10C = 41,860$ watt-seconds. If you only want to raise it by 1C, you only need 4186 watt-seconds, and so on.

The specific heat of steel is 0.49 j/gC. This means that if you have one pound of water and one pound of steel, the same amount of heat needed to heat the water by one degree will heat the steel by 4.186/0.49 = 8.54 degrees. Air is the only other common substance to use as a coolant. Air is not as efficient at cooling as water, as its specific heat is 1.005, meaning that air heats up about four times as much as water for the same amount of heat removed and temperature. Worse, that's for the same >mass< of air. Air's density is 0.001293 times that of water, so you have to move 773 times the volume of air to equal the mass of one unit of water. Overall, you have to use 3222 times the volume of air to cool as well as one volume of moving water.

Melting ice is about the most efficient cooling mechanism we mere mortals can use. Many K40 users know this instinctively, as the frozen bottle of water in the cooling tank predates my thoughts on the matter by quite a bit. Ice is also good for "transporting cold" from much bigger machines that have big, efficient refrigerating compressors, these same machines being ones you probably already have - refrigerators. You can actually store cooling in frozen water bottles.

The trick is getting some control of the process. Most K40s already have a bucket of water for cooling.

Put in a second bucket, fill it with ice and water, and selectively circulate the main K40 water through a copper pipe in the ice water bucket. Use something like an Arduino to measure temps and control how much of the K40 coolant gets pumped through the ice reservoir. Water running through a spiral copper tube in a water bath is a very efficient cooler. The Ice reservoir could profitably be a cylindrical drinking cooler - cheap, insulated, and easy to plumb.

I think this approach could handle holding the K40 water at optimum temperature constantly. One nice thing about an ice water reservoir is that the water temperature is CONSTANT at 0C as long as there is any ice at all. A second bucket, a second pump, and some electronics gives very good control over coolant temperature. And it can be automatic, functioning quietly until it runs out of ice and temperature rises. Then it can honk at you to feed it more ice.

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