Servicing A Late 2005 Power Mac G5 Quad Liquid Cooling System (LCS)

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v1.3

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Revision History

Version	Date	Author	Reason
0.1	4/9/2025	Michael Campbell	Initial release
0.2	4/10/2025	Michael Campbell	Added auto-generated TOC, additional detail in several places
0.3	4/12/2025	Michael Campbell	Added detail in several places
0.4	4/12/2025	Michael Campbell	Added content in loop building section
0.5	4/13/2025	Michael Campbell	Added detail in filling loop section
0.6	4/22/2025	Michael Campbell	Added more photos in several places
0.7	4/27/2025	Michael Campbell	Added tip to CPU pasting area
1.0	5/5/2025	Michael Campbell	First official release
1.1	5/31/2025	Michael Campbell	Minor enhancements throughout
1.2	8/1/2025	Michael Campbell	Additional details in several places
1.3	8/11/2025	Michael Campbell	Added details for loop construction and filling

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1. Disclaimer

*Disclaimer: this is a **long** document. It covers a deeply involved and detailed job, that of servicing the Liquid Cooling System (LCS) of a late 2005 Power Mac G5 Quad. This document provides a comprehensive step-by-step A-Z roadmap to this process. Please note that this document does not cover the equivalent process for any other model of Power Mac G5.*

If you prefer to convert your Quad to Air Cooling instead, see my companion guide to accomplishing this, "Converting a Late 2005 Power Mac G5 Quad from Liquid Cooling to Air Cooling, v0,1", May 31, 2025

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2. Introduction

Is your late 2005 Power Mac G5 Quad running hot and/or noisy? That is unfortunate, but you are not alone. This is a common issue with older Power Mac G5 Quads (and they are all "older" these days). The source of your problem is almost certainly the Liquid Cooling System (LCS) of your Quad, a largely invisible component of the machine tucked discretely behind the shiny "G5" logo panel that you see when you open the case up.

Power Mac G5 Quad Liquid Cooling System (LCS)

The PowerPC 970MP chip that animates the Quad is a **beast**, and it throws off a lot of heat… a lot! To keep that chip running cool and comfortable, Apple resorted to liquid cooling, not unlike a car engine – cooling fluid, fluid lines, one or more pumps to move the fluid through the lines and finally, a radiator. Variable speed fans drive outside air past the radiator and propel that air out the back of the case, carrying with it the heat that the LCS has transferred from the two PowerPC 970MP chips to the cooling fluid and ultimately to the radiator.

If the LCS develops a leak or loses some amount of its cooling fluid over time through infinitesimally slow evaporation, or mineral deposits crystalize out of the cooling fluid and begin to obstruct the free flow of coolant, or goodness knows what all else, the system has to work harder to keep its cool. For a time, you may notice that the machine gets noisier, as the fans ramp up to accomplish more of the cooling that the LCS itself should be doing.

Eventually, if LCS degradation continues long enough, you may notice that the fans go to full speed even though the machine runs hotter and hotter. This indicates that even at full speed, the fans can no longer compensate for the loss of cooling capability in the LCS.

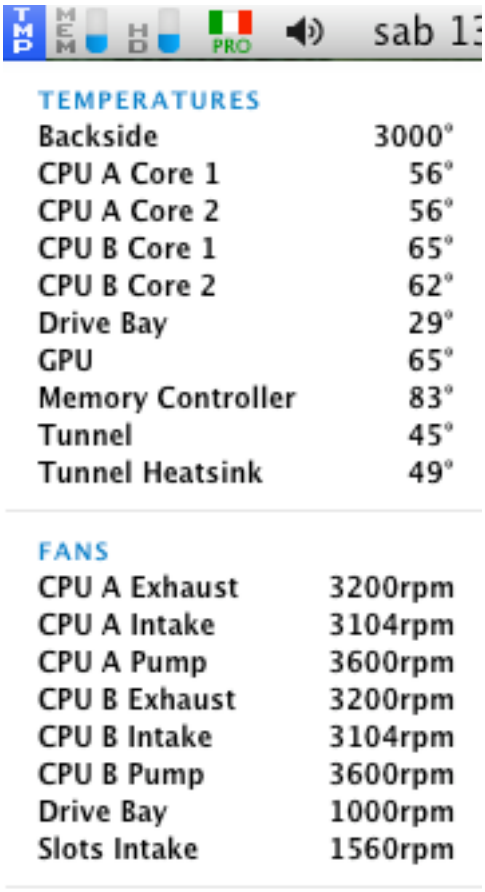
When this happens, it is time to service your LCS.

3. How Hot is Your Quad, and What to Do About It?

How do you know how hot your Quad is running? Install QuickFans or iStatMenus, both of which can provide you with CPU temperatures and fan speeds. Of the two, iStatMenus is the preferred choice.

IF you are running Leopard or Sorbet Leopard, you should also check out XRG, an excellent tool that can give you all the same information as iStatMenus, but in a detailed real-time updating GUI window, showing both temperatures and fan speeds. At the time of this writing, XRG could be obtained from Macintosh Repository, at:

https://www.macintoshrepository.org/71245-xrg



XRG Temperatures, Fan Speeds Pane

If any/all of these programs show that your Quad is running hotter than it should be, or the fans are running faster than they should be, or both, it is time to service your LCS.

Doing so is the subject of this document.

4. The Dilemma – to Service Your Quad LCS or Not?

You have determined that your G5 Quad LCS needs service. Unfortunately, you can no longer simply take the machine into the nearest Apple store and have them do it for you. G5 Quads are now well outside of their service period; you have to do the work yourself.

Many people simply walk away from their Quads at this point. Servicing an LCS is a daunting task (as the length of this document will attest!), and not one to be undertaken lightly. You need to be **part computer technician** and **part plumber** to accomplish this, along with oodles of patience, persistence and determination. It is not a job for the faint of heart.

On the other hand, however, you have a brilliant piece of computing history under your feet. The G5 Quad was the last and the fastest of the PowerPC line of Macs that Apple produced. It is an engineering marvel. Restoring one that is failing saves one more of these magnificent machines from the trash heap.

Power Mac G5 Quad – Engineering Brilliance

The work is difficult, but well worth it. Even today (2025), when loaded with Sorbet Leopard (10.5.9) and the latest Aquafox web browser (2.3), these machines can still surf the web, run your email, balance your budget, etc. Admittedly, they do all of this a little more slowly than today's most modern machines, but for a 2005 computer, this degree of functionality is truly amazing.

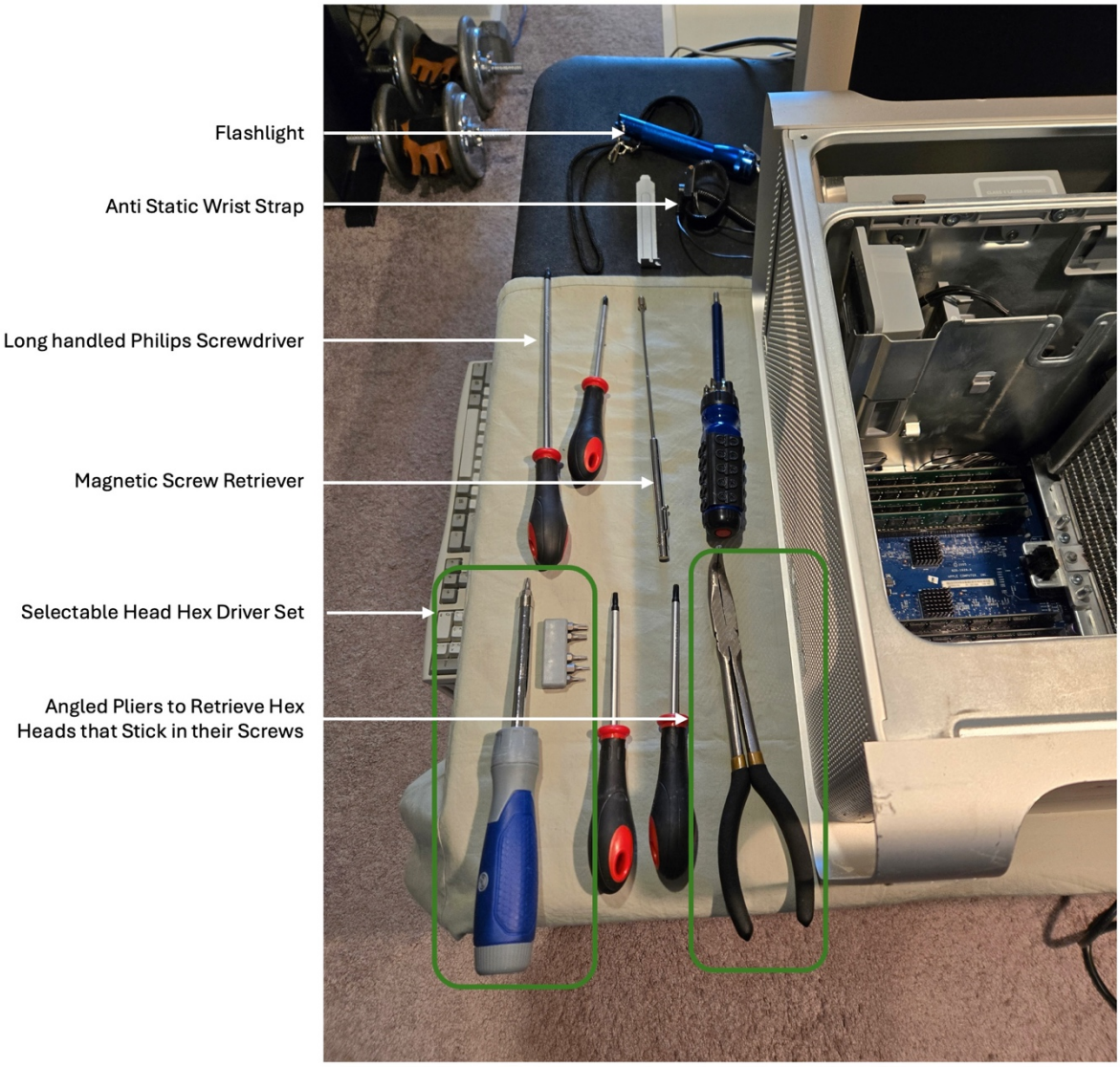
So, "screw your courage to the sticking point" and dig in but do so with your eyes open. You are going to need tools you don't own yet, procedures you have not dealt with before and the liberal help of experts in the field.

Happily, you can find such experts among the fine folk at www.macrumors.com, where the **real** Macintosh experts hang out. Without this group of people, I would never have been able to restore my Quad's LCS. So, if you don't already belong to www.macrumors.com, point your browser there and register. You will find me there, as user "mac57mac57", but I am one of the lesser lights at MacRumors. Nonetheless, all of us will do our best to help you, cheer you on and offer as much as advise as possible.

5. Tools, Supplies You Will Need

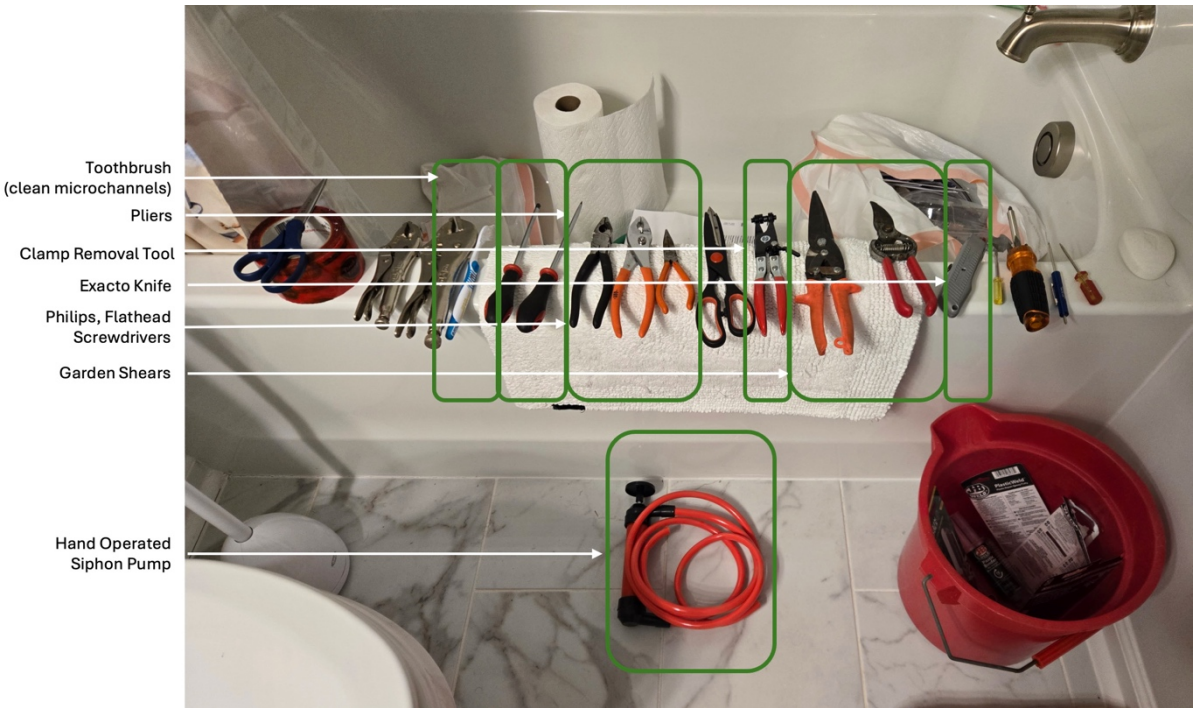
You have decided to proceed. Let's look at what you will need in the way of tools and supplies to get this job done:

Tools for Extracting the LCS

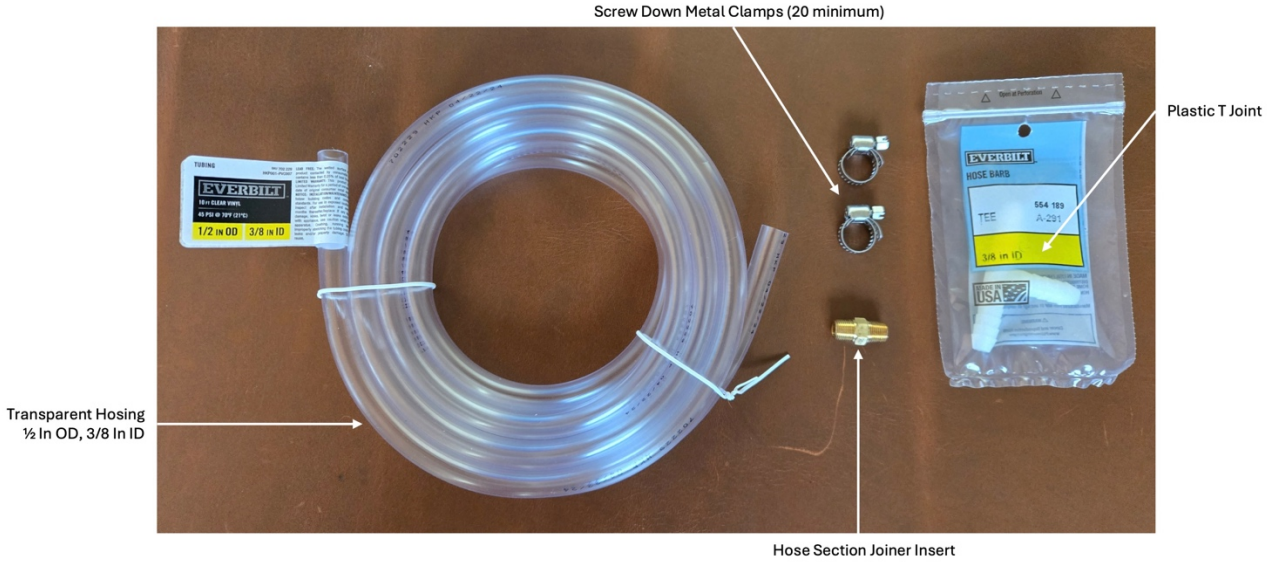


Tools for Removing the CPU Cards, CPU Cooling blocks

Tools for Building, Filling New LCS Cooling Loop



Supplies for Building, Filling and Sealing the New LCS Cooling Loop



Note that the “Hose Section Joiner Insert” shown above is a metal insert that can be used to connect two pieces of plastic hosing together (should that prove necessary). The method is to insert the metal “barb” of one end of the joiner piece into the end of one piece of hose, then connect the metal barb on the joiner’s other side to the other piece of hose, effectively joining the hose pieces together.

To complete the job, some form of sealant is needed, either screw-down metal clamps on each side (recommended), or waterproof construction grade tape or both. Over time I have used each of these (and both), and they all work well if applied correctly.

Kitchen Squeeze Bottle, to Fill Loop

Clamps, to Seal Loop

The clamps shown above are used to seal the fill/bleed line when done. Simply fold the line over on itself and clamp the fold with one of these. Even the small one exerts enough force to seal it completely.

6. Preparing the Quad for LCS Removal

Now that you have acquired all the necessary tools and equipment, your first task is to extract the LCS from the Quad. This all by itself is no simple job, but after you have done it a few times, it will become easier. Be prepared. You **will** end up doing this multiple times because your first efforts at restoring your LCS are not likely to succeed, requiring you to disassemble the machine again, fix whatever you didn't do as well as was possible last time and try again. You may have to go through this loop multiple times. Restoring my Quad took multiple cycles through this loop. Patience… did I mention patience? You will need it in abundance.

Let's start by opening the case, removing the plastic air deflector and extracting the front CPU fans, which simply lift straight out. Now sit back, take a moment and simply admire the beauty of the machine's interior. No wires hanging out, clean lines everywhere and simple access to all the most commonly serviced items, such as hard drives and RAM. The late 2005 G5 Quad is an engineering work of art.

Late 2005 Power Mac G5 Quad Interior

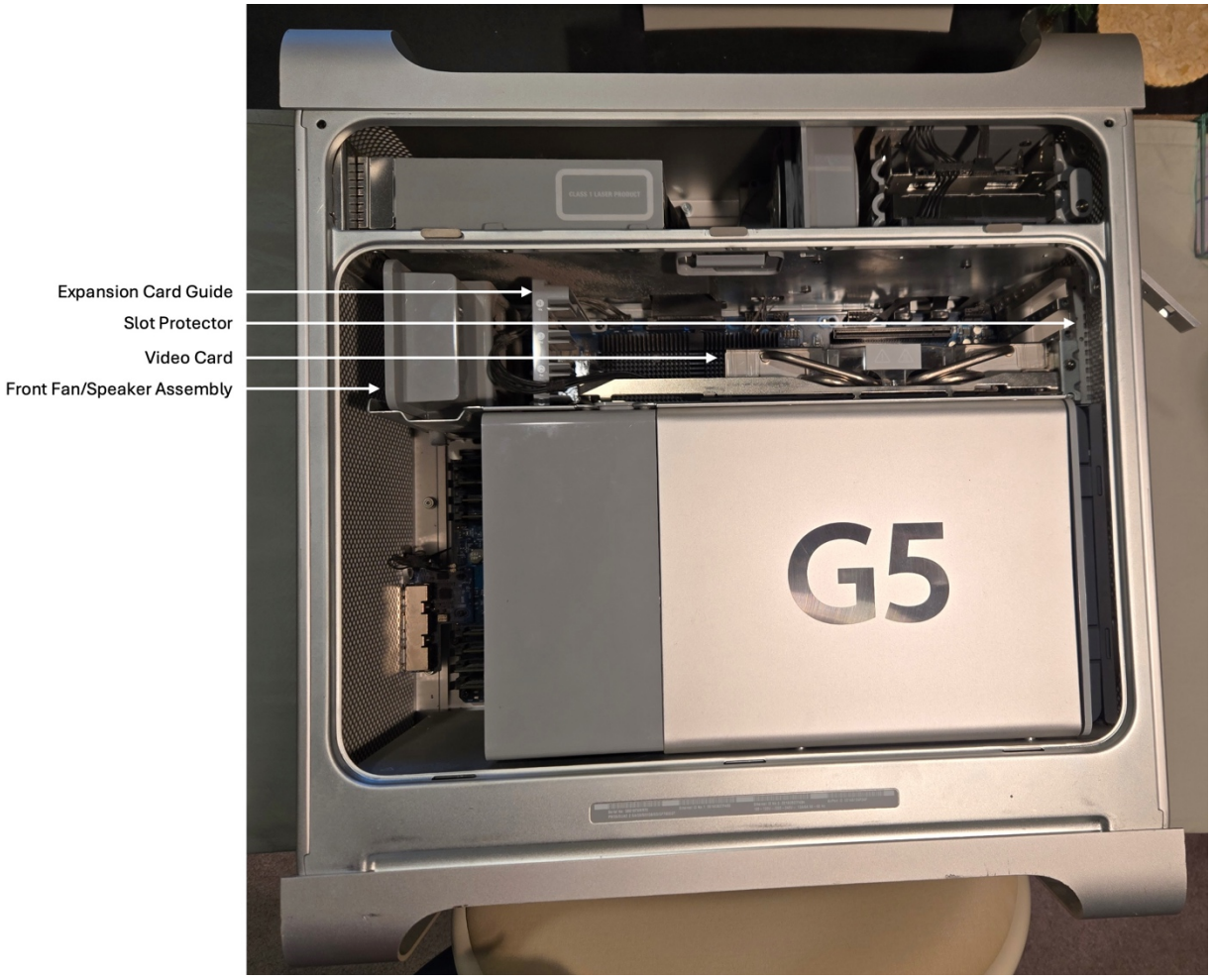
OK, enough admiration. Let's get to work. Lay the machine on its side on a work bench whose surface is covered with some form of soft material that will not scratch. I use a bedroom sheet for this purpose. If you do not lay the machine down, and you drop a screw, in all likelihood that screw will end up inside the power supply at the very bottom of the machine. You will be in a world of pain to retrieve it.

Don't go there – lay the machine on its side before you start working. Even so oriented, over my time working with LCS restoration, I have dropped two screws. Both ended up at the bottom of the machine. I managed to retrieve one of them. The other one remains unaccounted for to this day! ☺

Power Mac G5 Quad laid out on sheet covered worktable

Start by removing all of the plugin expansion cards. Typically, there will be just one of these, a graphics card. Undo the retaining screw and gently lift the card up and out. Mind the sheet metal slot protector. This thin aluminum piece has razor sharp edges per slot and can give you a deep and nasty cut… I speak from experience! So much blood…

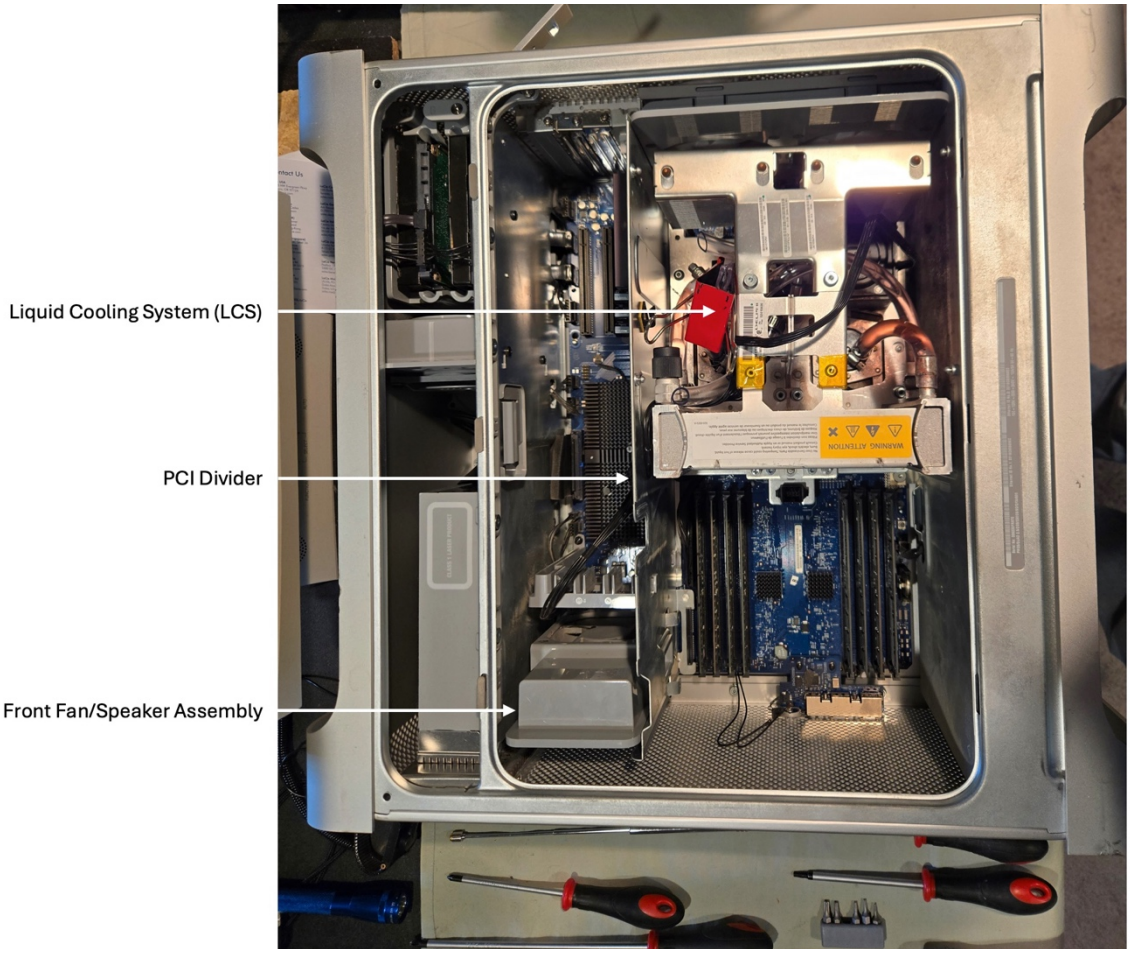
Next, you need to remove the expansion card alignment guide at the other end of the expansion card area. There are two screws, one on each end, and two clips that slide into the metal plate that separates the PCI slot expansion area of the case from the CPU area of the case.



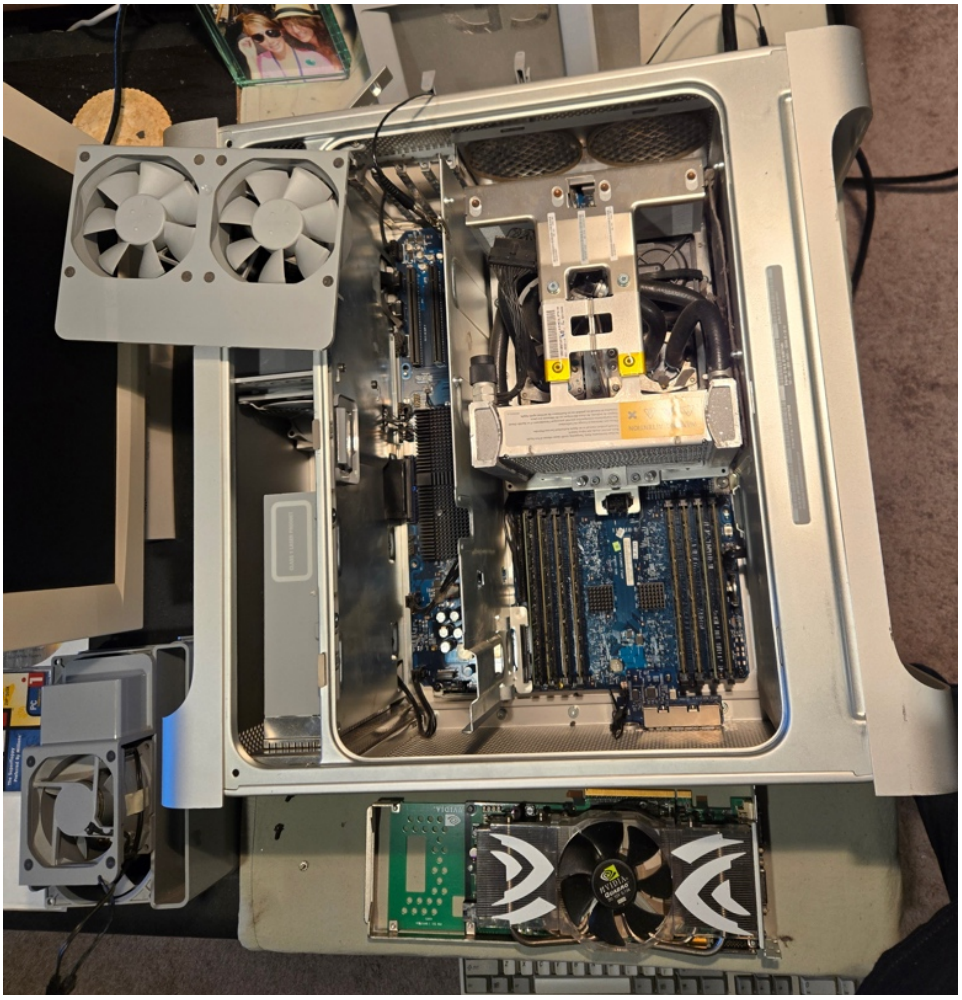
Now slide the front fan/speaker assembly upwards and turn it to its side, laying it inside the case; no need to disconnect its power unless you want to.

Next, we need to remove the metal plate that separates the upper PCI expansion slot area of the interior from the lower CPU area of the interior. Apple calls this plate the “PCI Divider”.

To remove it, there are three Philips screws that must be removed. Once done, the plate lifts straight up and out.



With the PCI Divider out of the way, you can now easily remove the rear CPU exhaust fans. Do this by pressing down on the two tabs at the top of the unit and pulling it towards the CPU assembly. You can then lift them out and twist them over on its side too, laying them on top of the case or down in the PCI expansion slot area. Again, there is no need to disconnect the power unless you are so inclined.



Power Mac G5 Quad with Rear Fans Removed

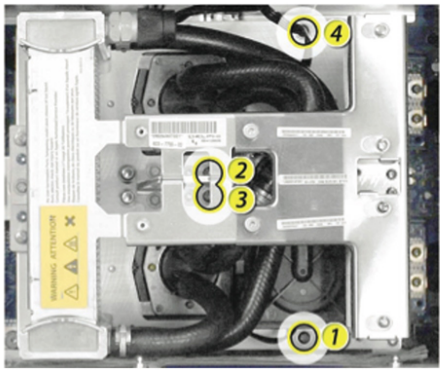
Excellent! You are now ready to extract the CPU Assembly/Liquid Cooling System (CPU/LCS, referred to hereafter simply as “LCS”).

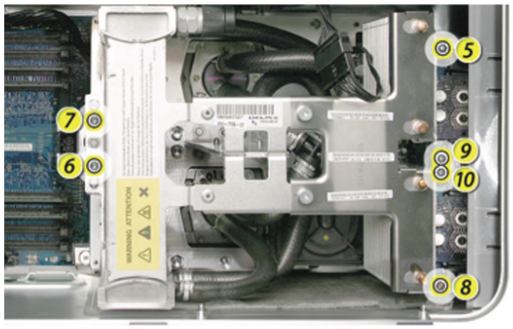
7. Extracting the LCS from the Quad

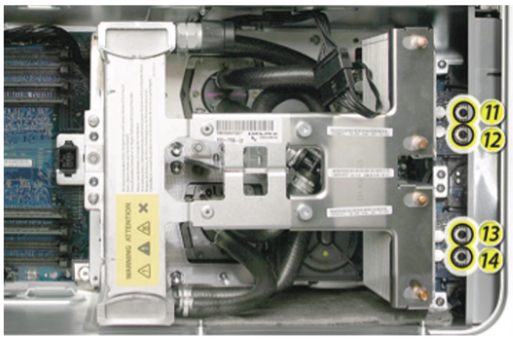
Cameron Kaiser has written an excellent guide to this part of the process (see Appendix B, items [1] and [2]), but in the interests of creating a single comprehensive A-Z guide, I will cover the same steps here. The photos however are shamelessly reused from Cameron's guide. At the time of this writing, that guide can be found at:

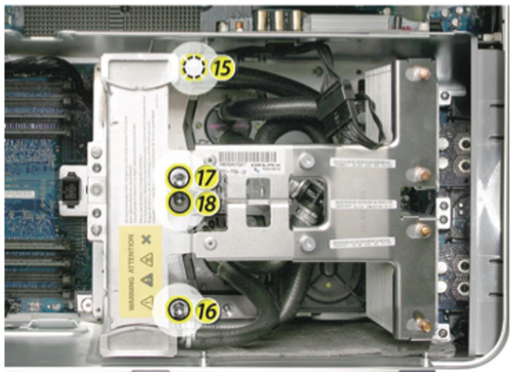
https://tenfourfox.blogspot.com/2021/07/and-now-for-something-completely.html

See the following four pictures, which show the LCS still in place in the Q5 Quad case, and circle and number each of the screws/connectors that you need to remove to extract the LCS. It may be just street lore, but I have read that if you do not remove these screws/connectors in the order shown, or fail to reconnect them in the reverse order, the machine may not work. While this has not been my experience, I pass this information along anyway for your consumption and decision.





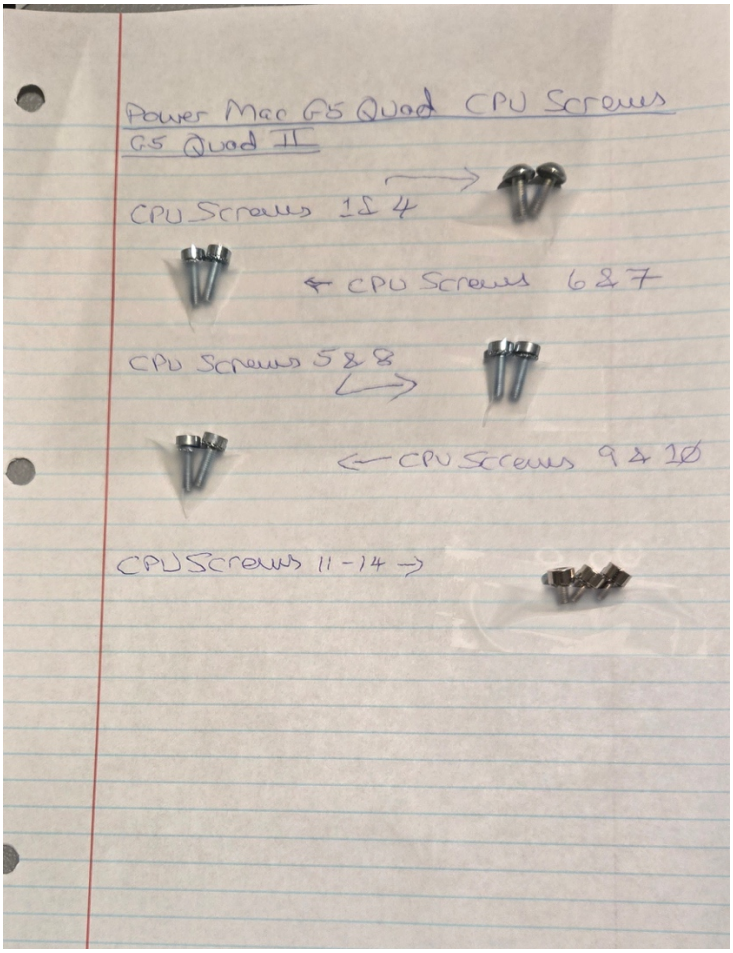




The G5 Quad case is quite deep and crowded, and you will almost certainly drop a screw from time to time. You will need long handled screwdrivers (primarily hex heads), preferably with magnetic heads, long handled pliers and a telescoping magnetic screw retriever, to …ahem… retrieve any wayward screws that might get away from you during the work. On eBay, these can be easily found by searching "telescoping magnetic screw pickup tool".

Remove all the screws in the order shown, starting with [1]. I have never found it necessary to remove screws [2] and [3] and so I always leave them in place. When you eventually reassemble the LCS into the Quad (after you have completed your LCS servicing), you will repeat this but starting from [18] and going in reverse order.

A helpful tip: when I did this for the first time, and in fact every time since, I have used an 8.5x11 sheet of white paper (printer paper will do just fine) and taped each removed screw, or set of logically connected screws, to the paper, labeling it with the screw number. That way, when I reassemble, I always know which screw was which.

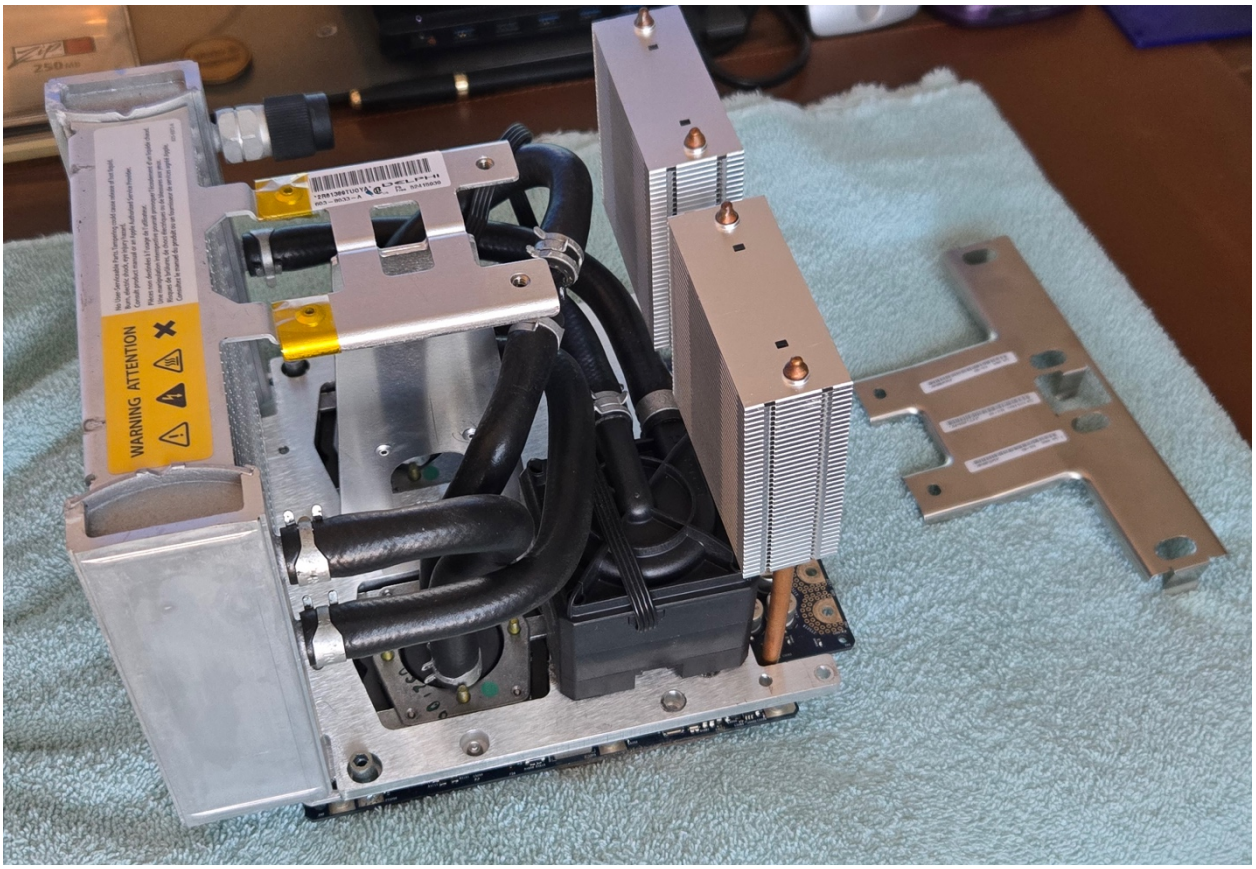


Note that not all the screws/connectors actually come out. In particular, connectors [15]-[18] simply loosen in place but do not come out.

Another note: I found that I only needed two sizes of hex head drivers to undo everything. Connectors [15]-[18] required the larger of the two. All of the remaining screws could be removed using the smaller of the two. You will need a long-handled screwdriver with replaceable heads, and a variety of hex head end pieces in various sizes. Find the two that fit and that should be all you need to complete LCS removal.

Once all the screws have been removed, grasp the LCS by the metal piece between the front and back radiators and lift straight up. Do not use any significant force. If it does not come out easily, go back and loosen connectors [15] - [18] and try again.

Repeat until you are able to easily lift the LCS up and out. Note that at this point in the procedure, the Quad's two CPU cards are still attached to the underside of the LCS. In the below photo, you can see them protruding if you look carefully. Treat the LCS with extreme care. If you mess up the CPU cards, it is "game over".



LCS Removed from G5 Quad Case

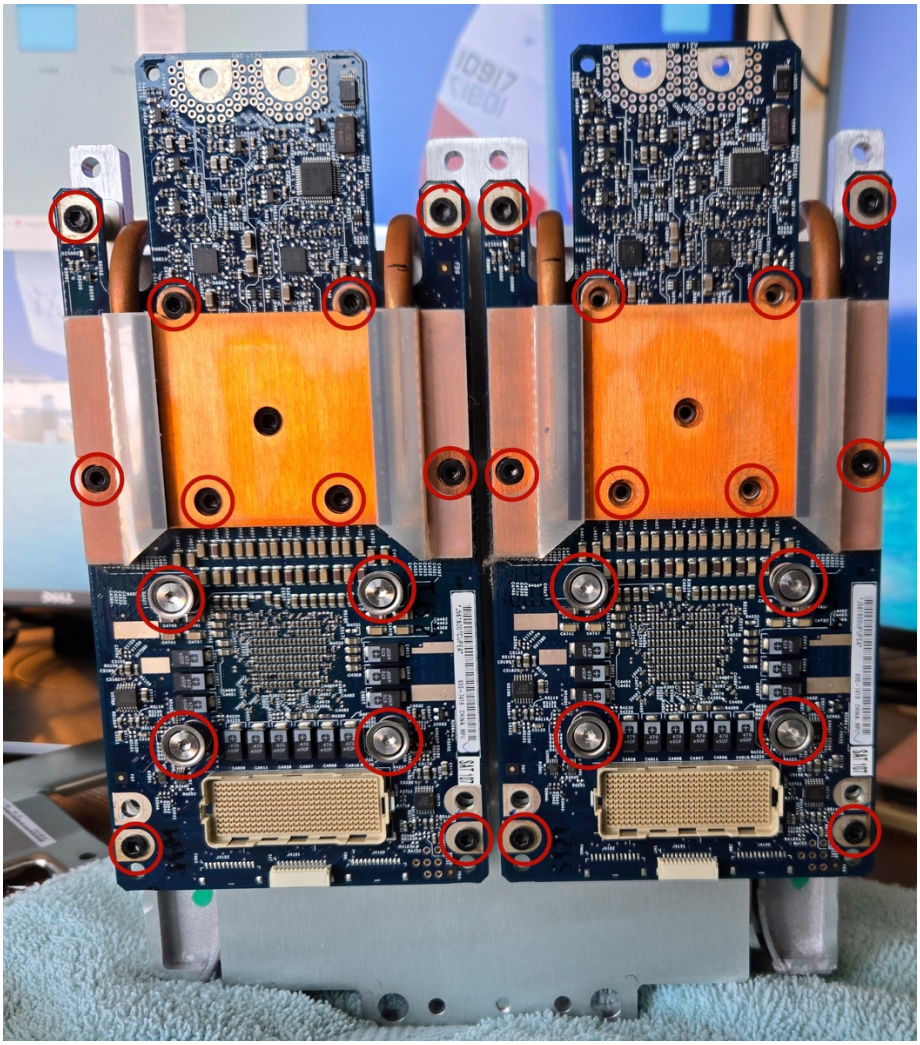
Congratulations! You have extracted the LCS, and there it sits, looking oh so innocent and oh so functional… except that it isn't anymore. That is why you are looking at it!

8. Servicing the CPU Cooling Blocks

The LCS is part cooling system and part CPU assembly. You need to separate these two parts before getting to work on the cooling part. This is for two reasons. One, you don't want to get potentially corrosive coolant onto the CPU cards, and two, you need to service the CPU assemblies too, not just the LCS they are attached to.

Turn the LCS onto its side and you will be able to clearly see and cleanly access the CPU cards.

Removing the CPU cards from the LCS is not a difficult job but it takes a bit of time. Each CPU card is secured to the LCS with 14 different screws/connectors that have to be removed in order to free the card. To remove these screws, you will need only one tool - a hex head screwdriver of the appropriate size. I purchased a Craftsman hex set with about a dozen different sizes of head – one of them fit perfectly and I have used it ever since.



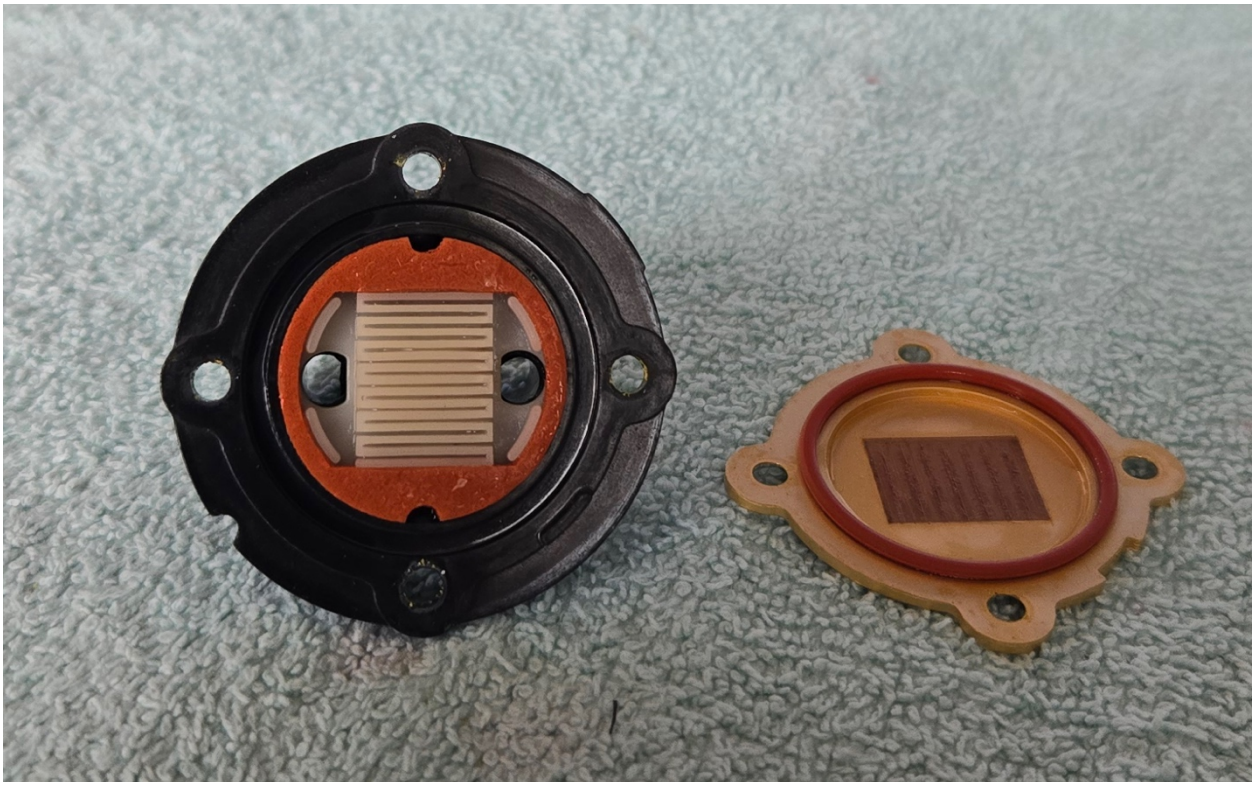
LCS CPU Cards with Attachment Screws Circled in **Red**

When you have removed all 14 screws/connectors, the card will come away from the LCS, and there before you very eyes will sit the mighty PowerPC 970MP chip. For such a powerful beast, it is a small unassuming chip, with no labeling of any nature and simply a polished reflective surface. You will not see the chip face itself however until you wipe off the old thermal paste that is on it. Go ahead and do that at this time. You will need to clean the thermal paste off the back of the heat spreader that the CPU chip mates up to as well. I used paper towel and rubbing alcohol to ensure a total clean.

With the CPU cards safely removed, you are now in position to service the cooling blocks that each CPU mates to. The cooling block is the focal point of the LCS. The whole purpose of the LCS is to circulate coolant through the two CPU cooling blocks, where the coolant picks up heat from the CPU heat spreaders that are a part of each cooling block. By the action of the pump, the heat-carrying coolant is then circulated to the radiator, where fan-forced air flows by, extracting the heat from the fluid and directing it out the back of the Quad's case.

Power Mac G5 Quad CPU Cooling block

These cooling blocks contain a set of coolant micro-channels that ensure that the coolant flows evenly across the full surface area of the heat spreader. Those channels can become clogged over time, reducing either the surface area of the heat spreader that coolant can come in contact with, the volume of coolant that can flow through that area, or both. In all cases, this will reduce the cooling efficiency of the LCS.



Cooling block Heat Spreader Removed, Exposing Coolant Microchannels

To ensure that the microchannels are fully clear, next up is to extract the cooling blocks for each of the two CPUs and clean all parts of them (not just the microchannels) thoroughly, to ensure that coolant can flow through them as easily as possible. This is one of the most critical parts of the LCS servicing procedure; all the good work you do to flush the radiator, design and build a new LCS cooling loop and fill it perfectly is all for nought if the "business end" of the loop is obstructed or blocked entirely.

What is the "business end" of the loop? It is the two CPU cooling blocks. As stated above **they** are what the whole loop is for.

Service the cooling blocks is not without its challenges. The cooling blocks are connected to the LCS by four screws each. In my experience, one or more of these screws is always completely seized and will strip the screw heads when you try to loosen them. There are lots of techniques for loosening seized screws; pull up a few YouTube videos on this and try several. I did this, but in the end, I found that nothing worked except the last technique I came across - drilling out the seized screws. I was never able to loosen them in any way.

Drilling Out the Screws Holding the Cooling block

This process destroys both the screws in question and often the threads they screwed into on the LCS body. To that end, you may need to find a nut/bolt arrangement that fits and use that to replace destroyed screws during reassembly.

When you can eventually extract the cooling blocks, be very careful with them. The contain multiple parts within, and with the screws removed, the whole block can come apart, with those internal parts falling out in random order. If you don't know the order they go back together in, you will have no small amount of trouble getting them back together. Proceed slowly and carefully!

With the two cooling blocks removed from the LCS it is time to disassemble them and clean them.

What is inside the cooling block is a “stack” of parts that all fit inside each other, rather like nesting bowls. Remove the outside heat spreader by simply lifting it off, and then carefully remove each of the remaining parts in order. Remember the order! Reassembly will be much more error prone if you don’t do this.

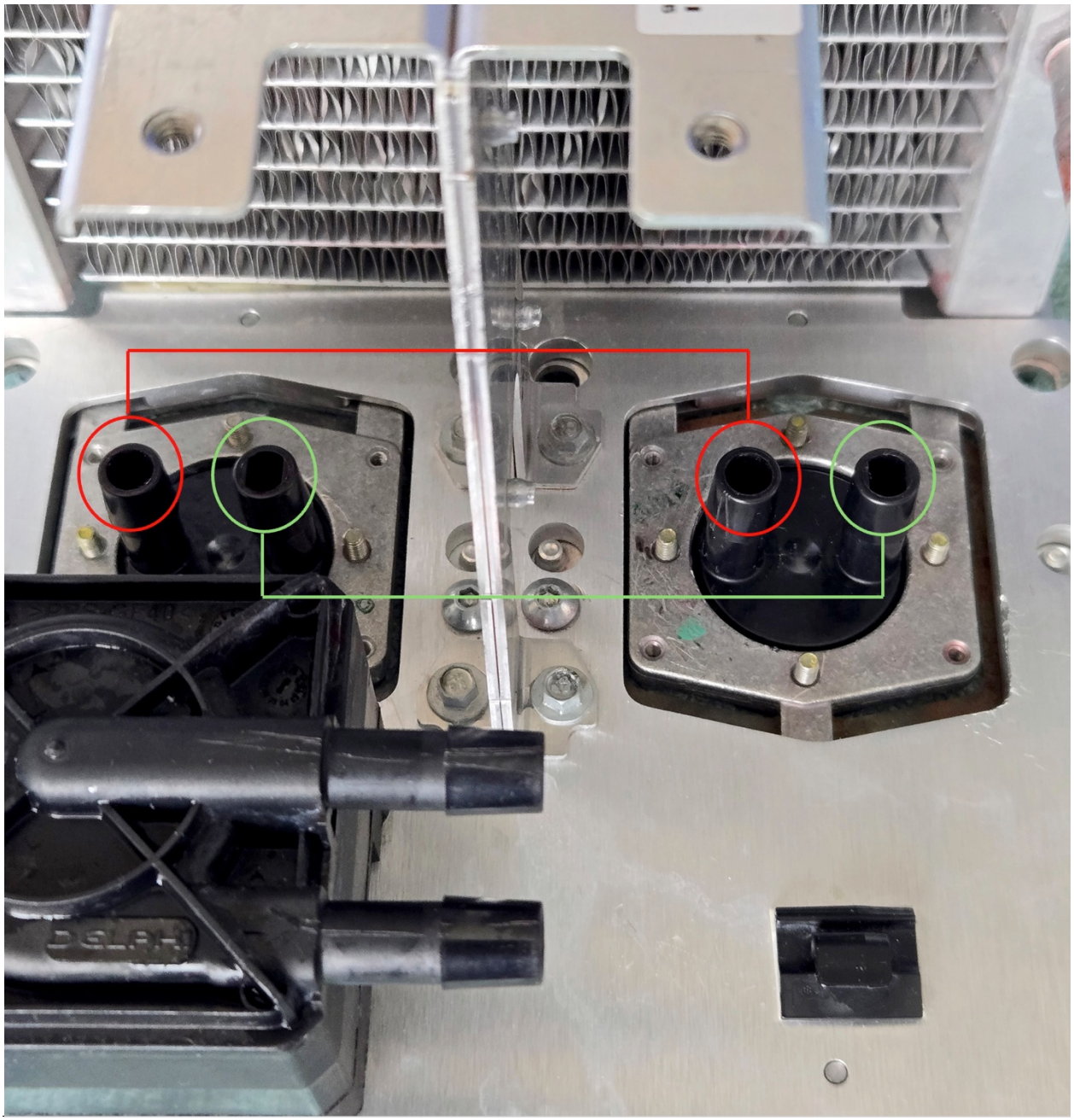
CPU Cooling block Disassembled

To clean each microchannel, I used a new (preferably stiff) toothbrush, and then methodically ran an exacto knife blade along each microchannel. I flushed it thoroughly with water (distilled water is preferred) several times during this process. Finally, when fully cleaned and dried, I reassembled each cooling block and reattached it to the LCS using the four screws (or the nut/bolt replacement set for the screws that had been drilled out) that had been undone earlier to extract them.

Below is a photo of what you are trying to overcome. This is an actual microchannel piece from an LCS I was working on. As you can see, it is dramatically obstructed:

There is one more thing to be mindful of at this stage. If you examine the two barbs of a cooling block, you will see that they are not the same shape, and it is important that when you reassemble them, they go back into the block in the same orientation they originally had.

The photo below illustrates this difference in shape:



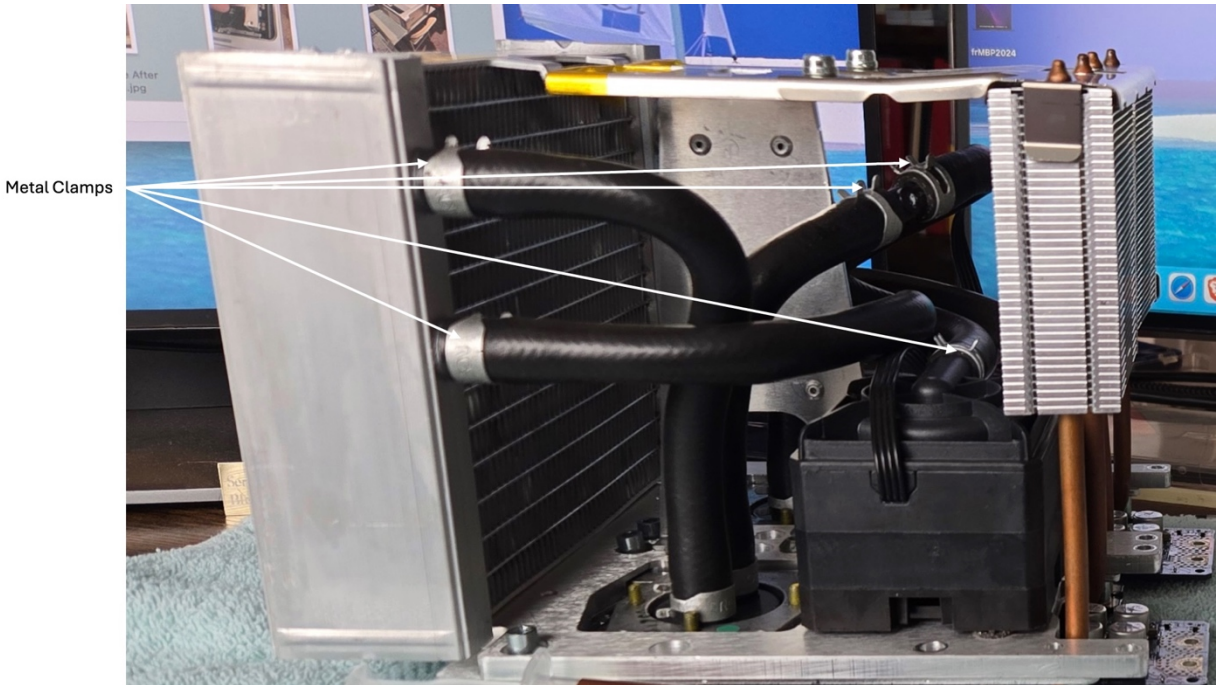
Note the different shapes of the barbs circled in red vs. those in green. Make sure, when you reassemble your cooling blocks, that they go back in this same orientation. It is probably not **critical**, but little details add up…

9. Draining and Removing the Existing Apple Cooling Loop

Now it is time to drain the existing Apple loop. Draining it is straightforward. Use a sturdy pair of garden shears to cut one or two of the fluid lines and drain the fluid out. It is useful to do this over a clean container that can collect the drained fluid. If you do this, you will be able to immediately see if the coolant is dirty, has crystals in it, or any other debris. This is not critical, but it is interesting.

Note that the original coolant is from GM's Delphi unit (A2 Cooling Fluid). This coolant seems prone to crystalizing sediment out over time, and sometimes quite a lot. A2 Cooling Fluid is composed primarily of propylene glycol and distilled water; despite what you may read about it on the web, it is not (very) toxic. The toxicity of the coolant in earlier G5 systems is a **very** different story – be forewarned. Despite the lack of toxicity, this guide recommends wearing disposable gloves while draining it from the original loop. No sense tempting fate!

Once drained, you need to remove the existing Apple hoses. This is a job made infinitely more complicated by the $#@%^ one-piece metal clamps that Apple has so "thoughtfully" placed at the end of each hose segment. These are necessary pieces to be sure – they clamp the hose segments onto the barbs below to seal them against leaks. However, they are the very devil to remove.



LCS, With Visible Metal Clamps – There Are More That Are Not Visible Here

Do **not** do what I did initially, which was to try to grab each of the small "handles" of the clamp with a pair of needle nose pliers and twist outwards. These clamps are remarkably springy, and no matter how much force you apply to them, they just seem to keep springing back into place. It takes a **lot** of force to successfully bend one away from the hose it is on.

Being the persistent type however, I kept at it, using larger pliers and more force, and I eventually managed to remove all of them this way except one… the last one, of course. On that one, I had to use so much force to bend it outwards that it sheared off the plastic barb below, causing days of trial-and-error work while I attempted to reattach it (**J-B Plastic Bonder** eventually did the trick)!

So, what **should** you do? There are two approaches, and both are needed. You can buy a purpose-built tool to install and remove this type of clamp. Here is the one I purchased (from Amazon):

This tool is the simplest way to remove these clamps… if you can get at the clamp. Unfortunately, you cannot get this tool onto all of them. The cooling loop is a pretty cramped space!

For those clamps that cannot be reached with the removal tool, a pair of pliers can be used, with one jaw on the single "handle" side of the clamp and the other jaw on the double handle side. Close down on the pliers and it squeezes the clamp open, allowing you to easily move it out of the way. This is more easily said than done, but you will get the hang of it with a little repetition. Regrettably, some of the clamps are hard to get at even this way. You will need to be very persistent.

When done, you are left with clamp-free hoses, but hoses that are still **very** tightly connected to their barbs. You will have to cut these off with an exacto knife or another sharp blade. Use as little force as possible to cut through the hosing. This will be challenging – the hoses Apple used are very thick and very sturdy. Force **is** needed to cut through them but remember that some of the barbs below are plastic, and if you use too much force, you may cut into the barb itself.

If you cut a barb, you are in a world of hurt. You cannot buy replacement barbs, and you are therefore going to have to try to reseal the cut you have made. Don't go there! Once you have successfully cut one hose off its barb (which is an exercise in repeatedly and lightly cutting along the same cut line with only as much force as needed) you will get good at it.

Cutting out and removing the original Apple cooling loop hoses has a hidden benefit. If you look carefully inside the end of those segments you cut off at each of the CPU cooling block intakes, you will find little inline filters, one of which is shown in the photo below:

In-line filter

These filters are there to protect the CPU cooling block microchannels from getting clogged with debris from the coolant, but if there is any such debris, it builds up in the filters, obstructing the flow of coolant. After I have cut off the hose segments from each CPU Cooling Block intake, I dispose of them, filter and all. I do not re-install the filters in the new hosing; coolant moves more freely without them there. Yes, they served a purpose, but now, 20+ years later, that purpose has long since been served. Time to move on, filter free!

10. Flushing the Radiator

You have the CPU cards removed and the original Apple hosing off. Congratulations! You have completely isolated the LCS and can now work on it. The first task is to flush the radiator! This is necessary because just like the CPU micro-channels, the radiator can get clogged with debris from the cooling fluid/loop. To flush the radiator, you will want a hand operated or electric siphon pump, so that you can force fluid through the radiator under pressure. Here is the one I used (purchased on Amazon):

Photo of Hand Operated Siphon Pump from its Amazon Listing

Connect the output hose of the pump (connected to the top spigot in this case) to the intake of the radiator, and the input hose of the pump to a gallon of 50/50 distilled water and distilled white vinegar mix.

Begin to pump the fluid mix into the radiator, watching for it to begin coming out of the two radiator outputs. In regular operation, each of these two radiator outputs is connected directly to the input of a CPU cooling block and so it is key that both outputs are flowing freely when fluid is pumped into the radiator input.

When the vinegar/water mix starts to come out of the two radiator outputs, the radiator is filled with the solution. Let it sit for an hour or more, so that the solution can do its magic, dissolving any built-up deposits within the radiator.

After an hour or more, pump it out with plenty of distilled water. As you do this, watch the volume, color and composition of the fluid coming out of the radiator. There should be little resistance, and as much fluid should come of out the radiator as you pump in. If you see any sort of color variation or debris, this is excellent. This means that the radiator was somewhat clogged and will work more effectively after your flush.

Keep pumping until the output is running clear (or you have determined that it is still so dirty inside that it never will).

Now repeat. Refill the radiator with a fresh load of the 50/50 distilled vinegar/distilled water mixture and let it sit again for an hour or more. Once again, pump it out with fresh distilled water. You will in all likelihood be amazed at how dirty this second set of vinegar/water has become, even though the radiator was flushing clear after the first “soak”. What has happened is that the vinegar/water has successfully dissolved more built-up deposits.

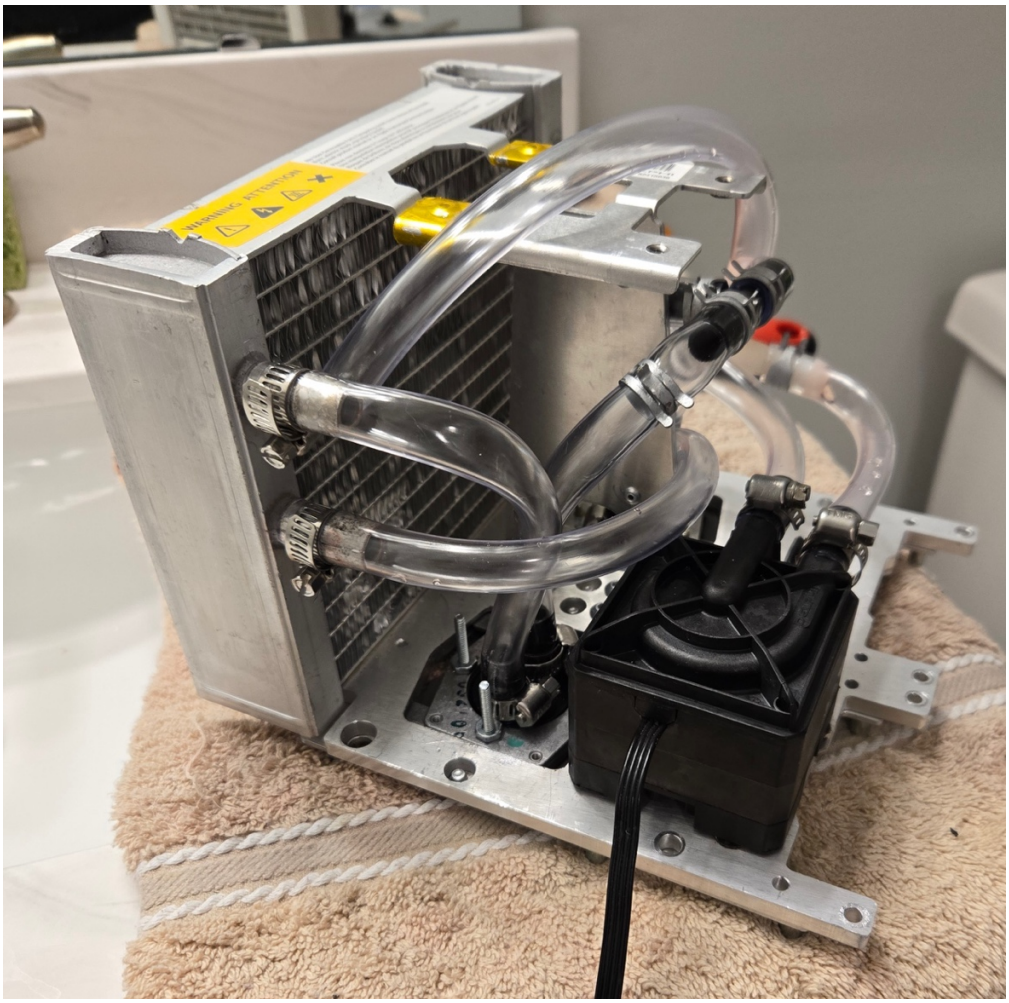
If the second flush comes out particularly dirty, keep repeating until what comes out is always running clear. When that happens, you have now thoroughly flushed and cleaned the interior of the radiator, bringing you one step closer to your goal of a cool, quiet Quad. You are ready to move on to the next step.

11. Building and Filling the New LCS Cooling Loop

With the CPU cooling blocks cleaned, the loop drained and disassembled and the radiator flushed, it is time to build the new cooling loop and fill it. For the new loop, I have found it useful to stick reasonably closely to Apple's original loop design. I have also found it useful to build the new loop using transparent hosing and then fill it with a brightly colored coolant – I used "blood red". The combination of transparent hosing and a brightly colored coolant allows you to easily see both coolant motion in the loop and the presence of any air pockets or air bubbles.

I did make one key modification to Apple's original loop design. I added a T-connector into the middle of the hose segment that runs between the output of the pump and the input of the radiator. I then connected an unterminated piece of hosing to the third leg of the T and used that hose line to fill/bleed the loop. For obvious reasons, I called this piece of hosing the "fill/bleed line".

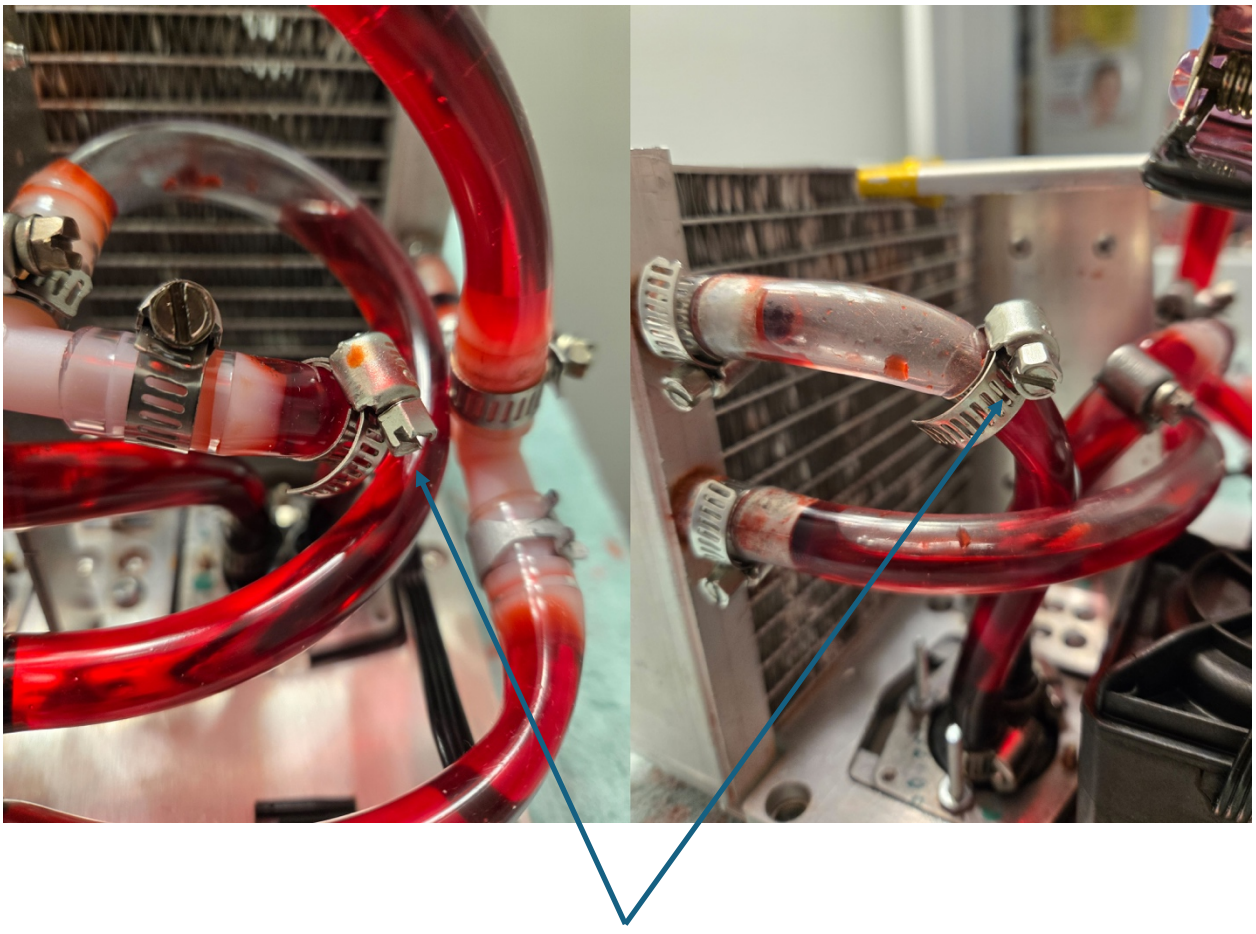
Here is a photo of my new loop, ready for filling:



A key tip when building a new cooling loop… there are a few right angles, and worse, one U-turn, in the Apple cooling loop design that this guide more or less re-uses (with the addition of the fill/bleed line). As you build your loop, depending on the tolerance of the hosing you use to changes in direction, you may find that constrictions/kinks develop in the hosing at the point of any such significant changes in direction of the hose (i.e. right angle, U-turn, etc.). If this is not corrected, coolant flow will be obstructed by the constriction, leading to reduced cooling efficiency.

How do you overcome this? Use one screw-down metal clamp at each constriction and tighten it until it forces the hose section underneath it to open up, essentially eliminating the constriction. I used this trick in several places in my loop design, and it works well.

Shown below are two examples of this trick in action in my current loop:



Clamps Used to Open Constrictions

Another **useful tip** when building cooling loops: As we will see, leaks in the new cooling loop are pretty much inevitable, no matter how well you think you have built your new loop. One way to banish a lot of these “new loop leaks” is to use heat to heat shrink the hoses onto their barbs. Then, at each barb, install a screw down clamp as an extra safety measure. Hose/barb connections made this way will not often leak, but if they do, further tightening of their screw down clamp should put an end to it.

Using heat is simple and straightforward. Get a long neck lighter, of the type you might use to light a grill or a home wood fire. Here is a photo of such a lighter.

Lighters like these are superior to, for example, matches, because they can provide a constant flame that will not end up burning your fingertips!

Start the lighter and run the flame all around the area where a hose is joined to a barb. Don’t leave the flame on any single hose area for too long, however. If the flame lingers too long, you may start to excessively melt the hose vs. heat shrinking it! Also be aware that in many cases the barb to which the hose is attached is itself plastic and so you also run the risk of melting the barb as well if you linger too long. Also, the longer you keep the flame applied, the greater the possible fire hazard. Have a means of extinguishing fire close at hand before you try this!

This mechanism (heat shrinking) works well for all the hose/barb contact points in the loop, including the T-joints.

Filling the system is easy. Filling it completely is not.

Let's start with the basics. You need a means of getting coolant into the loop. I went to a kitchen supply store and got the plastic squeeze bottle shown in the photo below for this purpose. This bottle has a funnel tip at the top which is perfect for inserting coolant.

Squeeze Bottle for Inserting Coolant

I then filled the bottle with a measured amount of coolant, inserted the tip of the bottle into the fill/bleed line and squeezed. This forces coolant into the loop under pressure. Any leaks present in the loop will show up first at this stage (... more may become evident later).

Filling the New LCS Cooling Loop

Here is another **key tip**. It is important that the LCS be oriented optimally during the fill operation. When starting to fill, the LCS should be positioned with the radiator on the bottom as shown in the photo above. This has the effect of filling the radiator first, with coolant then starting to move out into the transparent plastic hosing once the radiator has been filled. Filling the radiator first greatly simplifies and shortens the fill process. I discovered this via trial and error! Now you know!

Here is **another tip**, albeit a potentially **dangerous** one. Once the fill/bleed line is full of coolant, I have found it useful to literally blow into the line by putting my mouth around the top of it and exerting air pressure. When you apply air pressure, you will typically see coolant move a little in the loop, and in the best case, a few bubbles of air will be released and travel up the fill/bleed line. This usually allows a few cm of coolant to disappear down the line and into the loop. There is a beneficial side effect as well – this seems to exert more pressure inside the loop than the pump does. If there are any additional leaks not spotted earlier, they will show up at this point.

This is however an approach to be used with caution! Some coolants are toxic, and any accidental ingestion can lead to serious health consequences. In my case, I specifically selected a coolant that stated it was non-toxic. Even so, I was very careful to ensure that there was no coolant directly at the top of the hose when I did this. If you chose to use this approach, be **very** sure that your coolant is non-toxic and rinse your mouth afterwards, immediately and completely, if you accidentally get any in your mouth!

How much coolant is the right amount? Well, that depends on the loop you build. When I drained mine of its factory coolant, I got about 200 ml out. When I refilled my new custom-built loop, it took about 250 – 275 ml, although some of that was lost to minor leaks that I was tightening up along the way. For my loop design, 250 – 275 ml seems to be about the amount that it took and retained. Clearly my new loop has a little more volume than its Apple predecessor OR the Apple loop had lost a no small amount of coolant over time.

Leaks are a constant headache as you fill the loop. I cannot stress enough the importance of clamping each hose segment at both ends onto their respective barbs. I recommend the screw-down type of clamp, which can be adjusted to almost any level of pressure needed to stop a persistent leak. Be careful though – do not overtighten. Many of the barbs are plastic, and if you tighten too much, you may shatter them - caveat emptor!

When you have pushed all the coolant in that you can, it is time to bleed the remaining air out of the LCS.

If you have ever burped a baby, you will be familiar with the concept – the milk goes in and the burps come out of the same place; the baby's mouth.

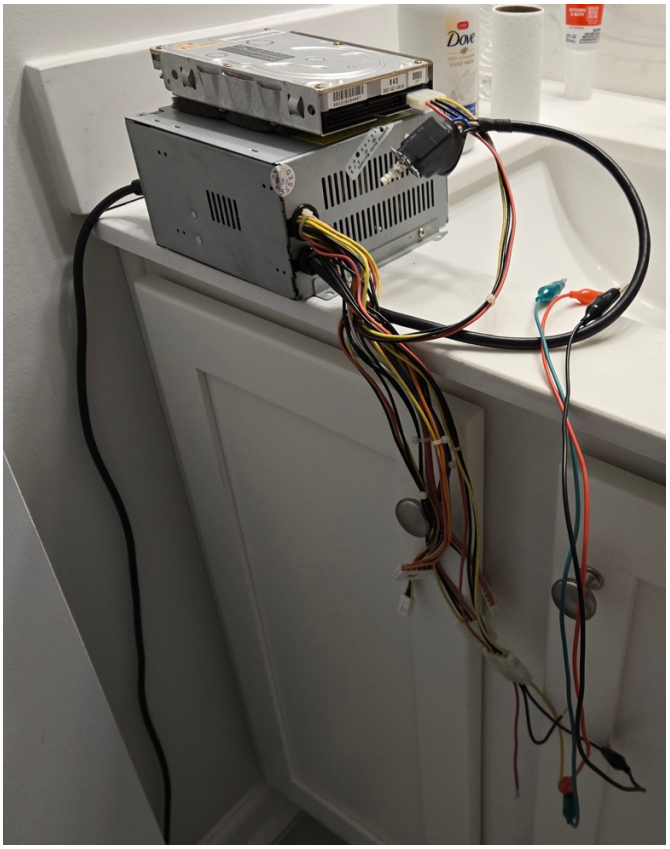
The idea is the same for filling/bleeding an LCS cooling loop. The coolant goes in, and the air comes out, of the same fill/bleed line.

12. Bleeding Excess Air Out of the Loop

Burping the LCS is neither elegant nor fast. Be ready and be patient. To free up air bubbles, I tilt the LCS left and right, front and back and even invert it, over and over until no more air bubbles can be induced to travel up the fill/bleed line. At that point, I start to shake the LCS from side to side and up and down, and eventually start to (reasonably) gently bump the system on the surface it is on, all in the name of freeing additional air bubbles. I continue this process (tilt, shake, bump) until no more air bubbles can be released.

THEN, I run the pump for a short period. Don't run it for more than 15 to 30 seconds at a time – I burned out one pump motor by running it for too long. Running the pump moves both fluid and air around the loop, hopefully moving at least some of the remaining air bubbles/pockets into the area of the fill/bleed line where it can be released. This process (tilt, shake, bump, run pump) is then repeated until no more air bubbles appear.

How do you run the pump outside of the Quad case? Well, some (likely) new equipment is needed. You need an external computer power supply with an independent on/off switch and multiple MOLEX connectors… or some other source of +5v, +12v and Ground that can be connected to one alligator clip each. You need three alligator clips and a MOLEX connector with the "other" end cut off, and the ends of each of its four wires stripped and exposed.



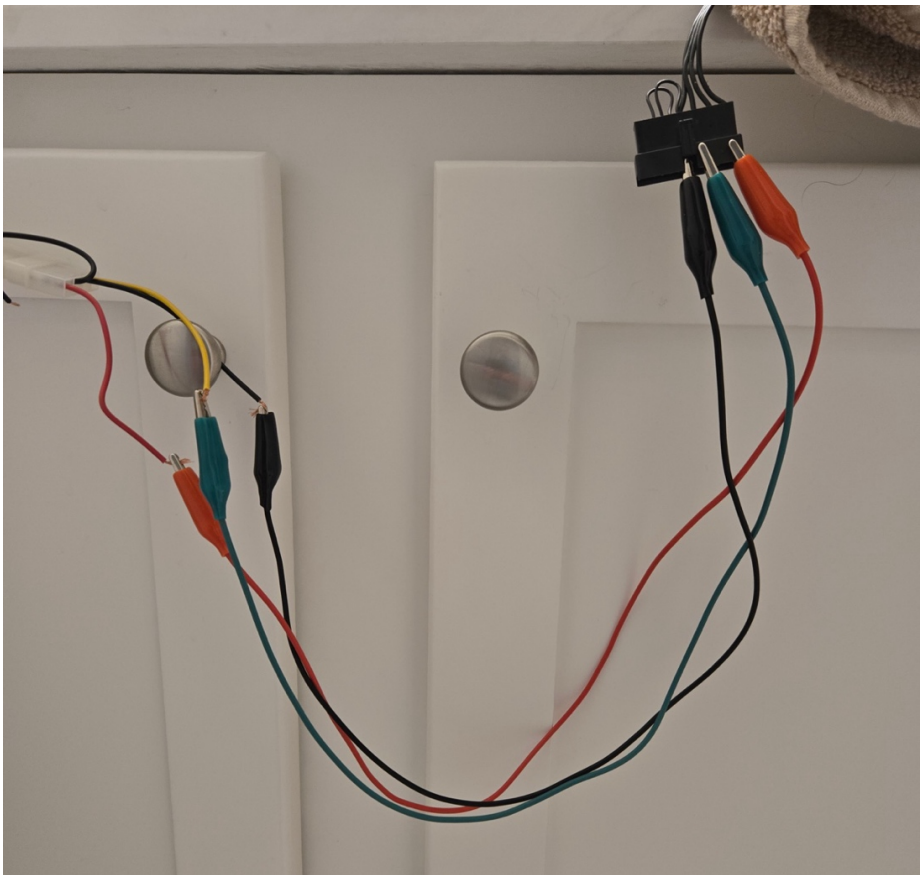
In the photo above, note the jury-rigged external on/off switch that turns the power supply on and off (vs. a front panel switch on a Mac/PC).

The particular power supply that I am using has had a long and hard life and will only turn on if there is sufficient load. For that reason, I added an old hard drive to it as well, to provide that load. The hard drive is not part of this procedure - just a means of loading a troublesome old power supply! You can see the hard drive in the photo above.

Using the alligator clips, connect pins 1 and 5 of the pump connector to +12v and pin 7 of the pump connector to Ground. The pinout of the pump connector appears immediately below, followed by a photo of the power supply/MOLEX/alligator_clip set up.

pin #	usage
1	+12 V ?
3	Tachometer
5	Motor control ?
7	GND

LCS Pump Connector Pinout

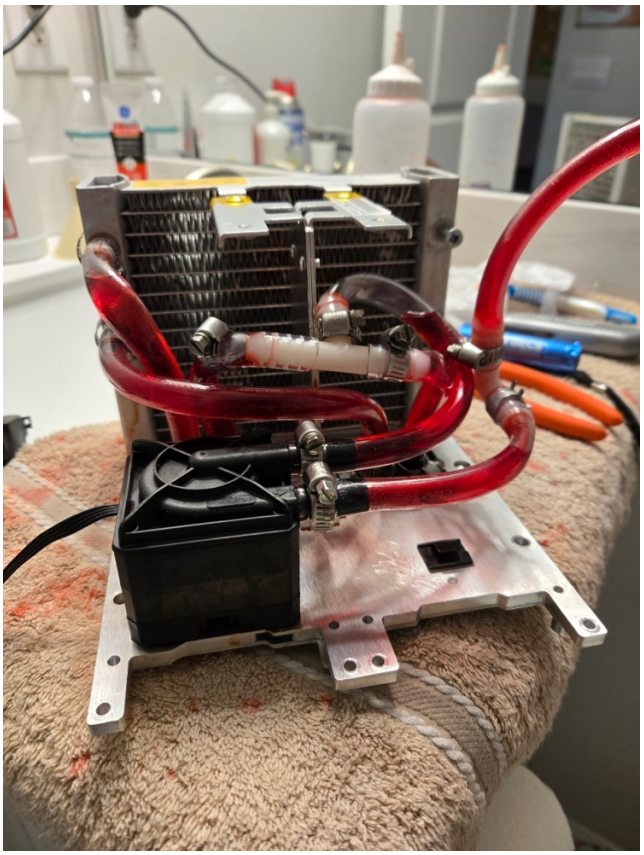


LCS Pump Connector Wired to Power Supply via Alligator Clips

When you turn the power supply on, the pump will activate and run. Remember not to run it for too long to avoid burning it out. The Quad controls the pump speed via Pulse Width Modulation (PWM). In routine operation, the pump speeds up and slows down as needed to keep the CPU temperature readings in the target zone. There is no PWM in a pump connector that has been tied to +12v however, and so this has the effect of running the pump at 100% capacity, 100% of the time. It is **NOT** designed for this, and it **WILL** burn out if you run it this way for too long. Regrettably, I speak from experience. Caveat emptor!

There are often still visible air pockets in the transparent tubing when this process is no longer productive, and so at this point I will attempt to force more coolant into the LCS under pressure (using the same kitchen squeeze bottle mentioned above) and then repeat the process again. Add coolant, tilt, shake, bump, run pump: Rinse and Repeat, over and over until done!

This is a game of patience. It can take an hour or more to achieve no more releasable air pockets and/or bubbles. I have on two occasions left the LCS to sit overnight, which has the effect of bleeding a small amount more coolant into the LCS and collecting a small amount more air from additional air bubbles into the fill/bleed line. In every case I have worked on so far, I have been able significantly reduce the remaining air pockets/bubbles, but I have never managed to eliminate them entirely.



My completed LCS Cooling Loop, Filled

When no more coolant can be added to the loop via the fill/bleed line, it is time to finish the fill off via syringe insertion. This may seem to be an unnecessary extra step, but it **is** worth doing because this allows you to achieve a nearly complete fill, and the the better the coolant fill, the better the cooling efficiency

Start by tilting the LCS around in space until you can clearly see one or more air pockets in the hoses. When you can spot air pockets, use a small hypodermic needle to poke two pin-size holes, nearly together, into the hose section(s) with the air pocket(s). The first hole lets air escape as you push coolant into the second hole with the syringe. Fill the air pocket up with coolant (this may take a few syringes of coolant) and then seal the two holes with a single dab of silicone sealant.

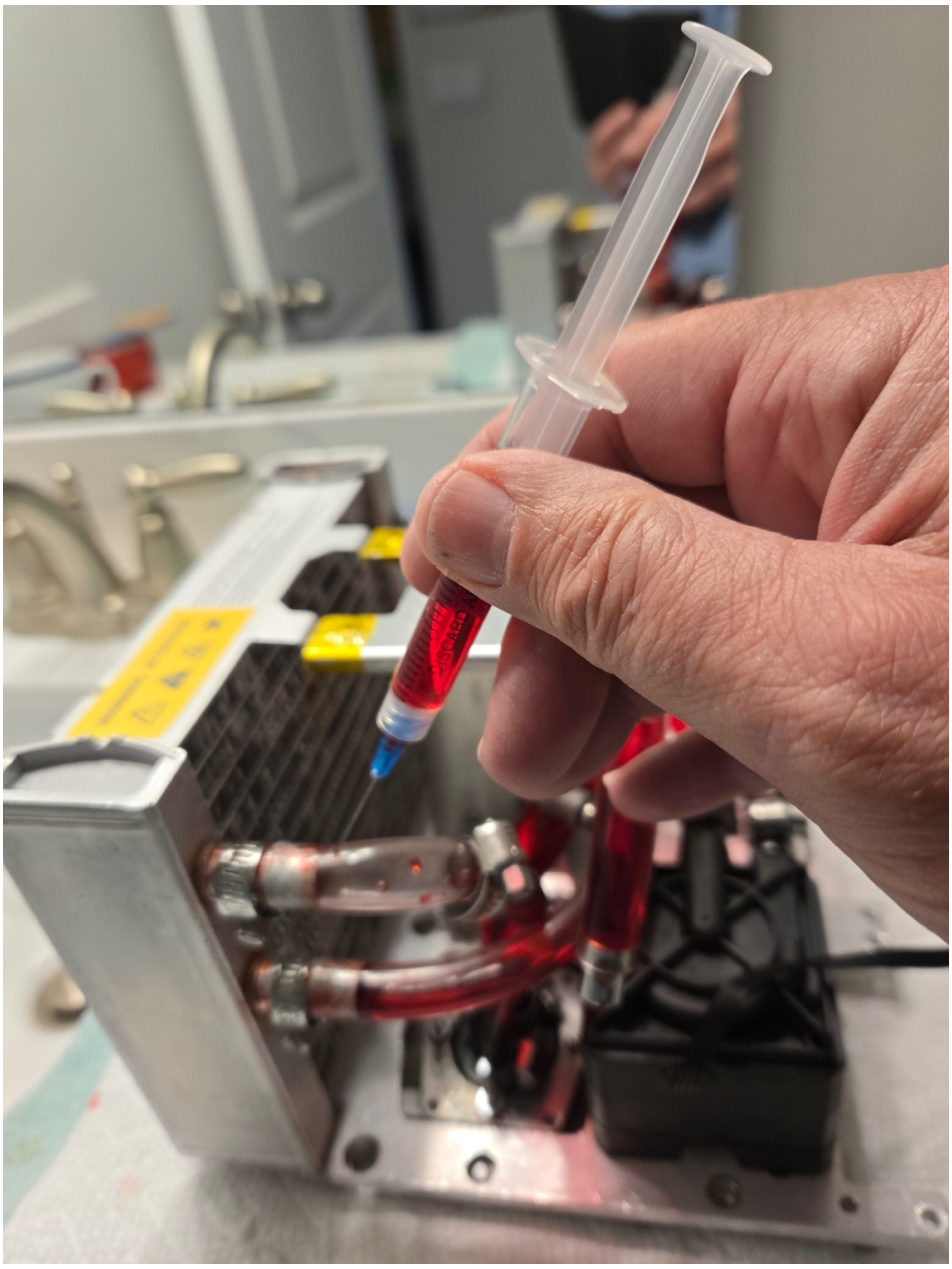
Syringe/Needle Used to Insert Coolant (get at Amazon for <$US 5.00)

The sealant I used (see details below) takes 30 minutes to set. In practice, I always gave it at least an hour and preferably longer.

Repeat the syringe insertion with each remaining visible air pocket, except perhaps very small ones.

At this point then, there are no visible air pockets remaining, or only very small ones. Once the sealant has been allowed to set, it is time to test the tightness of the loop. Blow into the fill/bleed line so as to generate high pressure within the loop. This allows you to check that the silicone sealant has fully set and that the pin prick holes you have made are well sealed and not leaking. As you well know by now, leaks are the very death of a liquid cooling system! The coolant needs to stay sealed inside the loop in order for it to work!

A small practical note: I re-used the same syringe, over and over for multiple air pockets. This is not a medical procedure – the loop doesn't care if the syringe was used before! ☺



Poking the First of Two Nearly Collocated Holes

I used the silicone sealant shown in the photo below and found that it worked well even under heavy pressure.

GE Silicone Sealant Used to Seal Pin Prick Holes

13. Reattaching the CPU Cards to the LCS, Rebuilding the LCS

When you reach the point where you cannot add another drop of coolant, and there is little to no air remaining in the loop, you are ready to reassemble the LCS into the Quad. Making the decision as to when this point has been reached is a little bit inspiration, a little bit experience and a little bit PFM (pure freakin' magic).

To accomplish the reassembly, you must first reconnect the CPU cards to the LCS and then go back to section **"Preparing the Quad for LCS Removal"** to run that whole disassembly process again, but in reverse.

When reconnecting the CPU cards to the LCS, you will need to apply new thermal paste. The photo below shows the brand I used (along with the Rubbing Alcohol I use to remove old paste). In the photo below, immediately beneath the tube of paste is a small hard plastic white tool I use for spreading the paste onto CPU surfaces.

If you haven't pasted a CPU before, a few points to keep in mind:

1. It takes very little paste (a small dollop, about the size of a grain of rice). This is shown in the photo below:

Dollop of Thermal Paste on CPU

If you use too much, you will reduce the efficiency of the result. Thermal paste is not magic. Its purpose is simply to ensure that the microscopic surface irregularities on the CPU chip surface and on the heat spreader the CPU mates to are filled in, so that heat transfer occurs with maximum efficiency.

2. Put a small dollop of paste onto the CPU surface and then use a broad flat surface to spread it evenly across the entire CPU chip face (I have used simple folded paper for this in the past – I now have the small, white hard plastic tool shown in the photo above specifically for this purpose). Make sure you cover the full surface of the reflective area of the 970MP chip. But remember that you do not want, nor do you need, thermal paste on the ceramic packaging of the chip.
3. Some authors advocate adding one more dollop of paste to the middle of the already pasted chip, so that when the attachment screws are tightened, this final dollop will spread out under pressure, filling in any points that you missed.

   Some authors even suggest not bothering to paste and spread at all, but merely to put a single dollop on the chip face and let pressure spread the paste as needed. I have tried all sorts of approaches and found no big differences in the end result irrespective of the approach I have used. I have returned to what for me is tried and true – paste the chip, spread the paste and that is that. It works every time.

With the chips repasted, reattach the CPU cards one at a time, using the same screws you removed earlier. It is useful to install the screws in opposing sets, adding one screw in the upper left for example, then the next in the lower right, and so on. This ensures that the pressure applied to the card and its chips as it is screwed back onto the LCS doesn't apply to any one area too much more than any other area. This helps to ensure even spreading of the thermal paste. In terms of the order of screw installation, I tend to start at the outside edges and work in, progressing in a crisscross manner.

Tip: when you re-install the four "can and spring" screws directly around the CPU, be very careful not to overtighten them. If you do, you may inadvertently squeeze most of the thermal paste out, reducing cooling efficiency. Tighten them just as tight as they need to be. This is a very subjective call – when you encounter mid-grade resistance, stop there. The same is true of all the screws to be re-installed, and for the same reasons.

When you are done, your LCS is now fully back together, and it is time to reassemble it into your Quad. To do this, go back to section **"Preparing the Quad for LCS Removal"** and run the whole disassembly process again, but in reverse.

With that done, **congratulations** - your LCS has been serviced, your Quad has been reassembled and you are ready to test out the results of your brilliance. What is next? Booting up the machine and seeing how it performs?

Well… not quite yet. It couldn't be that easy, could it? ☺

14. Thermal Calibration

Before you boot the machine and test out your work, you need to know about Thermal Calibration. Thermal Calibration is a software tool that is included in the Apple Service Diagnostics (ASD), version 2.6.3. Apple's Mac OS X fan and temperature control software rely on a set of thermal data that describes the cooling performance of the loop. Thermal Calibration is the mechanism that generates and writes that data out to a dedicated non-volatile memory set that Mac OS X consults while running.

Why bother with thermal calibration? Well, at this point in our procedure you have a shiny new cooling loop that almost certainly has different cooling characteristics than the original Apple loop that it replaces. If you just boot your machine now and expect your new cooling loop to perform the expected magic, you may be sorely disappointed.

Why? Because Mac OS X will attempt to control the fans based on the original (Apple) thermal data, which describes the thermal characteristics of Apple's loop, not your loop. As you might guess, this is unlikely to produce the cooling magic you are hoping for!

You need Thermal Calibration to write out new thermal data that describes the cooling characteristics of **your** new loop. Once this is done, Mac OS X will have the right thermal data under its feet; data that accurately describes your new loop. Using this, it will be able to extract maximum advantage from that new loop.

Where do you get Apple Service Diagnostics (ASD) 2.6.3, and how do you burn it onto a bootable DVD? At the time of this writing, you can get ASD 2.6.3 from Macintosh Repository, at:

https://www.macintoshrepository.org/33373-apple-service-diagnostic-2-6-3

It is also available from a number of other places on the web.

Burning a software title to a bootable DVD is a standard piece of Mac OS X work that won't be covered here. Note however that Apple's Disk Utility, included in all of the Mac OS X releases that would be of interest to G5 Quad owners, can do pretty much all of the work.

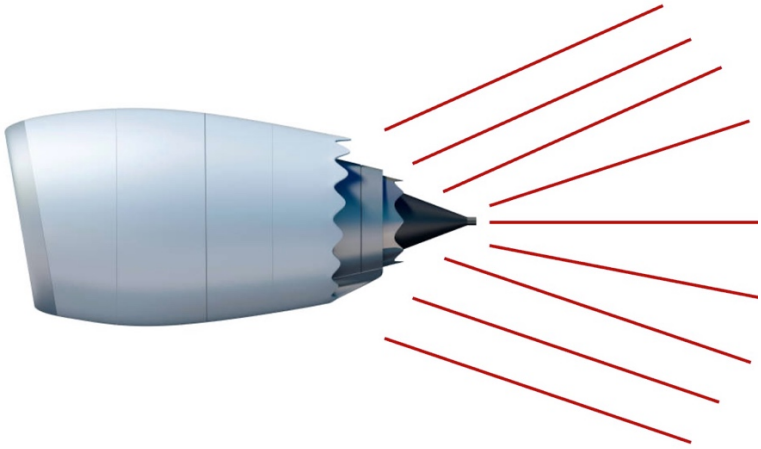
With ASD 2.6.3 burned to a bootable DVD, restart your newly reassembled Quad into its Open Firmware layer. To do this, hold down OPT+CMD+O+F during the boot process. After an unsettlingly long delay, the text based Open Firmware prompt will appear on your screen. Use this to insert the DVD by entering the following at the command prompt:

"eject cd"

This will open the CD/DVD drawer. Put the ASD 2.6.3 DVD into the drawer and then type “eject cd” a second time. This will close the CD/DVD drawer.

To boot this DVD, now type “multi-boot” at the Open Firmware prompt. This will bring up the Boot Picker screen, listing all bootable media. You should see two entries corresponding to the ASD 2.6.3 DVD, one called **Diagnostics (OF**) and one called **Diagnostics (OS)**. Wait for the mouse cursor to change from a watch face to an arrow pointer and then click on the **Diagnostics (OF)** item. Now click the arrow button at the lower right and the machine will boot the ASD 2.6.3 DVD.

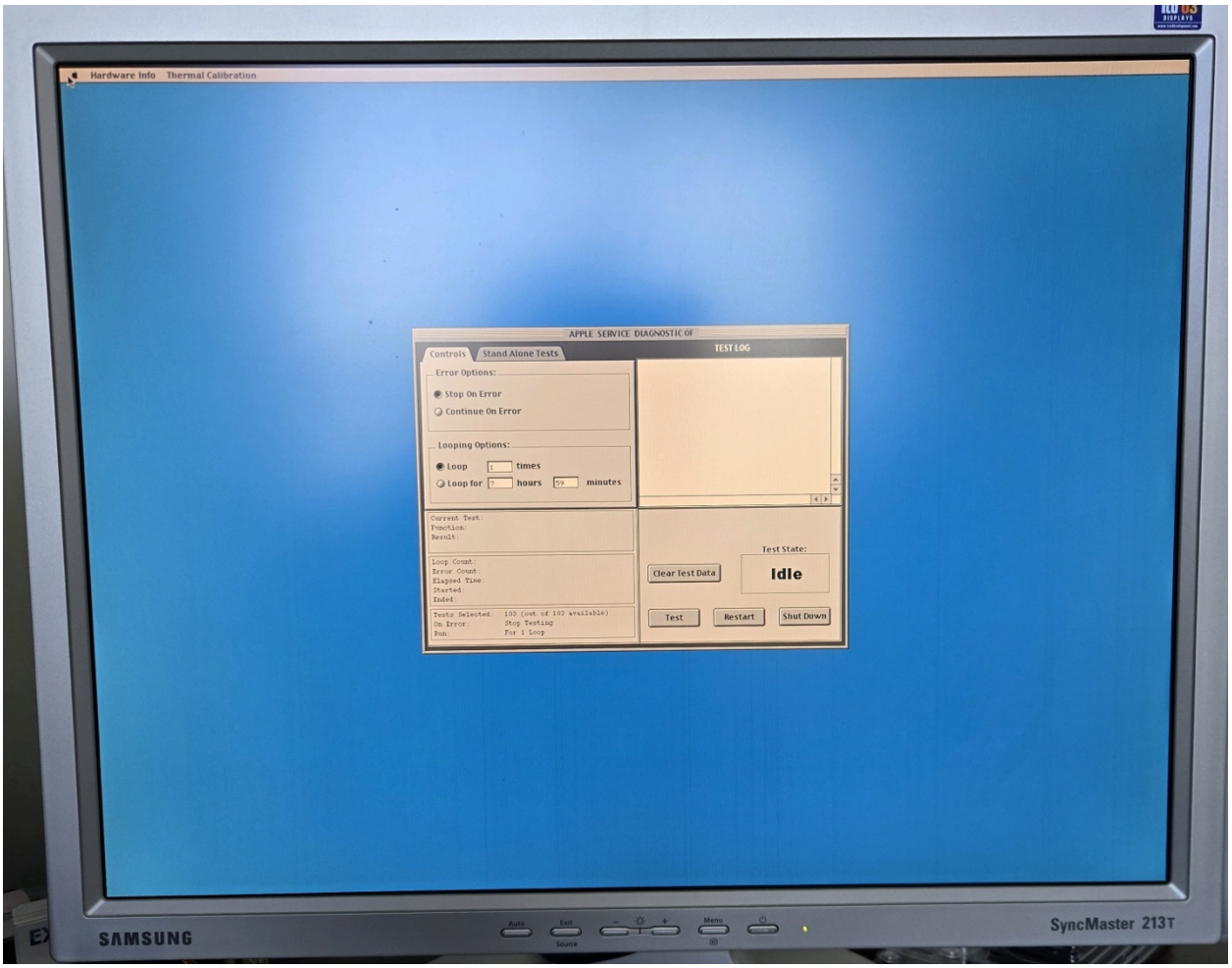
Don’t be alarmed! This takes quite a while to come up and when it does, it turns on the fans full blast, making a horrific racket. Your Quad will sound like the back side of a jet engine!



This infernal din will continue until the Thermal Calibration is completed, so get used to it! One thing to note about Thermal Calibration is that it also runs the pump absolutely flat out. This stresses the pump more than any other single activity, and so if there is a leak related to the pump itself, it may show up at this point.

To detect this eventuality should it occur, I always place a piece of clean white paper towel inside the Quad, directly underneath the LCS. Since this LCS servicing procedure uses bright red coolant, if anything leaks onto the paper towel, it is immediately evident.

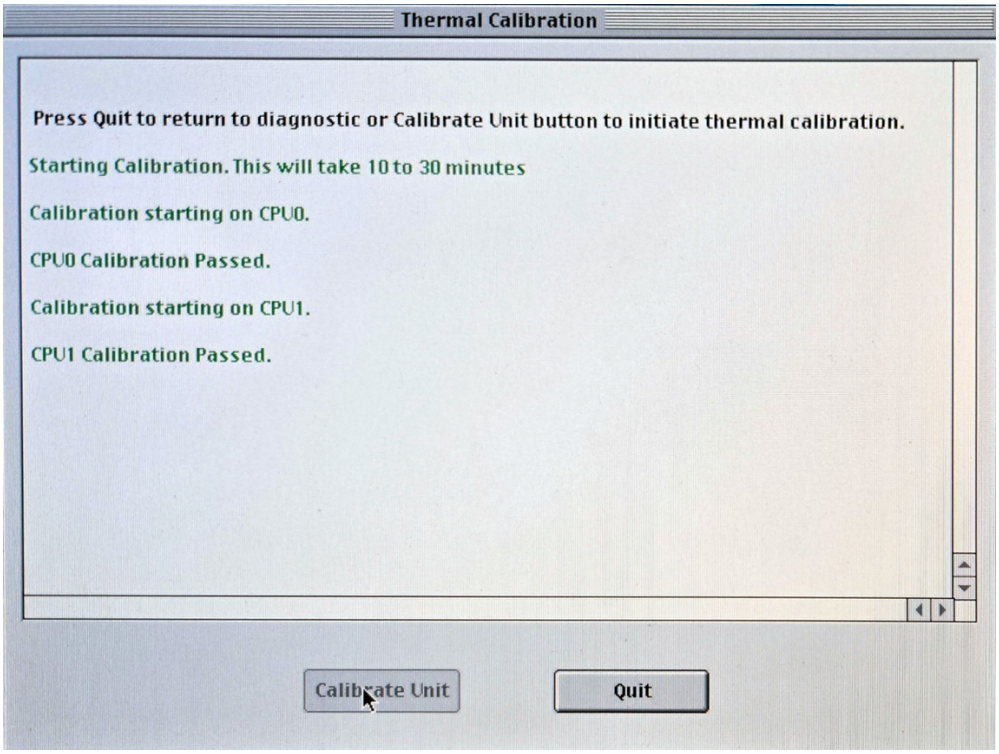
Eventually the ASD 2.6.3 splash screen will give way to a diagnostic GUI with two tabs along the top, one for **Hardware Info** and one for **Thermal Calibration**. See the screenshot below:



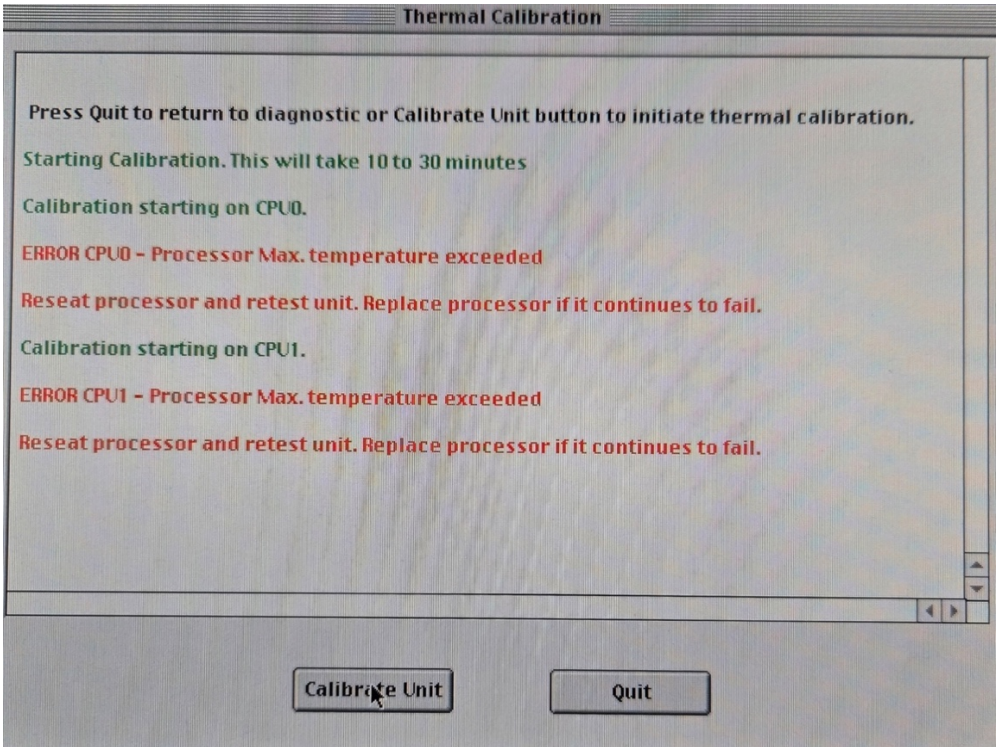
ASD 2.6.3 Diagnostic GUI

Click the Thermal Calibration tab, and then click the “Calibrate Unit” button at the bottom. Answer the resulting yes/no dialog box with “yes” (yes, I really **do** want to calibrate this unit!) and watch it take off. The GUI says it takes 10-30 minutes per CPU.

If you are incredibly lucky, both CPUs will pass thermal calibration and after an hour or so, you will see a result message something like this:



If both fail, you may see a message like this:



... or if your machine is like the ones I have been working on recently, you won't see anything at all! I kick off thermal calibration, come back two hours or so later and see nothing new displayed on the screen. However, the calibration seems to have run despite this. It always makes a big difference in how Mac OS X cools the machine afterwards, so even if nothing has been written to the screen, **something** has been written to the non-volatile thermal tables.

If the calibration fails, it is time to go back to the drawing board. You will need to think carefully about what you could do differently and/or better and then cycle through this entire process again.

If the calibration passes, or produces no output at all (in either case, you believe new thermal data has been written out), you can proceed in one of two ways:

1. Turn your machine off, wait a moment and then turn it back on. I always go back to Open Firmware at this point (boot while holding OPT+CMD+O+F), use the "eject cd" command to do just that – eject the CD – and then turn the Quad off again.

   Instead of turning the Mac off, you **can** type:

   "mac-boot"

   at the command prompt and the Mac **will** boot, but I always turn the machine off and then back on again to ensure that I am starting from a known clean state.

   So, turn it off, wait, and then turn it back on again for the first "normal" boot with your newly reconditioned LCS handling the cooling functions, supported now by the correct thermal data.

2. Instead of rebooting into the Open Firmware layer just to eject the ASD 2.6.3 DVD, go instead directly to the OS Picker GUI (hold down OPT while booting):

OS Picker GUI

When it comes up, type the letter “e”. This will open the CD/DVD tray and you can remove the ASD 2.6.3 DVD. You can then type “e” again to close the tray.

Then click the (almost) circular Rescan symbol on the lower left and the Quad will rescan all bootable media, producing a list from which the two ASD 2.6.3 entries will now be absent. Select the Mac OS X version you want to boot and press the Arrow button on the lower right. The Mac will boot that selection right away.

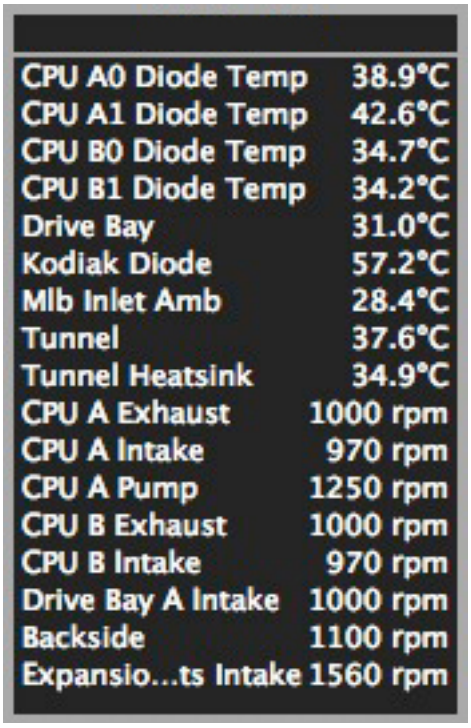
15. The Moment of Truth – Success, or Repeat?

At this point, all I can do is wish you luck. If your cleaning of the LCS and its cooling blocks, along with your loop design, build and fill, have all been flawless, you will see, via iStatMenus or XRG, CPU A and B temperatures somewhere in the 30 C to 50 C region. Lower is better. Neither CPU should idle at more than 50 C. If either CPU is at or above this value, you may wish to revisit your work and try again. Patience is critical - it took me multiple tries to get my Quad's CPU temperatures to where I wanted them!

At the end of those tries, I was able to achieve full success: high 30s C on the two CPU A cores, the same on one of the CPU B cores and finally, the last CPU B core in mid 40s C. CPU intake fan speeds settled into the 970 RPM value while the CPU exhaust fans settled into the 1000 RPM value. These are all very good values.

The 970 RPM value is particularly noteworthy. This is Apple's "easter egg" type nod to the PowerPC 970MP chip that powers the G5 Quad. If you see 970 RPM, you can be confident that you have restored your LCS to full factory cooling specifications.

The photo below shows the XRG and iStatMenus readings from my Quad once done:



BTW it is accepted folklore that Mac OS X uses CPU B more heavily than CPU A, but I saw no evidence of this in the above.

16. Wrap Up

Congratulations, you have reached the end of this marathon document!

This document has presented an LCS reconditioning guide from A-Z. If you run this process faithfully (and likely, repeatedly) you too will achieve a cool, quiet Power Mac G5 Quad.

Please keep in mind that you almost certainly won't be successful on your first attempt. Don't be disappointed. Expect it, be patient and keep at it. It is well worth it in the end. A cool, quiet Quad is a thing of beauty!

A tantalizing idea to close on… servicing an LCS is tough work, and even when it is done successfully, it is only done temporarily; the LCS will need to be serviced again at some point in the future. Liquid Cooling just inherently needs routine maintenance.

Wouldn't it be better to convert the Quad to **air cooling**?

It just might be… see my guide "Converting a Late 2005 Power Mac G5 Quad from Liquid Cooling to Air Cooling", v0.5, June 2025, for a full treatment of this topic.

Spoiler alert: it is possible to air cool a late 2005 Power Mac G5 Quad. It is not only possible, but also easier and the result should not need future servicing, other than what one might do routinely to service any older computer.

17. Appendix A: Key Things to Keep in Mind

As you overhaul your Quad's LCS, bear in mind that your objectives are (a) at the front end, a clean, free flowing radiator, (b) at the backend, clean free flowing microchannels in each of the cooling blocks, (c) in the middle, no constrictions/narrowing in the hosing of the cooling loop and finally, (d) a full fill of that loop with coolant. If you keep these things front and center as you work, all will be well.

Practically speaking, this means:

- Flush the radiator thoroughly and repeatedly. Blockages in the radiator will dramatically reduce cooling performance. Fill the radiator with a 50/50 mix of distilled white vinegar and distilled water. Let it sit for at least one hour and then flush it out with plenty of distilled water until the output is running clear.

  Then repeat! You will be amazed at how dirty the second fill of vinegar/water mixture is upon pumping out, even though it ran clean during the first pumping out.
- Disassemble and clean the two CPU Cooling blocks thoroughly. These blocks are arguably the most important part of the loop. They are literally where heat is transferred from the CPU chips to the cooling loop, for later dissipation at the radiator. If heat is not transferring into the loop, it cannot do its job!
- As you construct the new cooling loop, pay careful attention to ensuring that there are no kinks, constrictions or narrowing of any sort in the hoses you are installing. If you see one, eliminate it. Even one constriction can have a significant impact on cooling performance. Coolant MUST flow freely throughout the whole loop for the system to cool the CPUs as expected.
- Make sure the loop is **fully** filled. Less coolant in the loop equals less cooling performance of the loop. Practically, this means that after you cannot add any more coolant via the fill/bleed line, move to the syringe insertion method to complete a truly full fill. There should be few to no visible air pockets in the loop hosing, and any that remain should be quite small.
- Use metal screw-down clamps at each end of every hose segment. These are your primary defense against leaks.
- Make sure there are no coolant leaks, even small ones, before reassembling into the Quad case. Once the LCS is back in the case, it can be difficult to do anything about a hard-to-reach leak.

18. Appendix B: Related Work

I am not the first person to attempt LCS servicing, nor the first person to document what they have done. There are some related efforts that may be of interest to readers of this guide. They are listed below:

1. Kaiser, Cameron, "Long Life Computing (plus: Quad G5 CPU Swapping for Dummies", April 2014, TenFourFox Development Blog,
   Quad G5 CPU Swapping for Dummies

2. Kaiser, Cameron, "And Now for Something Completely Different: "Upgrading" Your Quad G5 LCS", July 2021, TenFourFox Development Blog,
   Upgrading Your Quad G5 LCS

3. Lindholm, H., "Work Log of Apple Power Mac G5 Quad Liquid Cooling System Repair", May 2012, www.h-lindholm.net,
   Work Log of Apple Power Mac G5 Quad Liquid Cooling System Repair
   The References section at the end is particularly excellent.

4. Campbell, Michael, "Converting a Late 2005 Power Mac G5 Quad from Liquid Cooling to Air Cooling", v0.5, June 2025. Published at www.retro-computing.com.

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