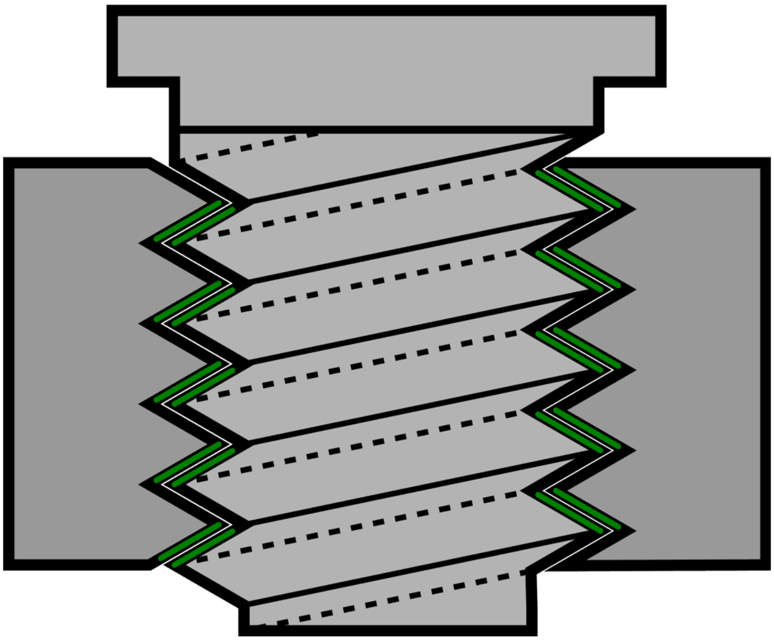
Chapter 1 - Freeing stuck parts

Why is a stuck brass part so bad?

Stuck parts in SCUBA gear are a special kind of frustrating. If you've ever faced the challenge of trying to separate two stuck pieces, you know exactly the dilemma you're up against. Do you crank up the torque just a bit more to get it to unscrew, or do you risk rounding it off in the process? The heart of the issue lies in the material from which most SCUBA parts are made: brass. While brass boasts some impressive qualities, like excellent thermal conductivity and corrosion resistance, it's terribly soft. This softness becomes a problem when you try to undo parts that have been screwed together too tightly or sat for too long. It's not uncommon for brass parts to strip under moderate force, particularly the hex or allen-key receptacles. Once that happens, separating the parts can feel nearly impossible. At that point, you're often left with no choice but to drill or chisel out the damaged piece. If you're lucky, you might be able to save the rest. Compare that to a normal steel bolt: it's much harder to strip one without using excessive force or a cheater bar. With SCUBA gear, though, you can easily damage parts just using basic hand tools. Steel, depending on the type, can easily be twice as hard as brass. Thankfully, there are a few tricks to safely free almost all stuck brass parts.

What determines torque needed?

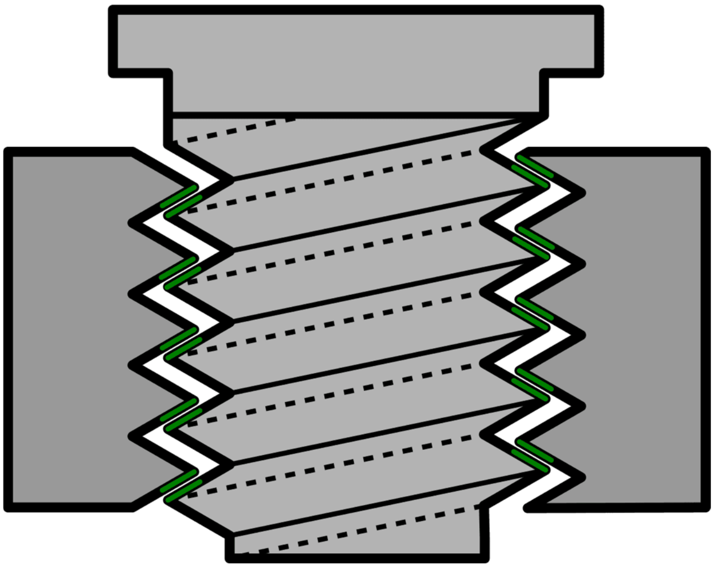
Let's dive into what determines the torque needed to break a threaded connection. When two parts are screwed together, the



Picture 240: Perfect threads would engage over half the flanks.

threads on each part make contact, and as you tighten, friction is created. This friction causes the fastened part to elongate slightly, creating a clamping force or "preload" that holds the parts together. This preload presses the threads against each other and can also press the bearing surface (under the bolt head or nut) against the clamped component. We'll skip the bearing surface for now, as it's not always present. To separate the parts, you need to apply enough loosening torque to overcome the static friction at the threads. This friction is directly proportional to the preload and the coefficient of friction at the thread faces. So, the torque needed to undo the parts depends on the initial tightening torque, the resulting preload, and the friction at the thread faces.

It's important to realize that not the whole thread face experiences friction, only half of it does. Imagine pulling the bolt upward while the nut stays stationary. You'll see that the downward-facing flanks of the bolt and the upward-facing flanks of the nut are pulled apart, meaning there's no friction between them. Friction occurs between the upward-facing flanks of the bolt and the downward-facing flanks of the nut. I know this is not entirely correct, but the bulk of the friction occurs in the manner we've described above, so bear with me.



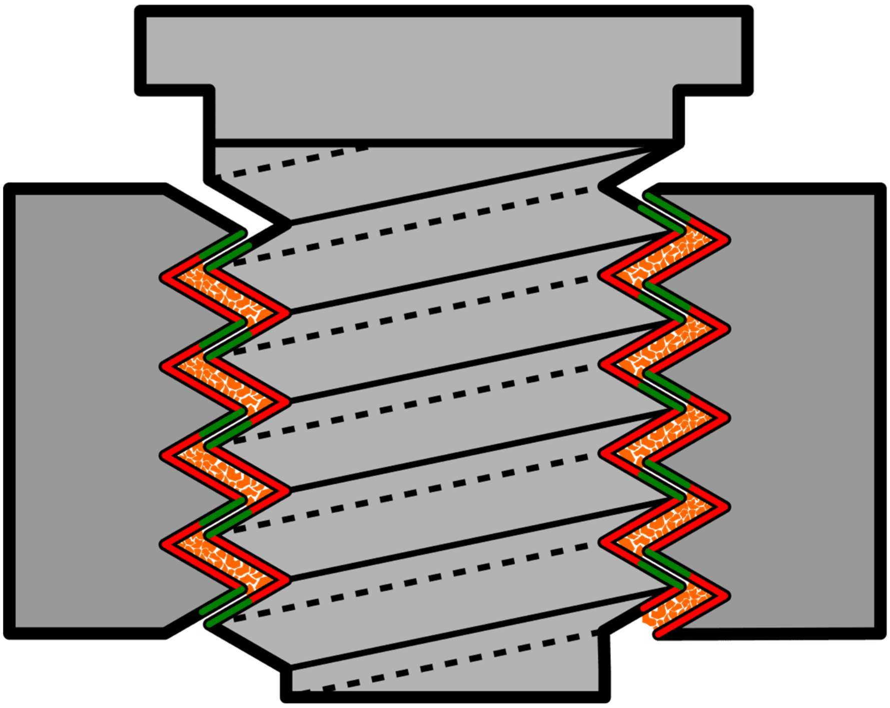
Picture 241: Real threads engage over less than the ideal could.

In an ideal world, the threads fit together perfectly, but due to machining tolerances and imperfections, only part of the opposing threads come into contact. (The accompanying illustrations have exaggerated this for clarity.) The more of the threads that touch and the harder they press against each other, the more friction is created, which makes it harder to separate the parts.

When we go diving, the threads of many SCUBA parts are exposed to harsh conditions. Under pressure, saltwater gets pressed deep into the threads. But when you rinse your regulator in freshwater afterward, no significant pressure is created, leaving saltwater trapped inside the threads. No matter how much you try, certain types of threads will never be fully rinsed.

I want to take a moment to thank the manufacturers who brilliantly decided to switch to face seals for DIN connections and yoke nuts instead of the perfectly functional radial seal. Radial seals prevent water from even reaching the threads, while face seals do nothing to protect them.

As a result, saltwater gets trapped in places it shouldn’t, slowly building up over time. Go diving, get saltwater in the threads, store the regulator, and the saltwater dries and crystallizes. Go diving again, get more saltwater in... you can see where this is going. The deposits build up, acting like thread sealants, like



Picture 242: Salt built considerably increases the friction between the threads.

Loctite. In areas where the flanks don't touch, salt deposits fill the gaps. Eventually, the flanks are connected by a salt layer, which adds a significant amount of friction, sometimes enough to make it nearly impossible to undo. A classic example is DIN bolts or yoke nuts with a face seal. Even when properly serviced and torqued, after a year they often require much more torque to loosen than they got tightened with. Leave them untouched for even longer, and they get progressively harder to break free.

Penetrating agents

Now that we understand the factors influencing loosening torque, we know we need to find ways to reduce friction between the flanks. A traditional method for doing this is using a penetrating agent, like WD-40. Unfortunately, this doesn't work well for SCUBA parts. Penetrating agents are great at reducing friction because they seep into tiny spaces. They have low viscosity and surface tension, and chemicals which allow them to break down rust and carry oils into the gaps. But here's where they fail in our case: most penetrating agents are made with non-polar substances, while the salts that build up between SCUBA threads are highly polar. The old saying *"like dissolves like"* rings true here. Non-polar agents can't easily break through the polar salt deposits as effectively as we'd like.

What dissolves salts effectively? Something that's highly polar; and that means most acids. Whether it's hydrochloric, phosphoric, citric, or acetic acid, most acids do a fantastic job of breaking down salts. The real challenge, though, is getting the acid to the threads where it can work its magic. To dissolve the salt, we'd need a combination: an acid to break it down, a fluid with low viscosity and surface tension (like acetone) to penetrate the threads, and an oil, any oil really, for lubrication. Unfortunately, these three elements don't mix well, and I'm not aware of a commercial solution that gets it right. I've experimented with acetone, transmission fluid, and hydrochloric acid, but the results weren't stellar. It wasn't a complete failure, but it certainly wasn't the game-changer I would have loved it to be. Just like commercial agents, it's a small tool in the toolbox, but not a full solution. Commercial solutions[1] often work brilliantly on stuck steel fasteners, as they incorporate substances that slightly break down iron oxides.

Chemical agents are not the answer to freeing stuck brass threads. While they can offer some help, relying on them isn't the best strategy. So, we'll have to turn to more physical methods to tackle the problem. Thankfully, we have a couple of tricks that can help.

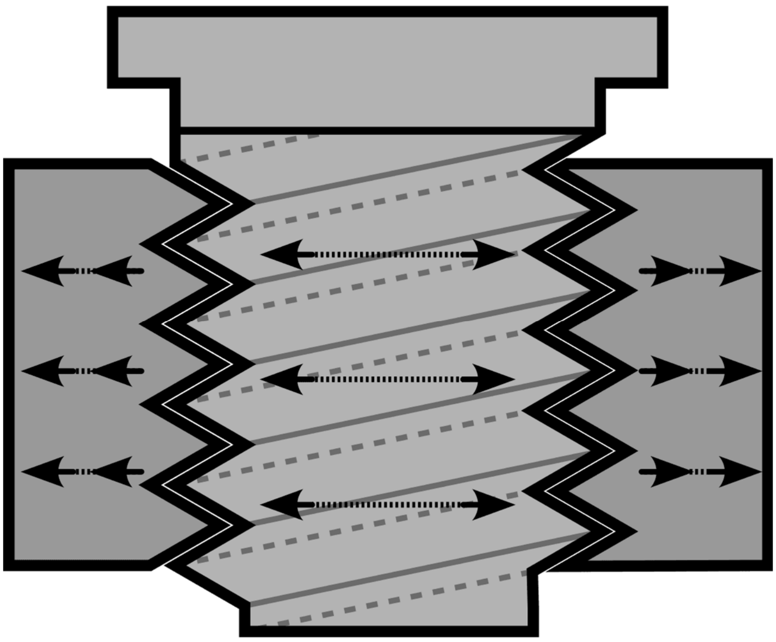
Looking at the image of the threads filled with salt deposits, it's important to note two things. First, the salt isn't one big mass but a collection of small, individual crystals. Second, when the salt crystals form, they grow smoothly along the thread flanks, making excellent surface contact. This large surface area is what contributes to the high friction. The primary reason the bolt and nut are stuck in our picture is due to the formation of corrosion products in the threads. These products act like a glue and also mechanically interlock the threads. While the friction between these debris particles is a factor in how tightly they bind, the primary issue is the bulk adhesion and interlocking caused by these products. All the methods we'll discuss aim to reduce or disrupt that surface contact.

The hammer blow

One method familiar to most mechanics involves using a hammer. But be careful: brass is soft, so you don't want to damage it. Use a nylon or polyurethane hammer, or place a piece of wood between your hammer and the brass. Let's go back to the bolt and nut example. The salt deposits and the preload from the initial tightening are what prevent movement. But a sharp blow to the bolt head or the side of the nut might cause a tiny relative movement between the two parts. This movement could crush or crack some of the salt crystals. By breaking up the contact between the thread flanks and the salt, we reduce the friction and, as a result, the torque required to loosen the parts. The hammer method is deceptively simple, but there's a key step to get right. In the example image, striking the bolt from the bottom wouldn't work, as it would push in the same direction as the preload. A hammer blow must always go against the preload or be perpendicular to it for maximum effect.

Using temperature to our advantage

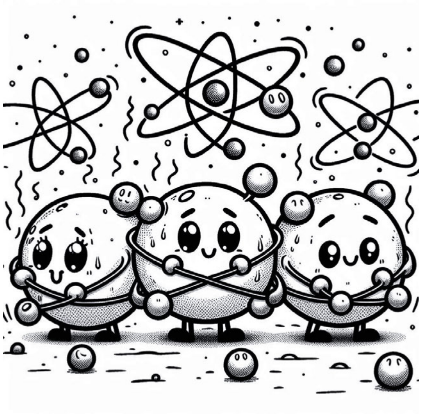
Our second method works on a similar principle: reducing the surface contact between the salt and the thread flanks. This technique, also common in workshops, involves temperature manipulation. Technicians often use blowtorches to loosen stubborn nuts and bolts, and the science behind it is straightforward. When you heat an object, you add energy to it. Molecules within the material are tightly bound, but as energy is introduced, they start to move apart slightly, each gaining more space. This increased atomic movement translates into a tiny expansion of the material. Not all materials behave the same way, though. For example, elastomers tend to contract when heated, not expand. But metals, like brass, expand, making this method effective in breaking the bond created by salt deposits. A common misconception, however, is that parts become easier to unscrew because the nut and bolt have slightly different diameters at the thread interface. Since the pitch diameter of the nut is slightly larger than the pitch diameter of the bolt, the nut's pitch diameter will expand just a tiny bit more than the bolt's.



Picture 243: Heating expands the parts.

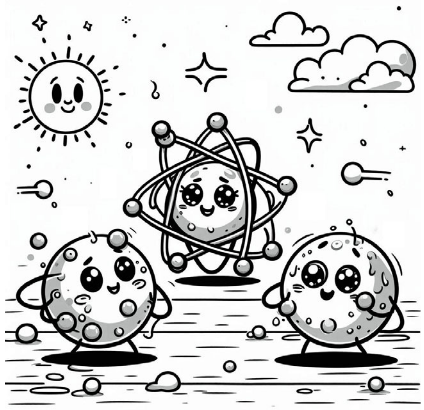
While this is true in essence, it isn't the primary reason the parts become unstuck. The real key is that the flanks of the threads will shift ever so slightly relative to each other. Remember, it's the debris between the thread flanks that acts like glue. When there's even a small amount of relative movement between the flanks, it can crack or loosen some of the bonds between the salt deposits and flanks, lowering the overall friction.

Unfortunately, this method isn't directly usable, since brass can anneal (soften) at temperatures as low as 300°C, a temperature easily reached with a blowtorch. But that doesn't mean we can't use the basic principle behind it: a change in temperature. Materials have a property called the thermal expansion coefficient, which tells you how much a material expands or contracts with temperature changes. It's usually measured in µm/m°C, where µm is one millionth of a meter. This unit may seem odd, but it's not difficult to grasp. For example, if you have a 1-meter-long stick of material and increase its temperature by 1°C, the stick will expand by whatever the thermal expansion coefficient is. A practical example for us is free-machining brass[2], which has a thermal expansion coefficient of 20.5µm/m°C. If you heat a 1-meter-long stick of this brass by exactly 1°C, it will expand by 20.5µm (to 1.0000205m). While that might seem insignificant, remember, this is just a 1°C change. Similarly, cooling the brass by 1°C would make it 20.5µm shorter.



Picture 245: The cold makes the huddle.

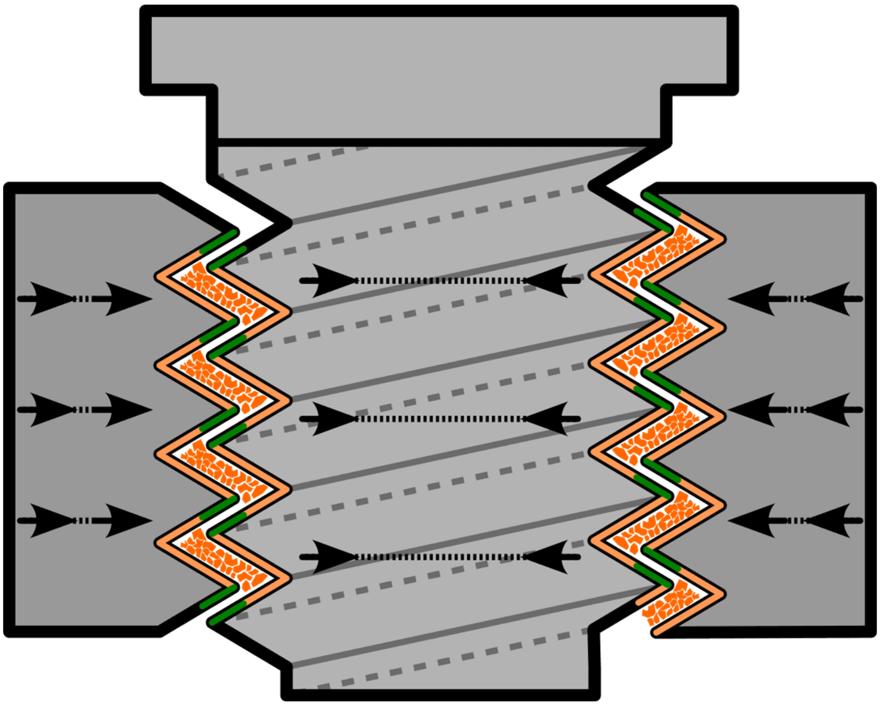
To make this concept more relatable, consider a somewhat silly analogy: Imagine atoms in a material are lined up like a chain of friends, all holding hands. When it's cold, they lose energy and start shivering. Naturally, they pull together tighter, causing the chain to contract. When it's hot, the opposite happens. The atoms get more energetic, like people on a crowded summer bus, pushing each other for more space, trying to find an empty corner. This causes the material to expand. It's not that the atoms themselves get bigger or smaller; they just need more or less personal space.



Picture 244: When it's hot you need space.

Different materials expand at different rates. Salt deposits from seawater are primarily composed of NaCl (table salt), which has a thermal expansion coefficient[3] more than twice that of free-machining brass at 44µm/m°C. The exact number isn't as important as the fact that the thermal expansion coefficient of salt is notably different than that of brass.

So, how do we use this information? The goal is to create as much of a temperature differential as possible. However, we can't use a direct flame since it would damage the brass. Start by placing the stuck part in a pot of boiling water. Most SCUBA parts can withstand temperatures up to 100°C, which is the boiling point of water. Be careful with plastic components, as they may deform in boiling water. While I can't give you a definitive list of which plastics are safe on your particular regulator, you may want to heat the water to around 70°C if you want to be on the safe side. At this temperature, most plastics used in SCUBA gear won't deform.



Picture 246: Through different contractions you may get some extra clearance.

When the part heats up, the salt deposits will expand more than the brass (since salt's thermal expansion coefficient is higher). However, the salt crystals are usually tightly packed within the thread flanks, so they can't expand freely. This leads to some of the crystalline structure cracking or fracturing. Meanwhile, tiny movements occur within the thread flanks, which also helps loosen the grip of the salt on the flanks. But we're not done yet. Take the heated part and throw it into a freezer. I like to cool it quickly in cold tap water before placing it in the freezer, where the temperature is around -20°C. This creates a 120°C temperature differential from the boiling water. You might think this change is insignificant, especially considering the thermal expansion coefficient of brass (20.5µm/m°C). But let's put this into perspective with a simple calculation.

Let's assume a rather small flank with 0.5mm length. The exact length doesn't matter all that much and 0.5mm is a fair number for a smallish thread. The general formula for thermal expansions and contractions is:

$$L = L_0 + \alpha \, x \, L_0 \, x \, \Delta T$$

L = Final length in metres.
α = Thermal expansion coefficient.
L_0 = Original length in metres.
ΔT = Temperature differential in °C or Kelvin.

All we need to do is plug in the numbers for our 0.5mm-long flank. The units might seem a bit odd at first, but if we stick to them, they prove that we didn't mess up.

$$L = 0.0005m + \frac{0.0000205m}{m°C} \, x \, 0.0005m \, x - 120°C$$

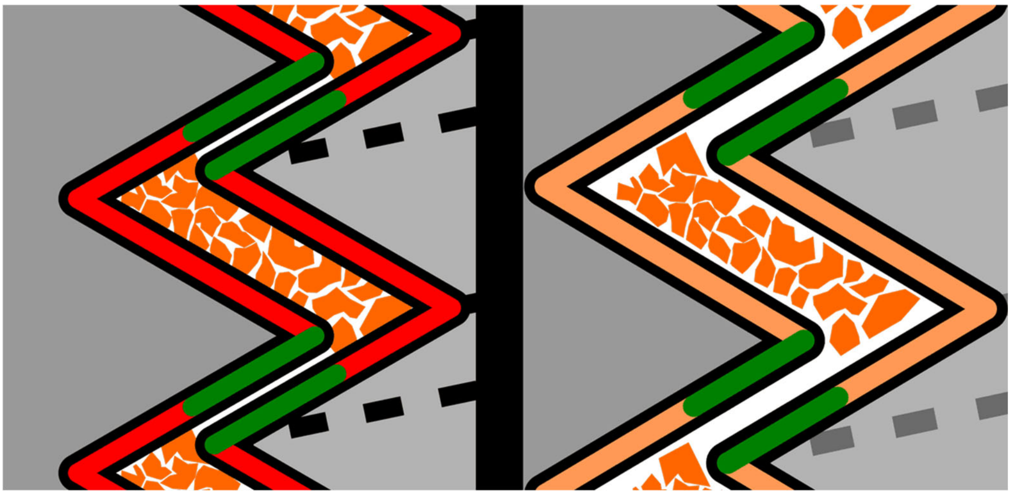
$$L = 0.0005m + \frac{0.0000205m}{m°C} \, x - 0.06m°C$$

$$L = 0.0005m - 0.00000123m$$

$$L = 0.00049877m = 0.49877mm$$

The change in length is 0.00123mm, which is pretty tiny. But put it in atomic terms, and it's a whole different story. 0.00123mm equals 1230nm, and with atoms being well under 0.1nm, it's easy to see why our technique might just work.

Remember, all we were trying to do was break the bond between the flanks and the debris. If we pull that off, we'll have dramatically reduced the torque needed to loosen the parts. And



Picture 247: Comparing untreated threads to heat-treated threads with potential clearance changes.

here's the best thing: while the brass contracted, the debris did too. And it shrinks about twice as much as the brass. That means, with a little luck, we've created enough clearance between the flanks and debris to unscrew the parts without causing damage. Even if we don't manage to create any meaningful clearance, the tiny movements alone can be enough to break the glue-like forces between the debris and the flanks.

In the real world, I've found that it's smart to combine the two methods or repeat them if one cycle isn't successful. Sometimes I've had better results working on a warm part; other times, a frozen one worked better. I chalk it up to how much water is trapped in the threads, as it annoyingly behaves differently from most materials and expands when it freezes. I haven't come across a single piece of equipment I couldn't separate with a mix of heating, cooling, and hammer tapping. Instead of getting frustrated and over-torquing a part, just toss it in the freezer overnight or cook it again. I've found that making the temperature change super rapid, like going from the freezer straight into boiling water, does wonders sometimes.

[1] WD-40—How penetrating agents work
[2] EngineeringToolbox-Metals—Temperature expansion coefficients
[3] Crystran—Sodium Chloride