Paruzzi Magazine

Digital Publication for the classic Volkswagen

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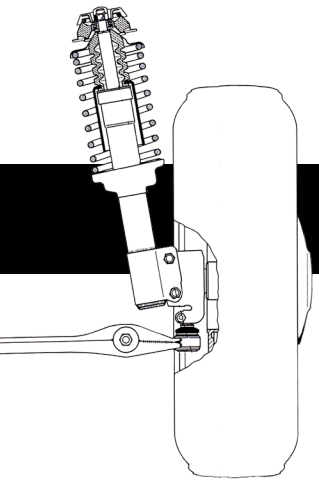


Introduction

After you have disconnected the brake hoses of a hydraulic brake system, to replace the wheel brake cylinders, master cylinder or calipers, for example, you will need to bleed the brake circuit, that goes without saying. But, replacing or flushing the brake fluid is also necessary after a certain number of miles driven, or after a number of years in the case of our vintage cars that don't drive much. If you have just purchased a vintage car, and you do not know the maintenance history, start changing the brake fluid already. Refilling is not enough, there may be water present in the brake fluid, or dirt particles.

If you want to know more about the hydraulic brake system, read edition 05 of this series. We also briefly discuss the role of brake fluid and the difference between DOT 3 and DOT 4.

'DOT' (Department of Transport). The number 3, 4, 5 & 5.1 after the DOT name, has to do with the minimum quality of the fluid, especially its boiling point and viscosity.

To better understand the importance, and sometimes urgency, of replacing brake fluid, we will discuss some basic properties of brake fluid.

brake fluid replacement

Brake fluid

Let's start with the frequently asked question, "*what type of brake fluid should I use for my vintage Volkswagen?*"

DOT 3 or DOT 4?

Do not consider the world of tuning and racing for a moment, with DOT 4 you are always right. DOT 4 has a higher boiling point than DOT 3. So it can also be used for a heavily loaded Camper or Vanagon with 8 people.

We would recommend DOT 3 only for lightweight cars with limited power engines, which are all original VW Beetles, Karmann Ghia's, VW Thing and Type 3's. But even for these standard models, DOT 4 can be used.

Refill with DOT 3?

If DOT 4 is recommended for your vehicle, refill only with DOT 4 or DOT 5.1. Refilling with DOT 3 will lower the boiling point. If you do not demand high performance, such as driving in the mountains or on the highway, or fully loaded with caravan or trailer, then topping up with DOT 3 should not be a drama, as a quick fix. Then change the brake fluid as soon as possible.

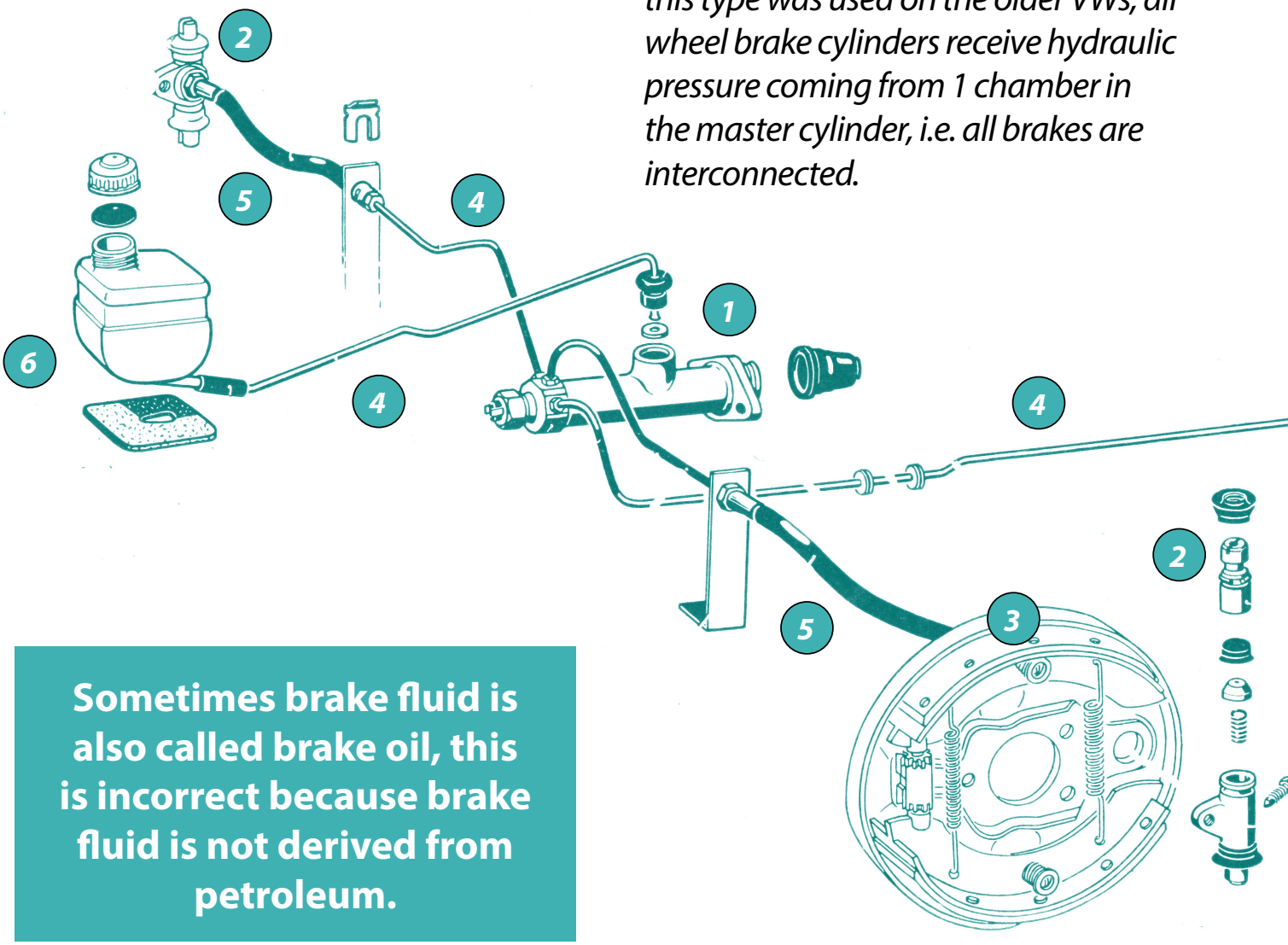
Never mix DOT 5 with DOT 3, DOT 4 or DOT 5.1, or vice versa!

#73 Brakes

The function of brake fluid is to transmit the pressure in the master cylinder (1), which is generated by your foot on the brake pedal, to the wheel brake cylinders (2), which in turn press the brake shoes (3) against the brake drums. If your VW is equipped with disc brakes, it is the pistons in the calipers that are pressed against the discs by the hydraulic pressure.

Brake fluid is not compressible, so the force of your foot on the brake pedal is transmitted directly to the brake cylinders without loss.

Representation of a single brake circuit: this type was used on the older VWs, all wheel brake cylinders receive hydraulic pressure coming from 1 chamber in the master cylinder, i.e. all brakes are interconnected.

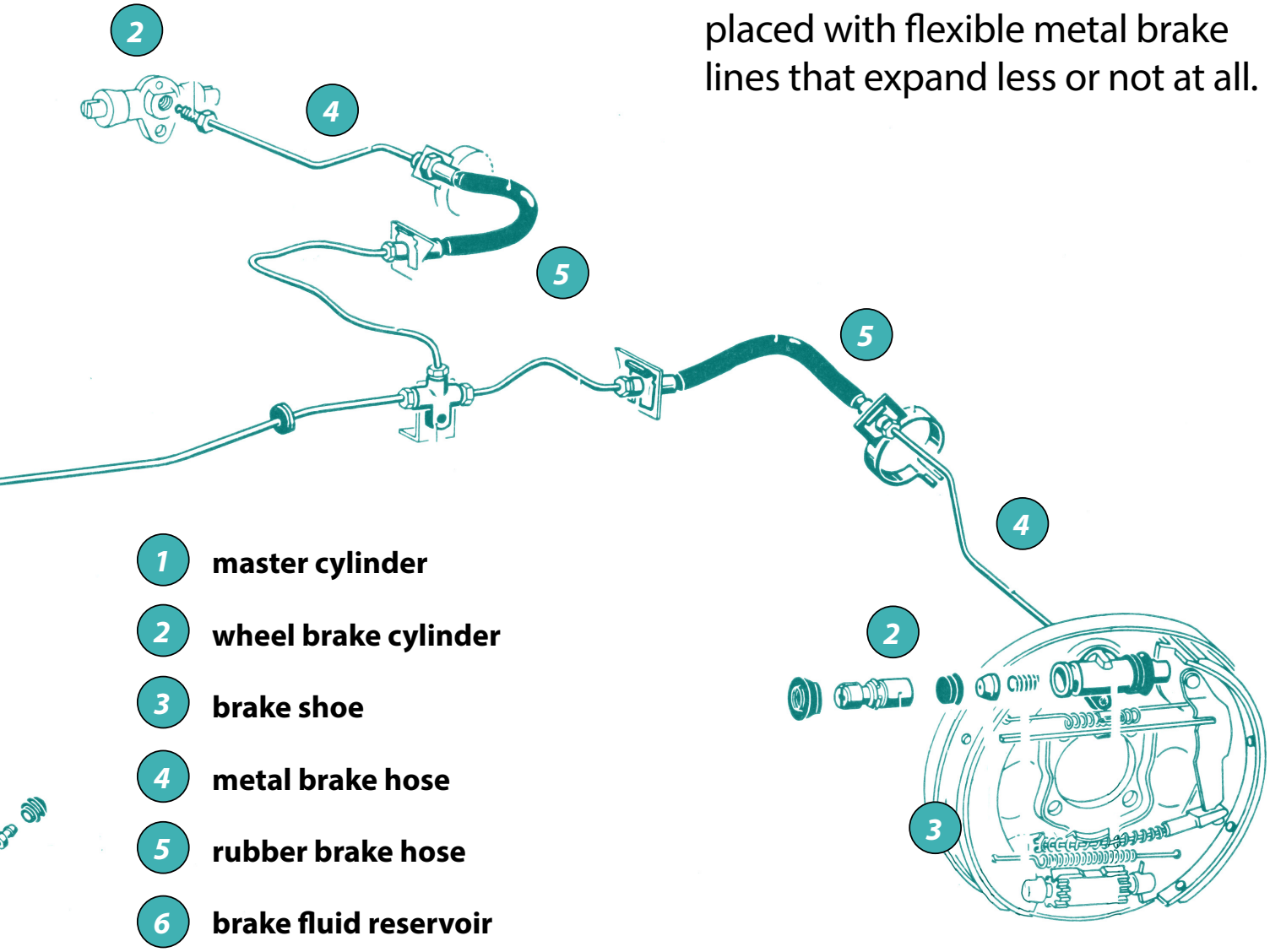


Sometimes brake fluid is also called brake oil, this is incorrect because brake fluid is not derived from petroleum.

brake fluid replacement

Any component that could slow the force of your foot on the brake pedal should be avoided. This is why almost all brake lines are made of metal, except for those that connect the car's chassis to the wheels. These flexible connections are necessary because the chassis is sprung against the wheels. By making these flexible connections with brake hoses that expand little or not at all, and by keeping them as short as possible, pressure loss is minimized.

In tuning applications, the standard rubber brake lines are replaced with flexible metal brake lines that expand less or not at all.



1. **master cylinder**
2. **wheel brake cylinder**
3. **brake shoe**
4. **metal brake hose**
5. **rubber brake hose**
6. **brake fluid reservoir**

Water and moisture

DOT 3, DOT 4 and DOT 5.1

Glycol-based brake fluids have the property of absorbing moisture, they are **hygroscopic**. These include the brake fluids DOT 3, DOT 4 and DOT 5.1. Moisture causes the boiling point of the brake fluid to decrease.

Most of our classic VW's are not subjected to much stress. But, think of a fully loaded Westfalia camper, descending mountain passes, or a standard VW Beetle on its way to Francorchamps. Brake fluid contaminated with a high water content is more compressible and will boil faster, resulting in a spongy-feeling brake pedal.

An additional consequence of moisture in brake fluid is that it will eventually lead to corrosion of hydraulic components such as the master cylinder, brake cylinders and brake lines.

DOT 5

Silicone-based brake fluids do not absorb moisture, they are **hydrophobic**. This includes DOT 5 type brake fluid. Another advantage of DOT 5 is that it does not attack the paint. Since water does not mix, it can accumulate in the brake cylinders and cause corrosion. Regular brake fluid changes are also important with DOT 5.

Never mix DOT 5 with DOT 3, DOT 4 or DOT 5.1, or vice versa!

We will primarily use **DOT 3** or **DOT 4** on our vintage VWs. Switching to DOT 5 can only be done with a completely new brake system, or after thoroughly cleaning the old brake circuit, to make sure that all residual glycol brake fluid has been removed.

brake fluid replacement

It is inevitable that the temperature of the brake fluid will rise when braking. A boiling point has been calculated for each type of brake fluid. For DOT 3 it is 205°C, for DOT 4 230°C and for DOT 5.1 270°C. A "**wet boiling point**" is also given by the Department of Transport (DOT). This was determined at a contamination of 3.7% water in the brake fluid. The boiling point drops dramatically to 140°C, 155°C and 190°C respectively for DOT 3, 4 and 5.1.

DOT 3 fluid can absorb up to 2% water per year. Moisture can enter the system when you remove the reservoir cap to add brake fluid, through worn seals and even through the rubber brake lines themselves. So the "**wet boiling point**" of the fluid is the number that reflects what is really going on in your car.

Rubber and metal particles

So brake fluid must be clean, free of water and impurities. Minuscule metal particles and rubber residue will mix to the brake fluid over time. Metal particles from the brake cylinders and brake lines, and rubber particles from the flexible hoses and seals. These impurities can clog the lines, and will adversely affect the properties of the brake fluid.

All these reasons for contamination and their consequences will hopefully have motivated you to replace the brake fluid in your classic Volkswagen.

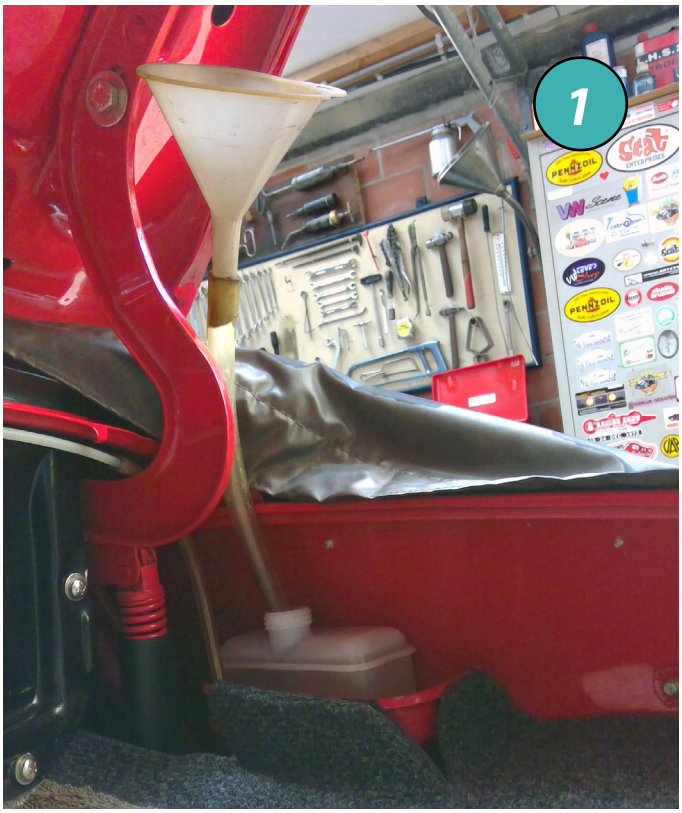
We will discuss different techniques, where you will need special tools, and in the next edition also the basic technique where you depress the brake pedal to flush the brake fluid.

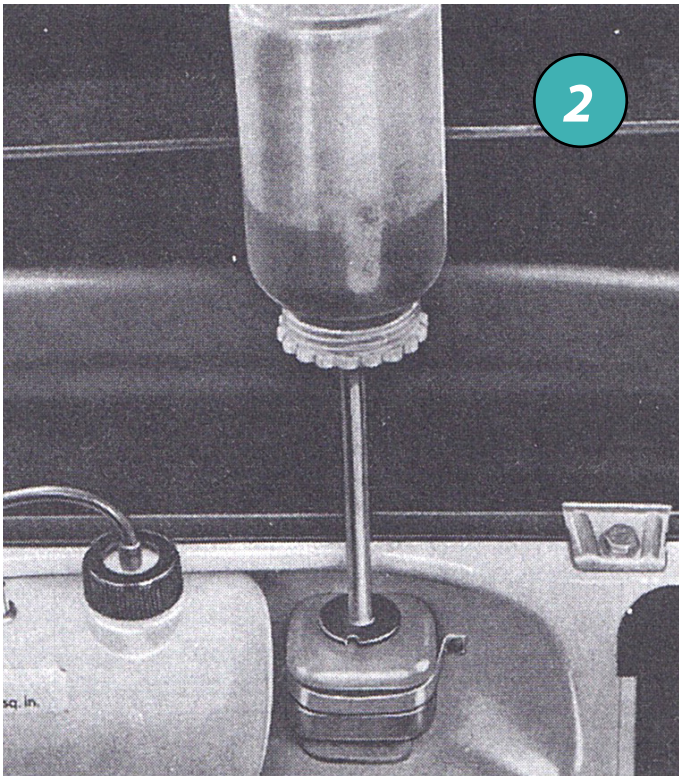
Flush sequence and refill

With any technique you use, you will first need to check the level in the brake fluid reservoir. You may fill with slightly more fluid than normal, but be careful not to spill since DOT 3 and DOT 4 are very corrosive! Keep in mind the advice at the beginning of this article about mixing different types of brake fluid.

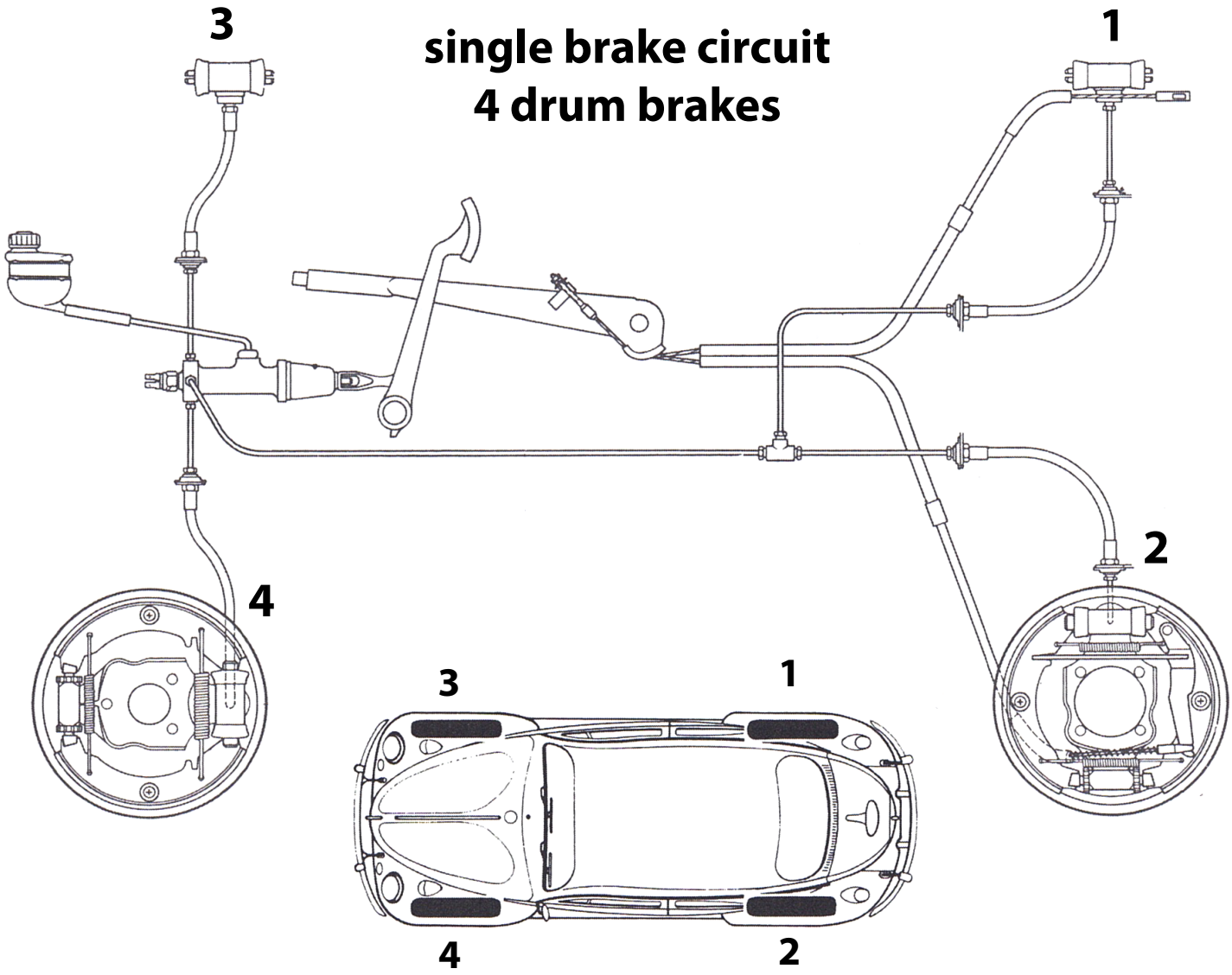
A funnel with a hose long enough to comfortably refill the brake fluid is recommended (photo 1). You will need to refill the reservoir several times while flushing all four brakes on your VW.

A refill bottle like the one shown in photo 2 from the VW workshop manual is very convenient, but you don't always have room for it. This type of container is sometimes included with special brake bleeding tools.





brake fluid replacement

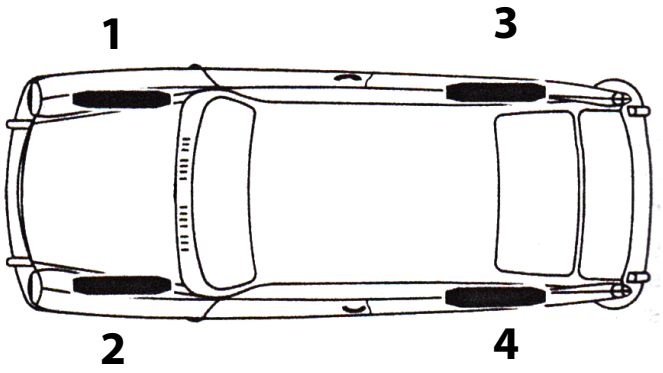


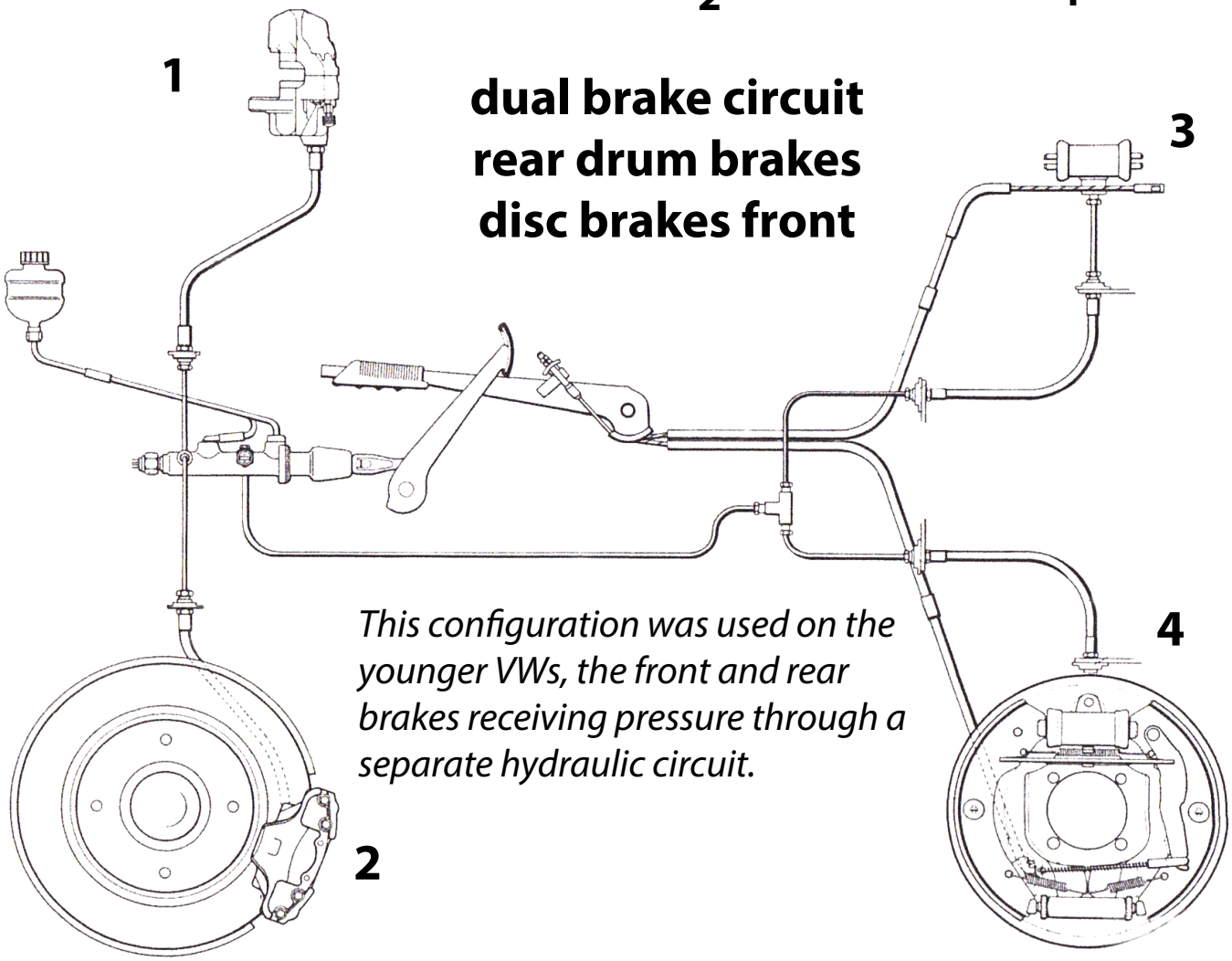
Which brake comes first is indicated in the workshop manual for your type of VW. For a **single brake system** with four drum brakes, you start with the brake furthest from the brake fluid reservoir, which is right rear, then left rear, then right front and you end with the brake closest to the brake fluid reservoir on the left front. Possibly your VW's brake circuit is modified or you don't have a workshop manual for that type of VW, then it's a matter of measuring the brake lines at the bottom of the car to determine which wheel brake cylinder is farthest from the master cylinder.

#73 Brakes

With a dual brake system, on the classic Volkswagen, the hydraulic lines of the rear brakes and the front brakes are separate. You could follow the order as with a single brake circuit. The VW Type 3 workshop manual recommends starting with the front first, then the rear.

Consult your workshop manual to know what the order is for your type of VW or measure the length of the brake lines if your car is no longer factory original.

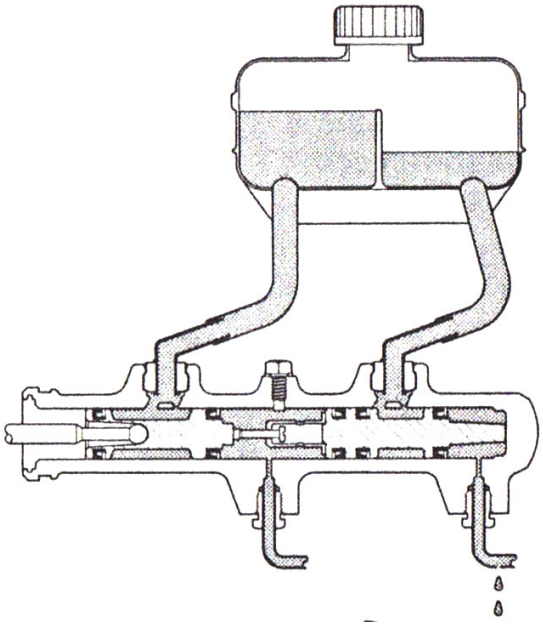




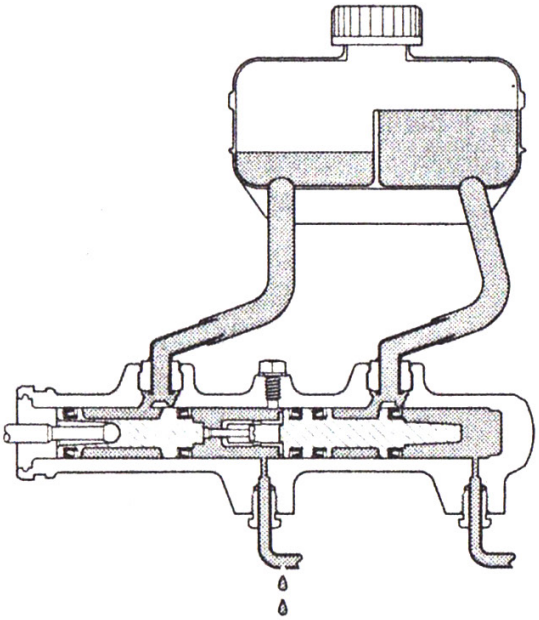
This configuration was used on the younger VWs, the front and rear brakes receiving pressure through a separate hydraulic circuit.

brake fluid replacement

front leak



rear leak



With a dual brake circuit, the master cylinder will have two connections to the fluid reservoir, it has two hydraulic pressure chambers, which independently serve the front and rear brakes. The reservoir has a divider to ensure that both brake circuits are supplied with brake fluid separately.

The drawing at the top left shows what happens when there is a leak on the front brakes, the brake fluid leaks out but on the other side of the wall in the reservoir, the level remains level. The drawing at the top right shows the scenario when there is a leak somewhere in the circuit of the rear brakes.

On the left a master cylinder with two connections for a dual brake circuit, on the right a master cylinder with brake fluid reservoir mounted directly on the connection to be used with a single brake circuit.

Flushing the brake fluid

Do your brakes work well, and do you feel that your brake pedal provides firm back pressure, then your brake circuit components should be fine. If the brake pedal feels soft, then the cause may be contamination of the brake fluid by water or moisture. In this case, you will need to flush the brake fluid completely and replace it with fresh brake fluid.

If there is a problem with pedal pressure, then you will first need to check for leaks in the brake circuit. Look at the following places with extra attention:

- **the brake fluid reservoir**
- **the master brake cylinder**
- **the wheel brake cylinders**
- **the bleeding nipples**
- **all connections between the metal pipes and rubber hoses**

If that's all in order, no leaks to detect, then you can start flushing your brake circuit.

If you can push the brake pedal too far, it may also be that the brakes are poorly adjusted in the case of drum brakes, disc brakes are in fact self-adjusting.

There are two methods for flushing your brake circuit:

1. either build up a **vacuum** at the bleed nipples to suck the brake fluid out of the brake circuit

2. either use **compressed air** in the brake fluid reservoir to drain all the brake fluid through the bleed nipples

1. with vacuum

We start with the technique of creating a vacuum at the bleed nipple. This is also the simplest way to flush the brake fluid.

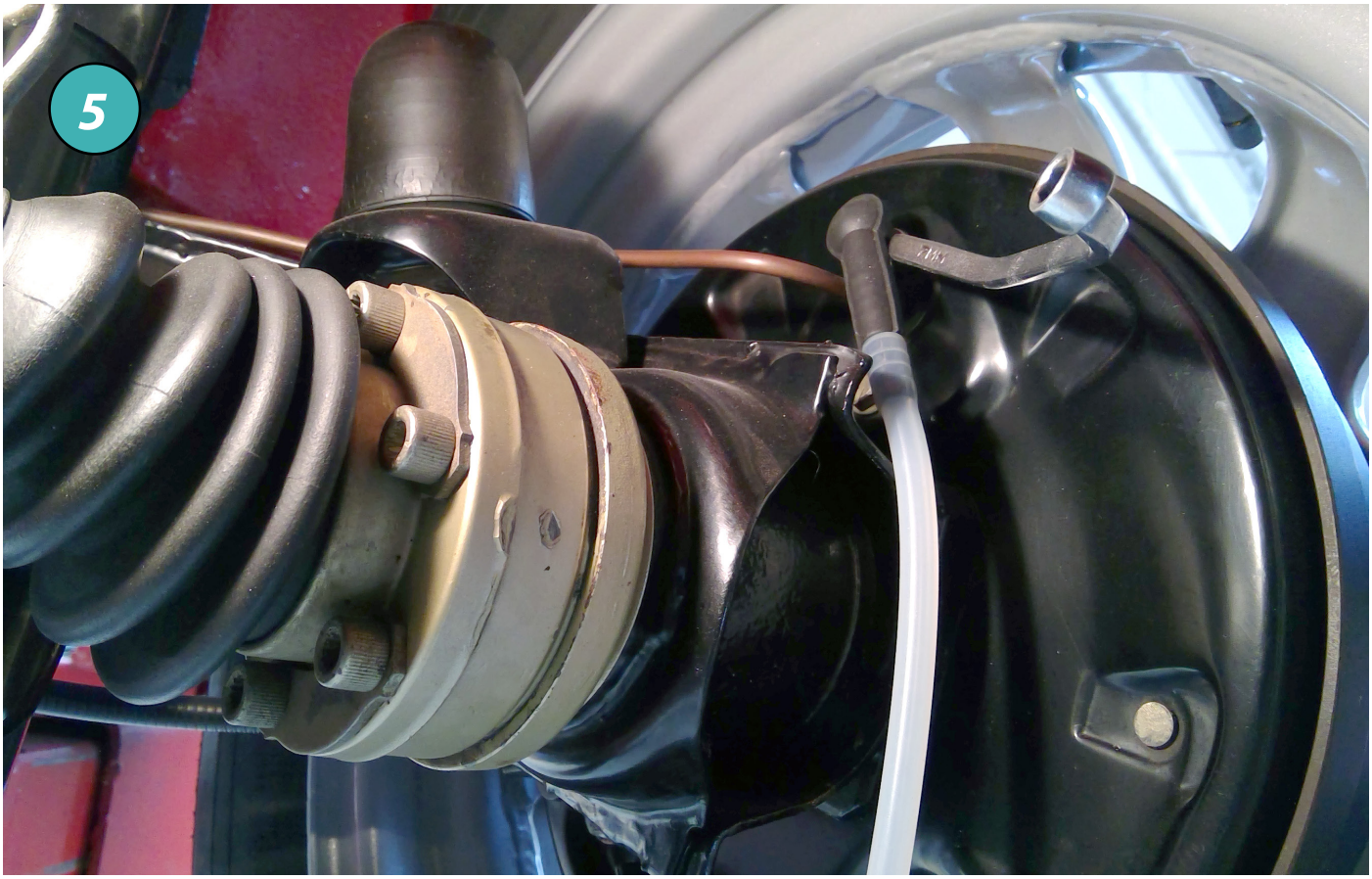
You need an air compressor for this, something most enthusiasts have on hand anyway, and a brake bleeder like the one shown in photo 3. Such a tool is not expensive, it gives a good result without too much spillage, and, you can perform the flushing alone.

Even better is the version with an extra fill bottle (photo 4) that you place on top of your VW's brake fluid reservoir. This extra reservoir is filled with brake fluid, and will keep the brake fluid level at a constant level. So you don't have to run back and forth to check for enough brake fluid.

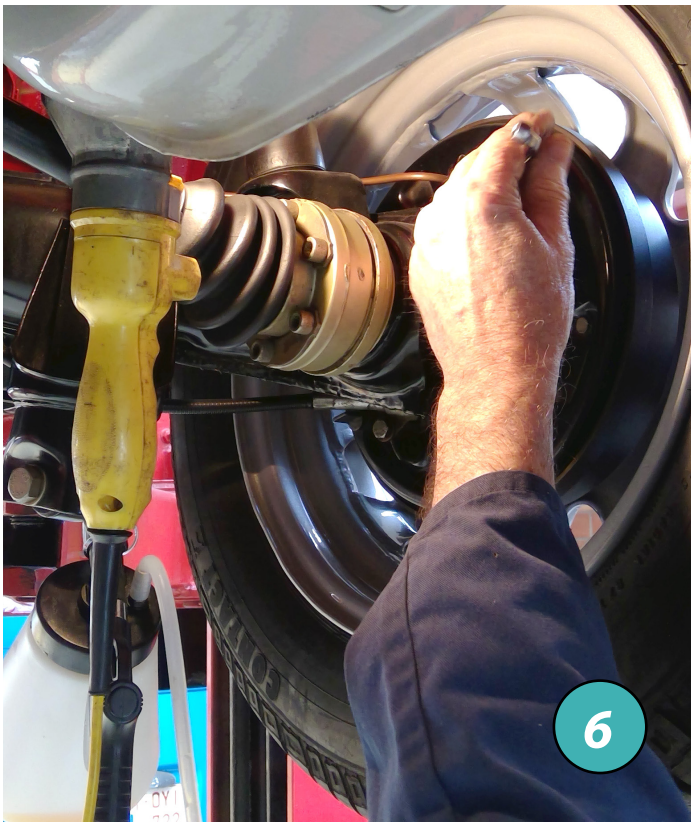
3

Unfortunately, this can't be used on every type of VW, as we'll see shortly on our Volkswagen 1303 convertible.

4

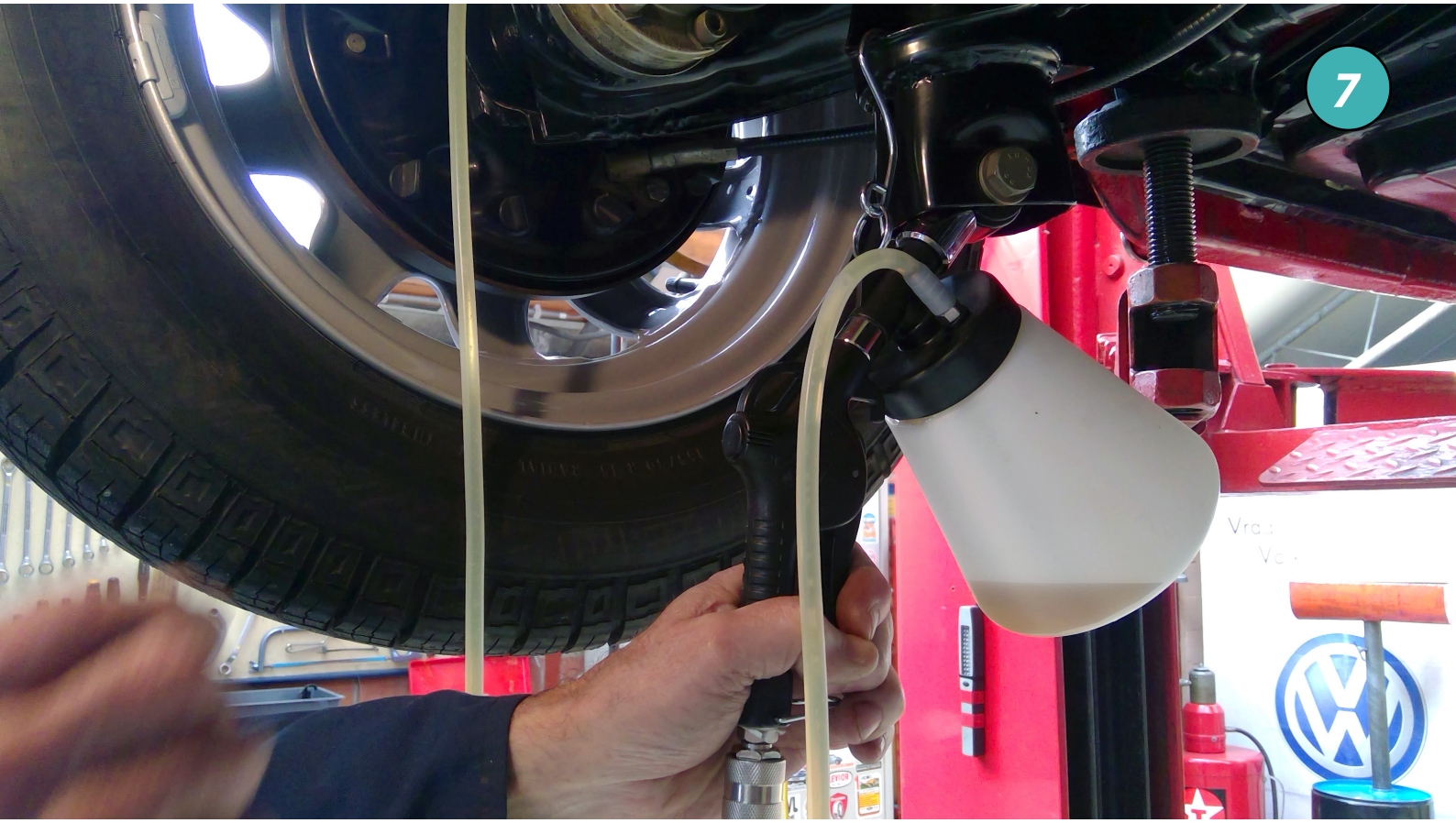


Remove the dust cap from the bleed nipple, use a wrench that fits the nipple and push the suction hose onto the nipple as shown in photo 5, and open the bleed nipple about half a turn (photo 6).



Turn on the air compressor (**6 to 8 bar**), you should see the brake fluid flowing through the transparent hose and into the reservoir (photo 7). The brake fluid may be dark in color if old and contaminated.

brake fluid replacement



You may see air bubbles in the hose, that does not directly mean that there is a lot of air in the brake circuit.

If you are not using a fill bottle to keep the brake fluid level up, you will have to **check regularly to make sure there is enough brake fluid**. Running out of brake fluid is not an option; you will draw air into the brake circuit.

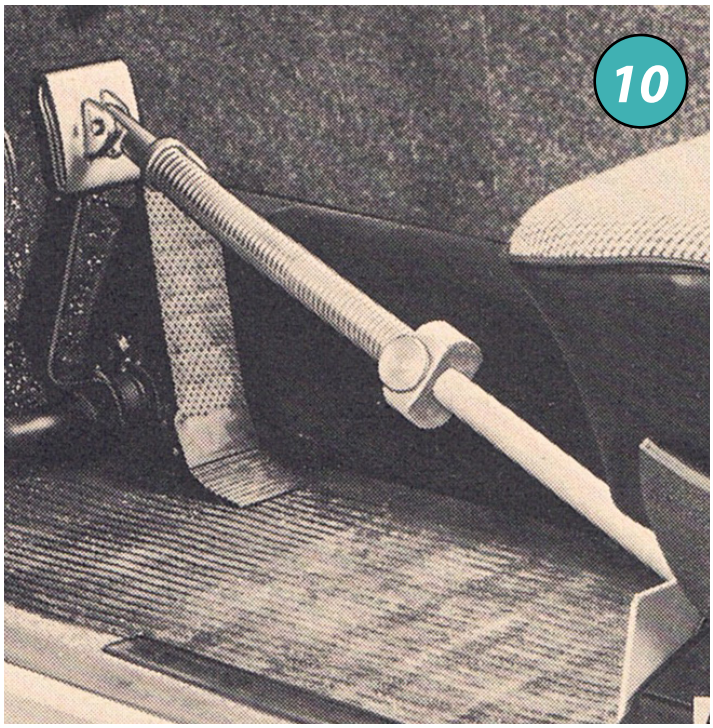
With the filling bottle below, you don't have to keep an eye on the level of the brake fluid reservoir.

On the VW 1303 we used, it is not possible to place the fill bottle on top of the brake fluid reservoir. We use a funnel and fill it ourselves. You then have to keep a really close eye on the level. In picture 9 we show how such a filler bottle works in practice, different small plastic feet are included to fit the most common brake fluid reservoirs.

Photo 9: With any luck, you can use the filler reservoir, which makes the job a whole lot more convenient. You won't have to keep an eye on the level of the brake fluid reservoir.

If the brake fluid does not flow nicely, try opening the bleed nipple a little more than half a turn. If it still doesn't work, Volkswagen recommends holding down the brake pedal while flushing the brake fluid. Our experience tells us that momentarily pressing the brake pedal is sufficient.

In the Volkswagen workshop manual, it is advised to keep the brake pedal pressed down tightly during flushing, they use a special tool for this purpose (photo 10).



brake fluid replacement

Continue until the brake fluid is clear in color or until you have flushed about 0.5 liters of brake fluid. This should be sufficient for the right rear brake. Tighten the bleed nipple and remove the vacuum hose. Continue with the left rear brake.

Looking at the drawing on page 9, by flushing the right rear brake, we have replaced the brake fluid in the line up to the brake fluid reservoir. For the left rear brake, we only need to flush a short section of pipe. So now the brake fluid should lighten in color much faster.

Next it's the turn of the front right brake, and then the front left. The front brake lines are much shorter, so you don't have to flush for as long as you do for the rear.

If you have disc brakes, there may be **two bleed nipples** present on the calipers (photo 11). Because air tends to move upward, use the upper nipple to flush the brake fluid.

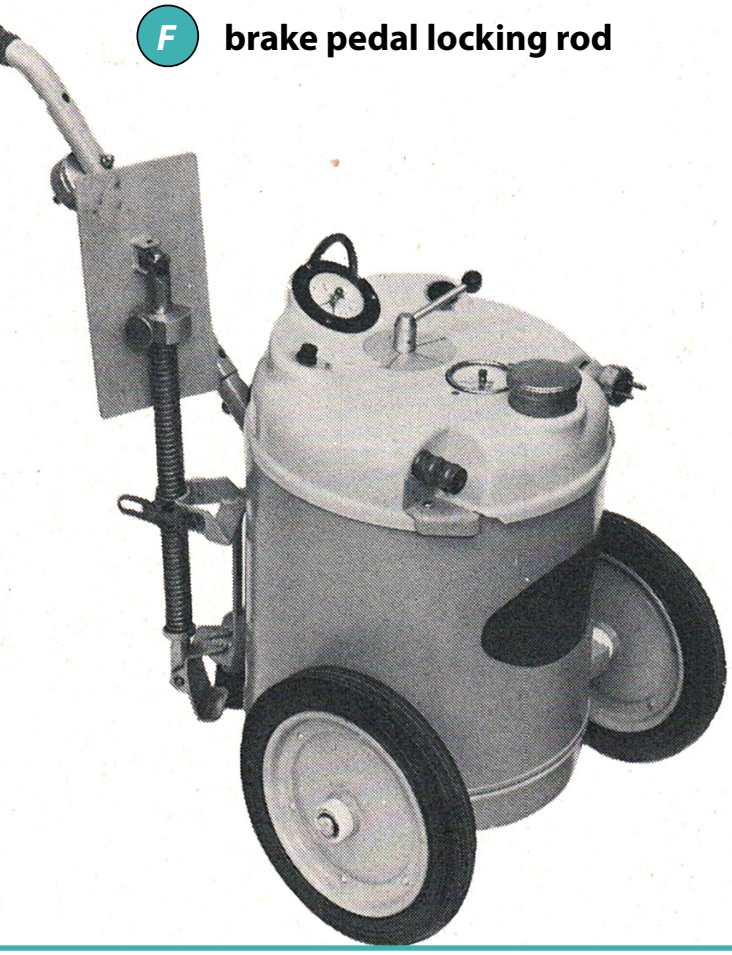
The VW workshop manual also recommends flushing a little (100 ml) of brake fluid through the lower nipples. If only one nipple is present, then the choice is very obvious.

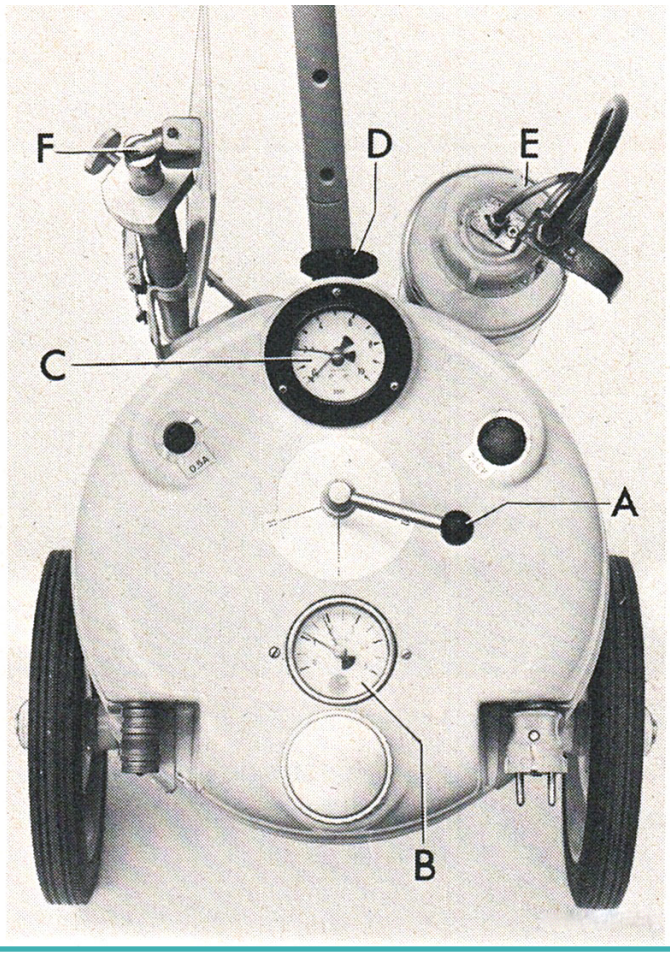
2. with compressed air

A second technique uses a compression reservoir to force brake fluid through the brake circuit. In the photo below, we show the device used by Volkswagen garages back in the day.

- **A** control lever
- **B** brake fluid level
- **C** pressure gauge/manometer
- **D** pressure reducer
- **E** brake fluid recovery bottle
- **F** brake pedal locking rod

It has a pressure reservoir with brake fluid. The unit shown in the VW books has, as an extra, a catch bottle and a rod to hold the brake pedal when depressed. The pressure gauge with pressure reducer is important because the brake circuit and plastic brake fluid reservoir should not have too much pressure. The manual for this unit recommends a pressure of 2 to 2.5 bar.





We use a Vintage device (photo 12). There are simpler and affordable devices on the market that offer similar features.

They usually come with a set of different reservoir covers (photo 13) to fit just about all makes and models.

The device we use has a pressure reducer, so you may set the compressor to maximum, the pressure on the brake circuit will never exceed 2 bar to avoid cracking the brake fluid reservoir, or leaking the brake lines.

The container can be filled with fresh brake fluid, in this case we use DOT 4, as the sticker indicates on the container.

Such a system is used in a workshop where brake fluid is flushed regularly.

If you have one vintage car to maintain, then the vacuum bottle technique discussed earlier in this edition is more efficient.

brake fluid replacement

DOT 3, DOT 4 and DOT 5.1 are very damaging to paint. Take your precautions while changing brake fluid, and clean up immediately if brake fluid was spilled.

The input of the unit is connected to the air compressor, the pressure is set to about 2 bar, and the output is connected to the car's brake fluid reservoir via an appropriate reservoir cover.

On the wheel side, the procedure remains the same as for the technique with vacuum discussed earlier in this edition. You may use an empty can of motor oil with a transparent hose, if no bottle is supplied with the pressure tool. A transparent bottle is more convenient to see when it is full.

With pressure on the brake fluid, open the bleed nipple half a turn, the brake fluid will be flushed out.

When the brake fluid is light in color, and no air bubbles can be seen, you may close the nipple. A half-liter flush is common for a standard VW Beetle, as we explained earlier. Use this technique for each of the four brakes.

The great advantage of this technique is that you do not have to check the level of the brake fluid, of course you must make sure that the pressure vessel is properly filled.

In the next edition we will bleed the brakes with the brake pedal, without using special tools.

Introduction

You can recognize a good mechanic by the quality of his tools, and the cleanliness of his workshop, my old mechanics teacher would say. I can only agree with him. You can't get started with just a set of screwdrivers and a hammer when it comes to automotive engineering. For each brand, you will also need very specific tools. You can sometimes purchase them, sometimes they can't be found, or if they are, usually too expensive for one-time use. You can also get started yourself and build special tools.

Removing the crankshaft pulley on an engine that has run 100,000 km and more is best not done with just a hammer and brute force. You would prefer to reuse the original crankshaft pulley on your engine, were it not for the budget, also for the factory originality.

In this article we will show how to disassemble the crankshaft pulley, without damaging it, with a homemade tool, a special tool so to speak.

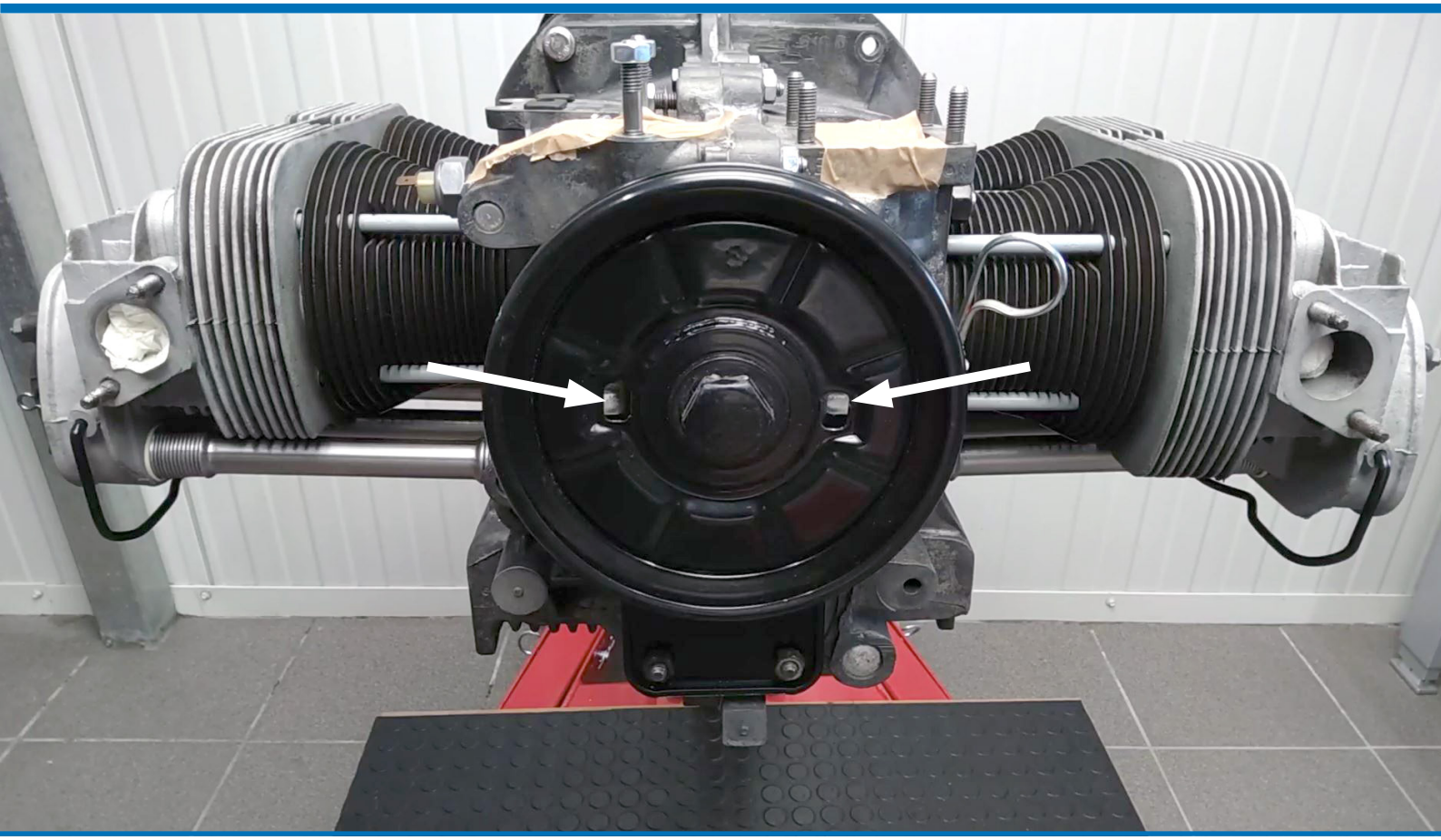
The crankshaft pulley can be disassembled with this tool both when the engine is built into the car, or when the engine is on the workbench or hanging from an engine mount.

crankshaft pulley removal

This article is mainly for the standard steel crankshaft pulley. As a rule, an aluminum pulley will not stick as much as the original pulley, and in most cases you can just gently pull or tap it loose. It is different with the steel crank pulley, especially when it has had a lot of mileage on it.

Preparations

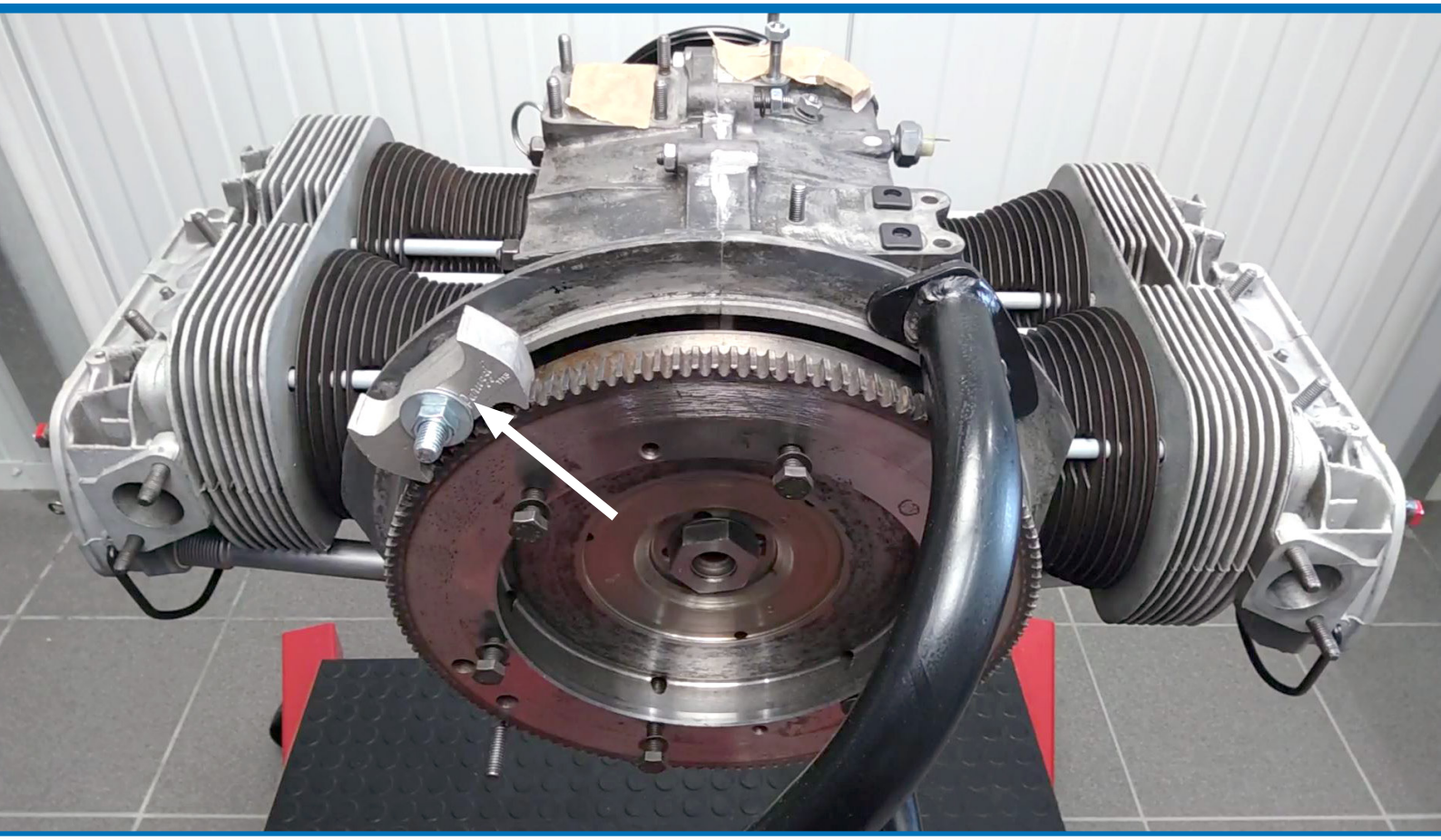
After removing the V-belt and perhaps some engine shroud to make the crankshaft pulley more accessible, we recommend turning the pulley so that the holes are horizontal (photo below). This will later make it possible to attach a tool through those holes.



#74 Engine

If the engine is built in, put it in second gear such that the crankshaft will not turn with it later when you loosen the crankshaft pulley bolt.

If the engine is on the workbench, you will need a special tool to block the flywheel (pictured right and below). Don't try to block the flywheel with a screwdriver! You risk damaging the teeth of the flywheel, or hurting yourself.

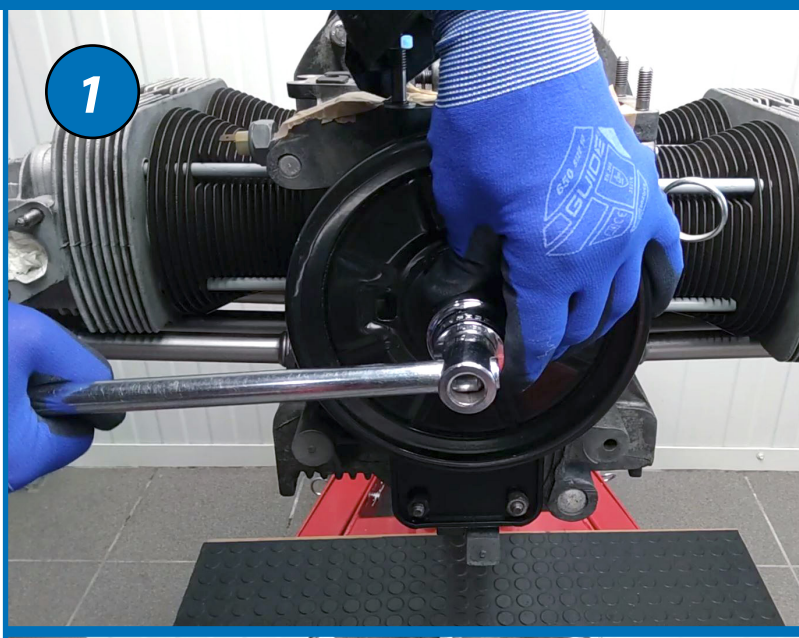


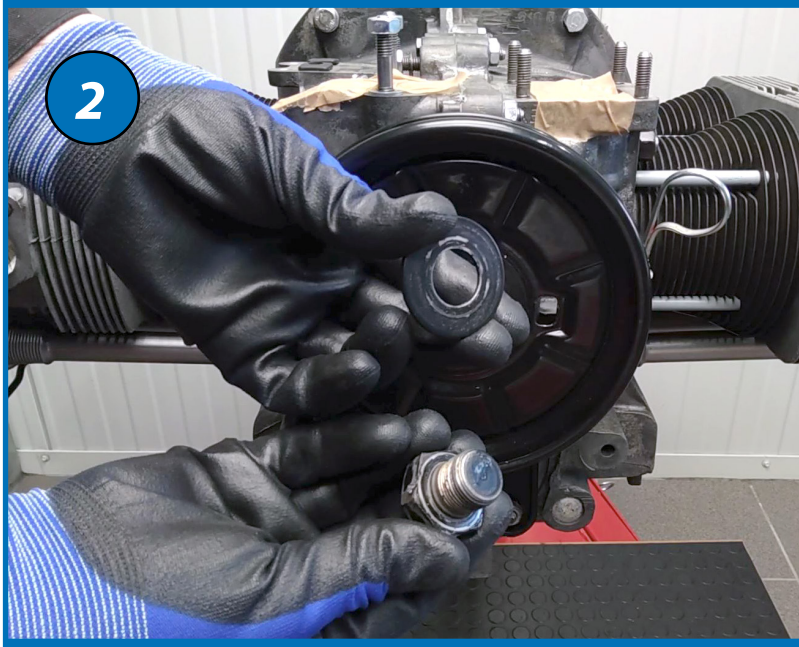
crankshaft pulley removal

Now you can unscrew the pulley bolt, for this Type 1 engine we use a 30 mm socket wrench (photo 1). If the bolt is tight, use an extension piece (piece of metal pipe) on the power arm of your socket wrench, do not use an impact wrench, it is really not necessary here.

Store the 30 mm bolt with its washer safely away (photo 2). With some luck you can manually pull the crankshaft pulley loose (photo 3), if the engine hasn't been running much, chances are you can. Don't force anything, if you can't remove by hand, use a special tool.

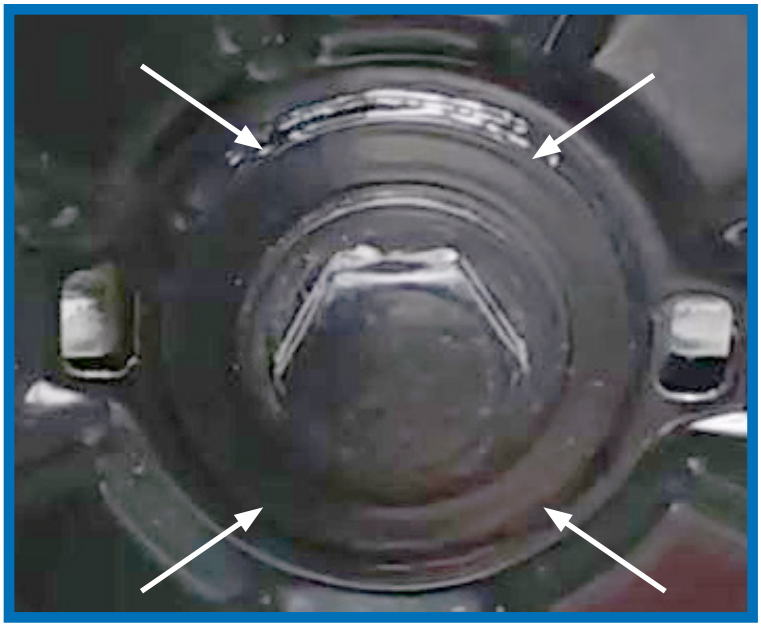
The outside of the crankshaft pulley cannot withstand large pulling forces in the axial direction (this is forward and backward). Manually you will not warp the pulley, but with a hammer, or with a pulley puller on the outer edge, the crankshaft pulley does not need much to warp.

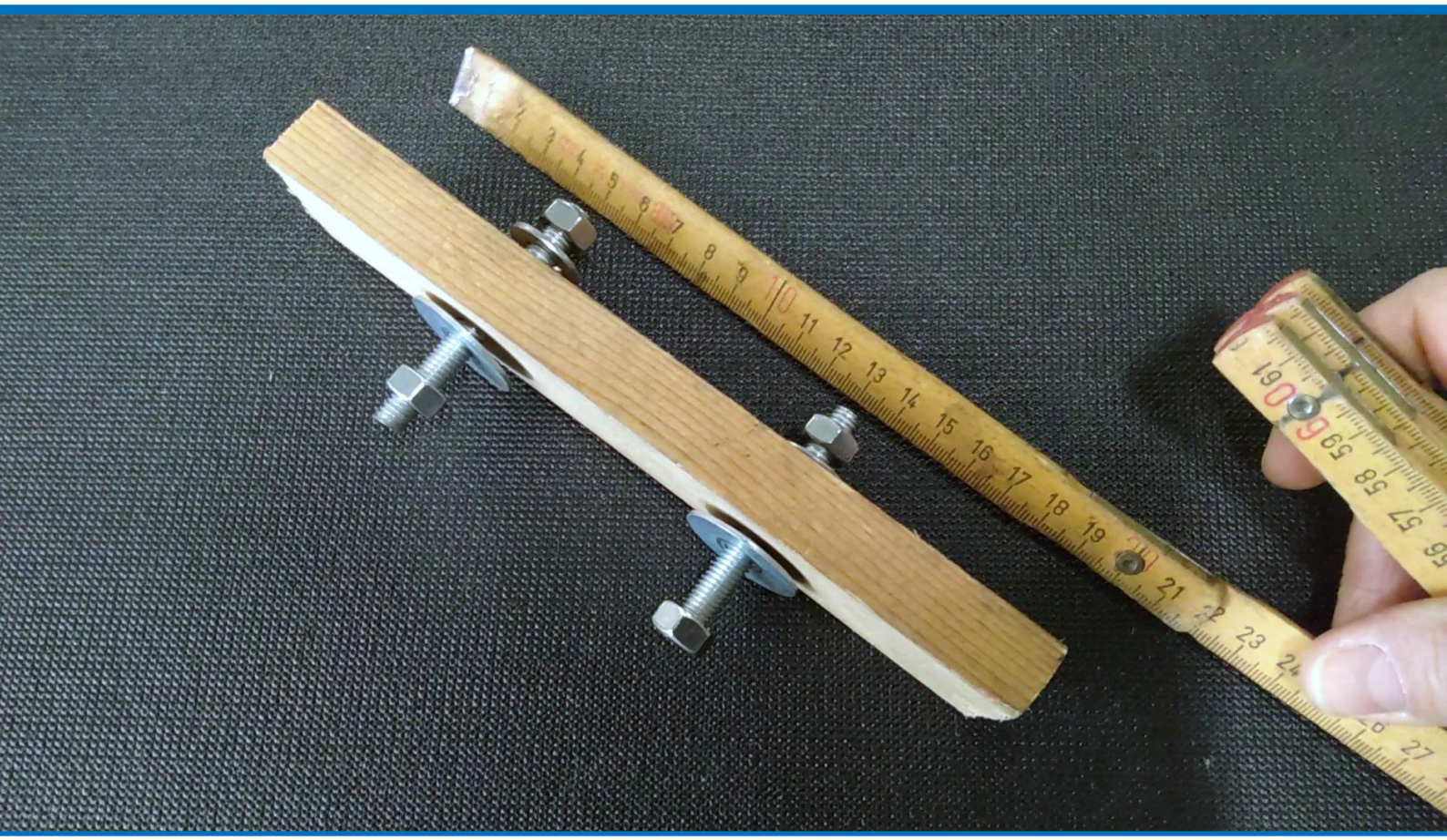




Homemade pulley puller

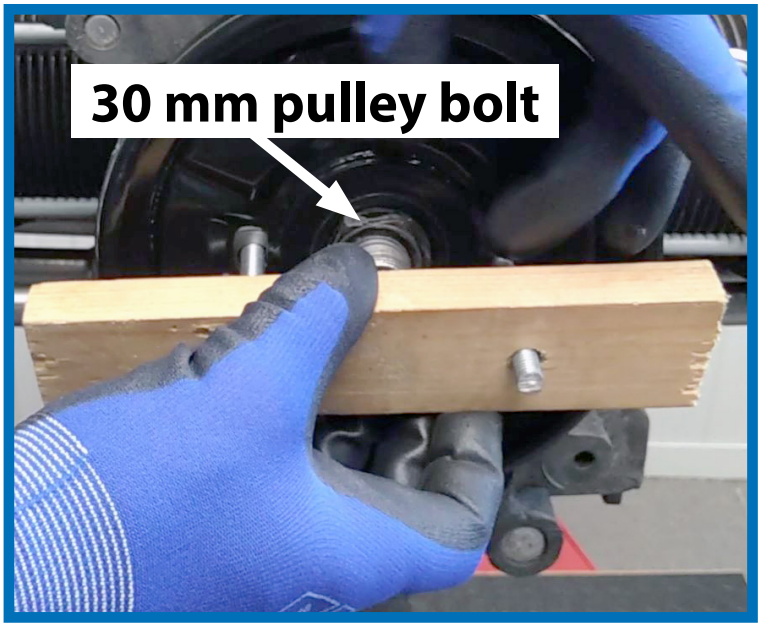
The crankshaft pulley is reinforced in the middle; you can see the welds in the photo on the right. The two holes are designed to apply large forces to loosen a stuck crankshaft pulley with a pulley puller.
We will use a homemade pulley puller for this purpose (photo below).
This tool consists of a 20 x 4 x 2 cm piece of wood, two pieces of M8 threaded rod at least 6 cm long, two large and two small washers, and four nuts.

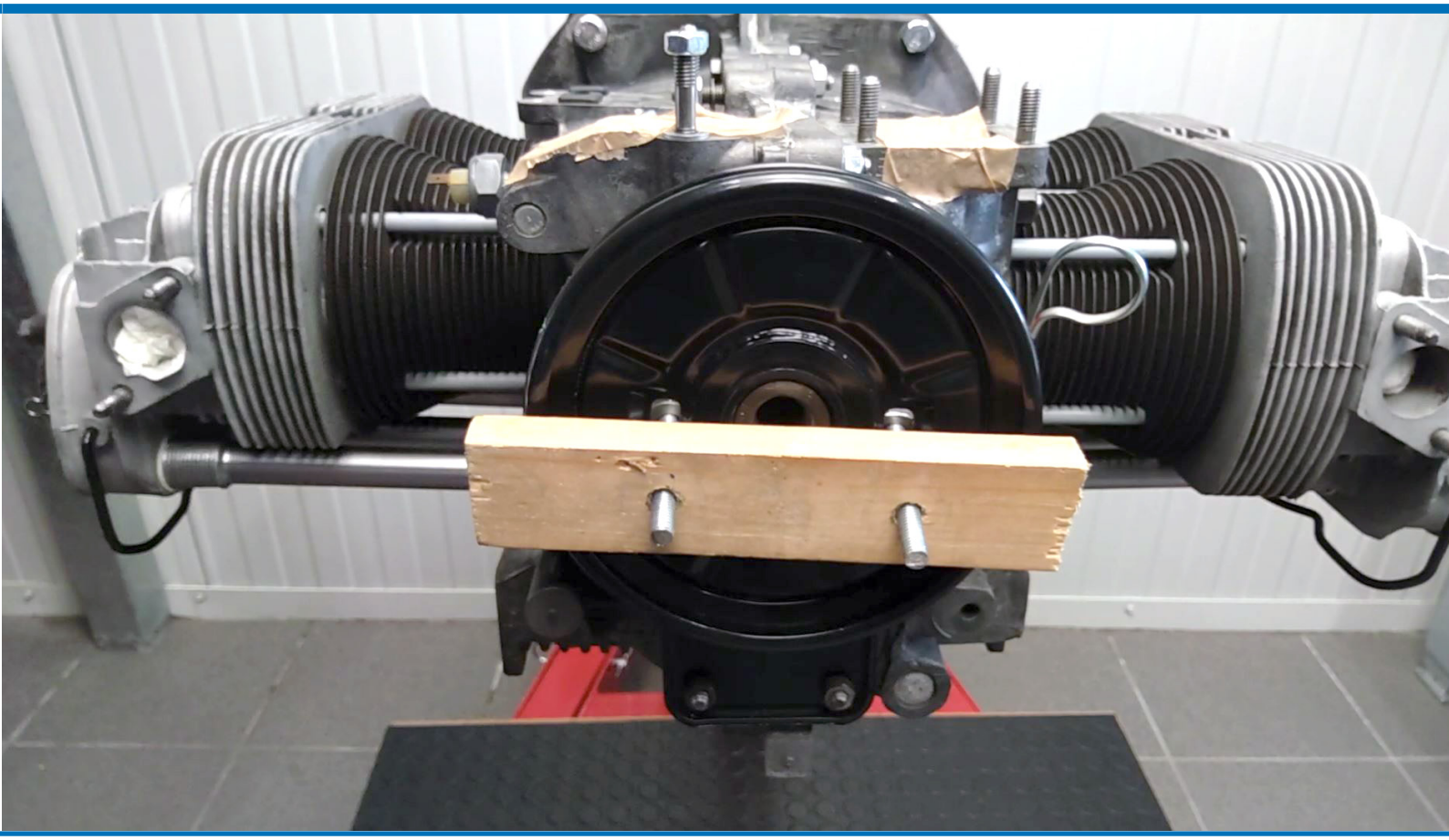




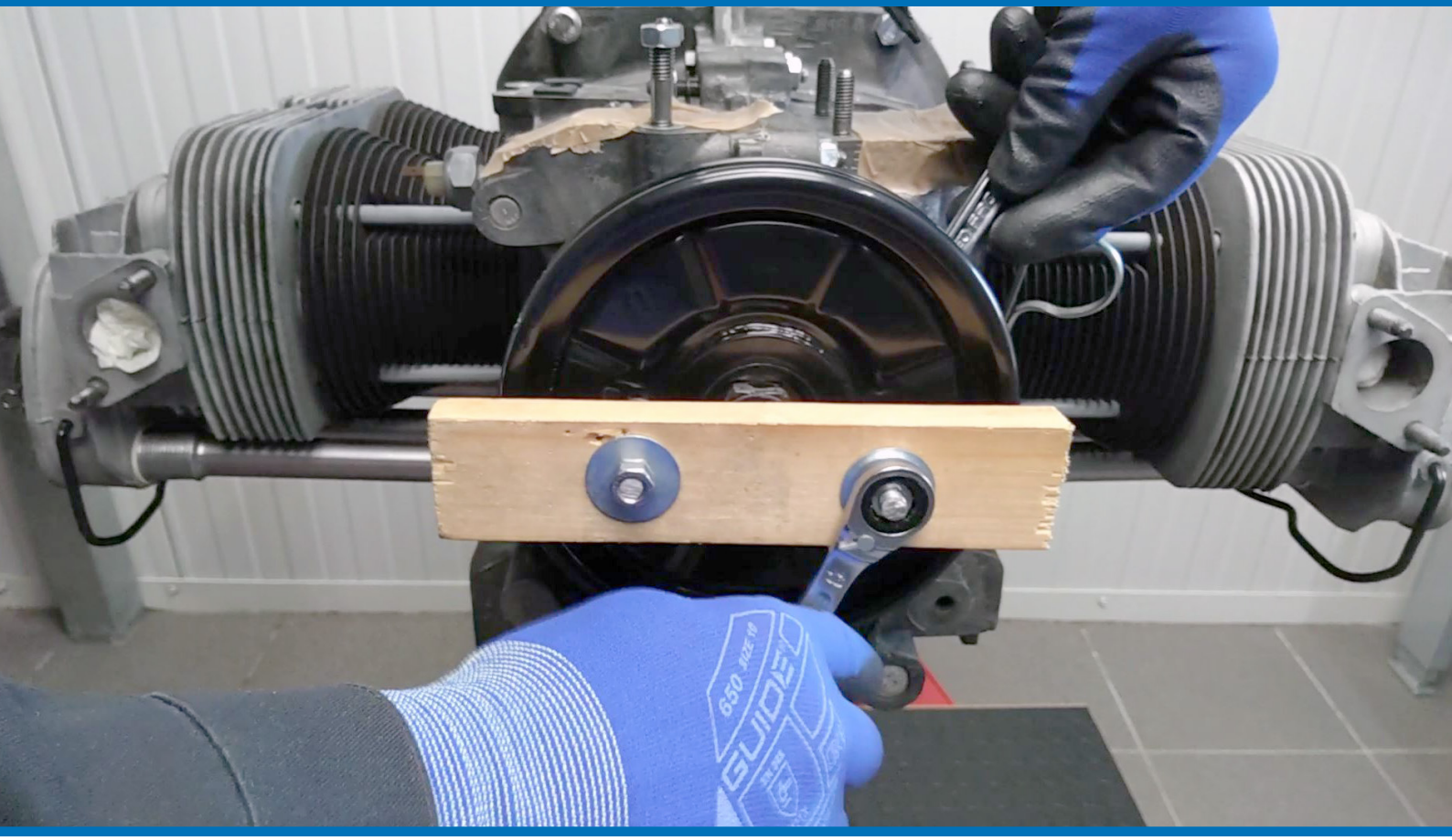
crankshaft pulley removal

Slide the threaded rods through the pulley holes and place two small washers with two nuts on the back, then slide the piece of wood over the threaded rods (photo below).
The crank nose is a suitable pressure point for our homemade pulley puller. To bridge the distance to the wooden bar, use the crankshaft pulley bolt, as we show in the photo right. You may use a piece of rubber between the bolt and the crankshaft nose to prevent damage.





#74 Engine



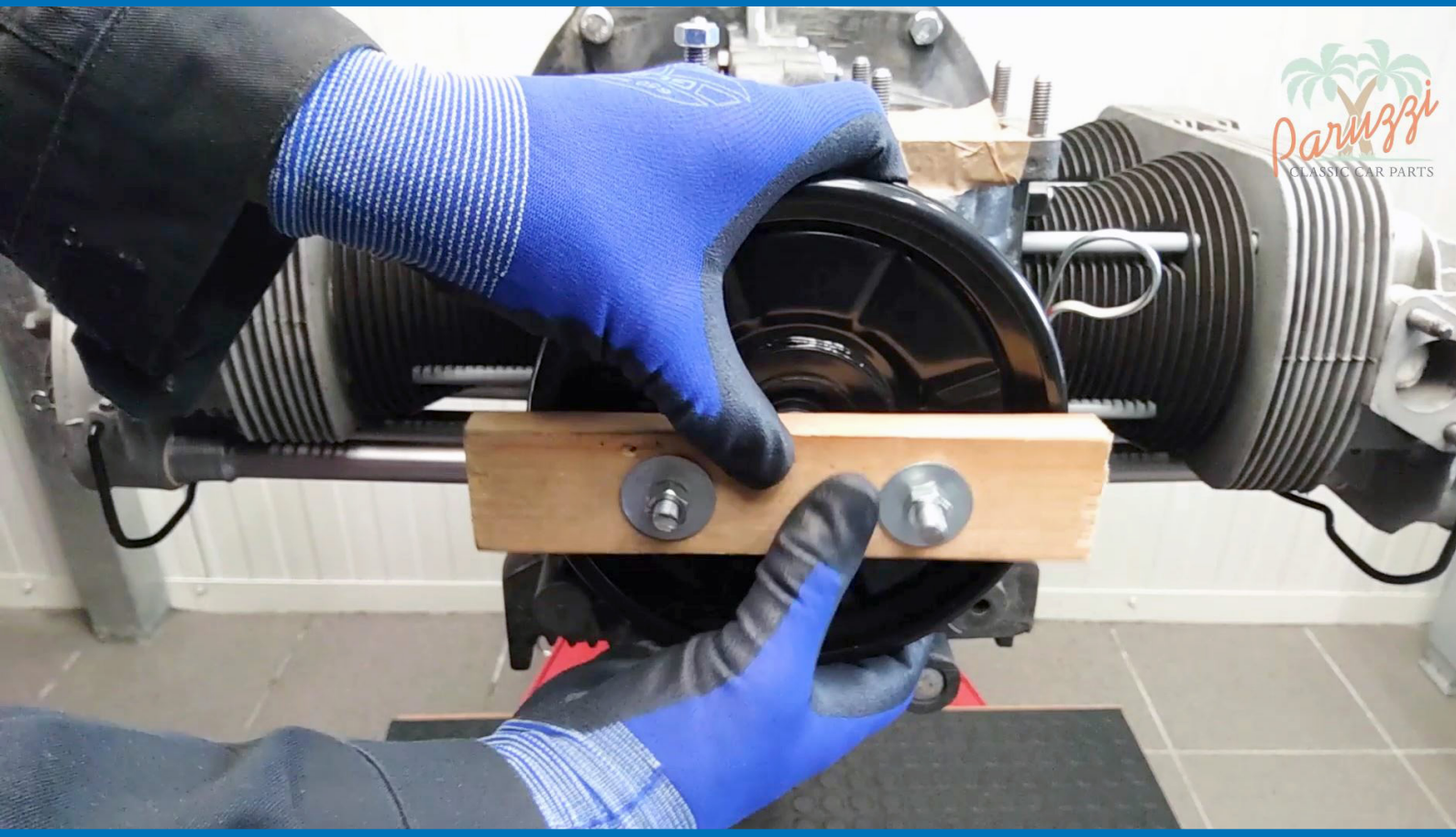
Place the two large washers in the front over the threaded rods, followed by the last two nuts. You need the large washers to prevent the wood from being compressed by the force on the nuts.

Manually tighten the nuts both at the back and front until the wood bar is parallel to the crankshaft pulley and properly pressed against the pulley bolt.

Now you can tighten the front nuts quarter turn by quarter turn, hold the rear nuts so that they do not turn.

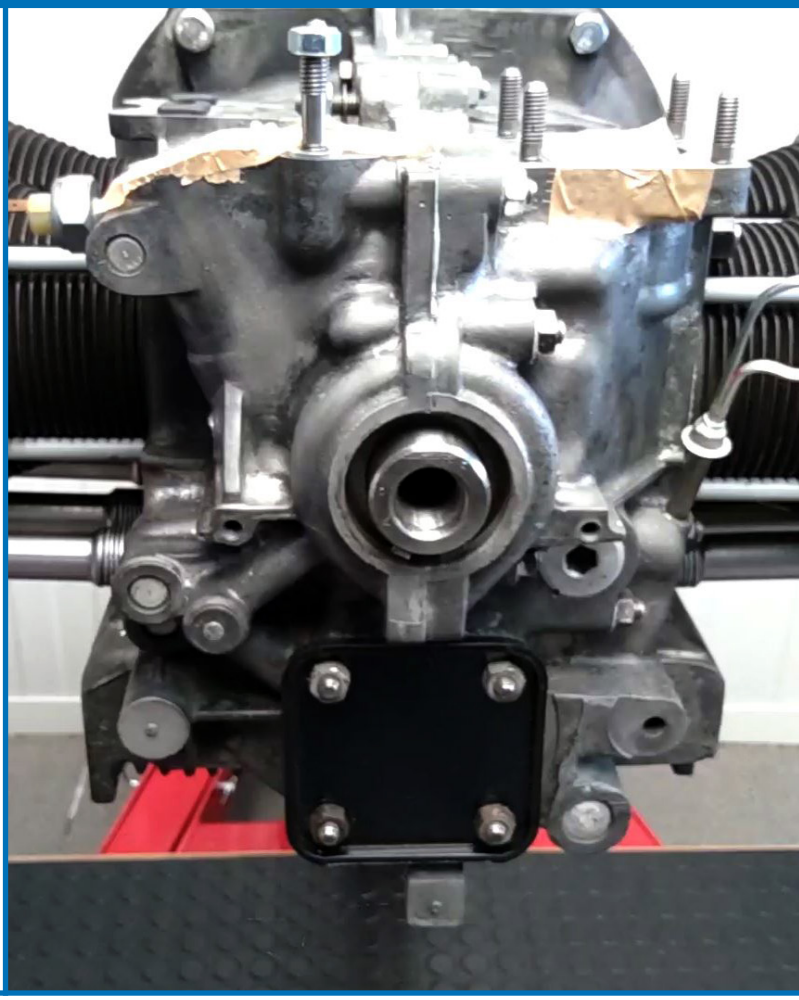
Tighten the right and left nuts alternately, you will slowly but surely see the crankshaft pulley move, forward. Patience is a good thing, especially in the workshop. If the crankshaft pulley is tight, use a rubber mallet and gently tap the back of the pulley.

crankshaft pulley removal



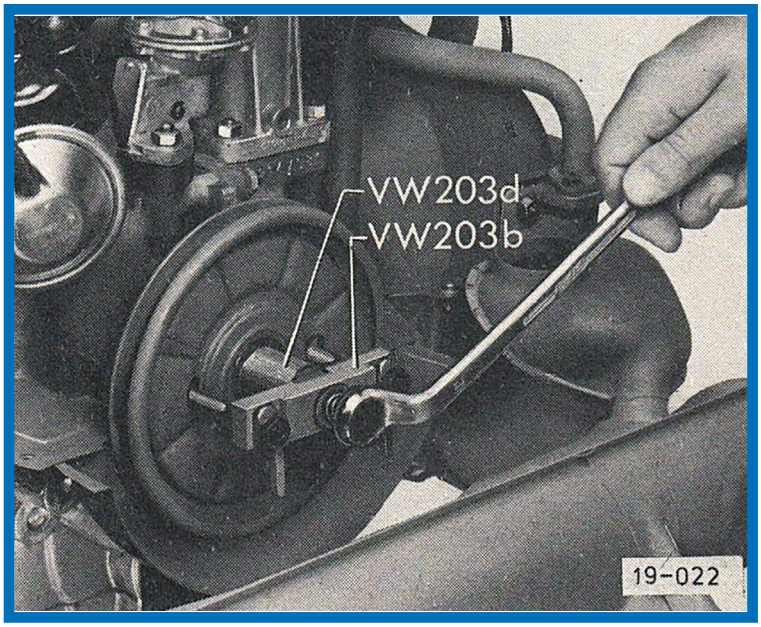
You'll see that the crankshaft pulley slides forward and at some point becomes loose enough that you can pull the pulley off with your homemade tool. Hold the crankshaft pulley bolt, it might fall to the ground. On the right you can see the crankshaft nose against which the pulley bolt pressed.

With this tool, you have a budget-friendly solution to pull off the crankshaft pulley without damaging it.



Pulley pullers

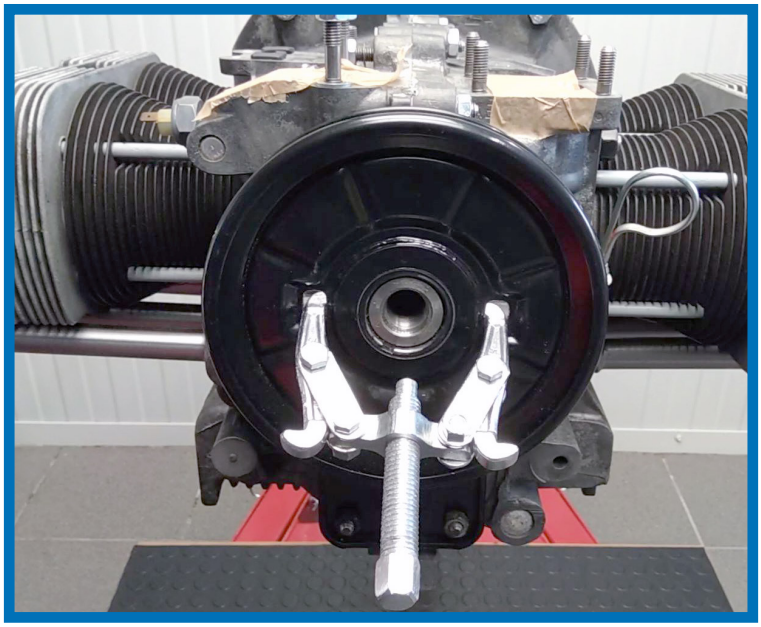
This VW pulley puller (pictured right: VW 203b and VW203d) can be used even when the engine is still in the car, just like our home-made tools.



Chances are slim that any VW enthusiast will have these in their workshop. But we mention it for completeness and because this pulley puller does it the right way. It pulls the pulley on the inside and pushes against the crankshaft nose, just like our homemade tool.

In the photo below we show a similar pulley puller that we use a lot in our workshop.

crankshaft pulley removal



Finally, you can use the EMPI crankshaft pulley puller (pictured below). This one has the advantage that it can be used even when the engine is in the car. But it presents some dangers if the user has little experience. Namely, it pulls on the outside of the pulley, and thus will quickly warp the pulley if you put too much force on it.

You can also use a standard pulley puller (pictured above), these are fairly inexpensive and will come in handy if you regularly work on cars.

For the Type 1 crankshaft pulley, we use a 75 mm pulley puller.

The disadvantage of this tool is that you can only use it when the engine is on a workbench or on an engine mount.

If you want to learn more about this topic, and see how each tool is used, check out video 10 in our YouTube Playlist on engine overhaul: www.paruzzi.com/youtube/en

#75 Front and rear axle

Introduction

Too little attention is often paid to the wheel geometry of our classic Volkswagen. Cars are lowered, both front and rear, which will affect the wheel geometry. If a car should only be able to drive straight ahead, at a constant speed, without ever having to brake or accelerate, then the wheel geometry would be simpler. But our cars must also be able to take sharp turns, drive on bad roads, and brake suddenly from 100 km/h to standstill.

For that, there are engineers in the car factories who study the position of the wheels and shock absorbers, to choose an ideal setup for the application.

If you need your classic to compete at the top of the "quarter mile" sprint, then the factory setup is disadvantageous because it also takes into account cornering.

Camber and King Pin

But if your classic Volkswagen will be used on public roads, the factory settings are usually ideal. In this article, and in subsequent editions, we will explain the basics of wheel geometry, as well as show how to adjust wheel geometry on our classics.

Photo left: wheel geometry ensures that even the sharpest turns can be taken in complete safety.

In addition to wheel axle and shock absorber settings, the choice of rims and tires also play a role in wheel geometry. We will discuss this in detail in a future edition of this series.
You could add edition 16 as a supplement to this article, in which we have already explained some of the principles of independent suspension.

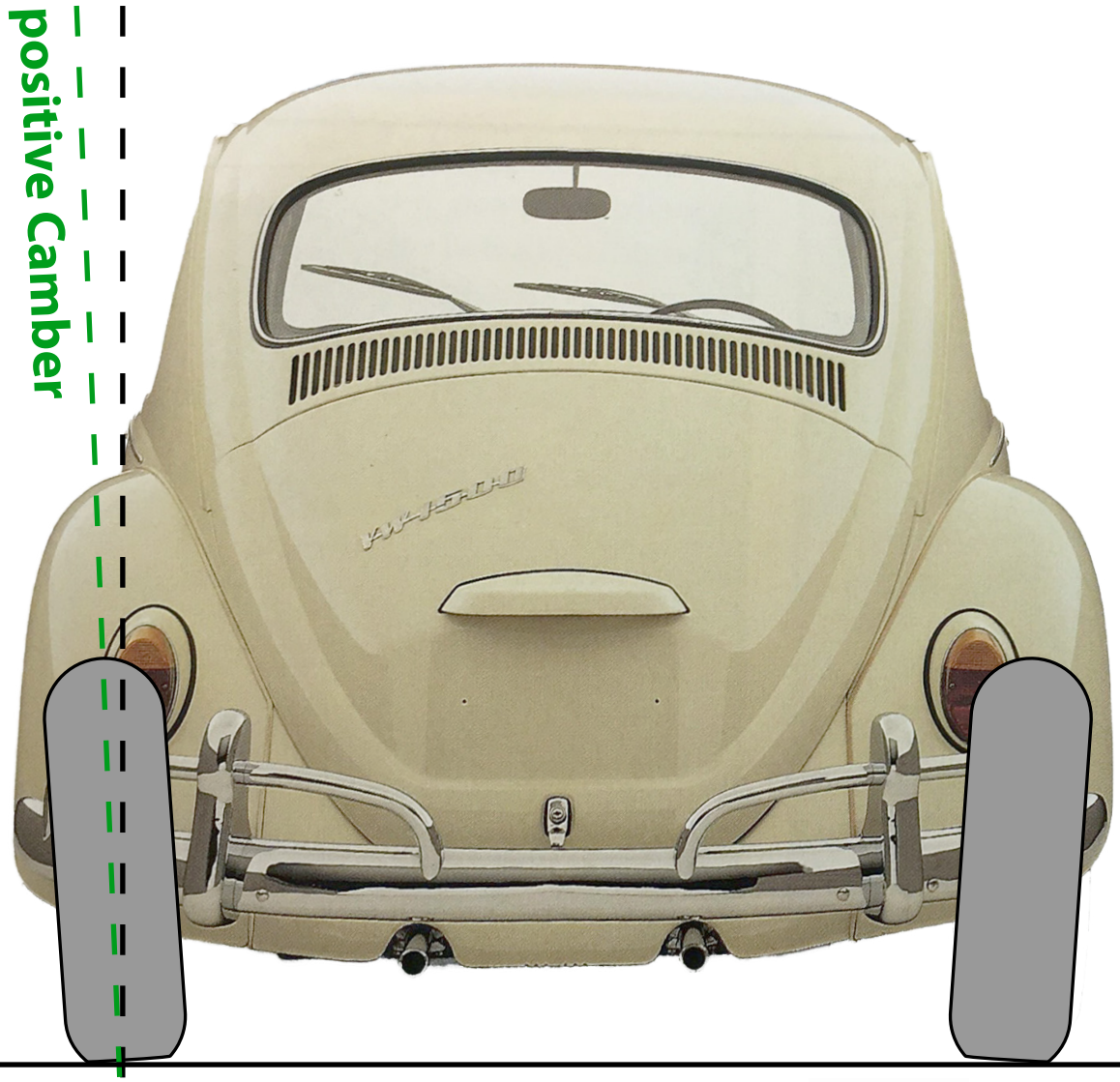
Photo below: an example of extreme rear Camber.

#75 Front and rear axle

Camber

The most visually striking of all wheel geometry settings, is wheel Camber. In this article, we will sometimes exaggerate wheel Camber to make it clearer for the reader.

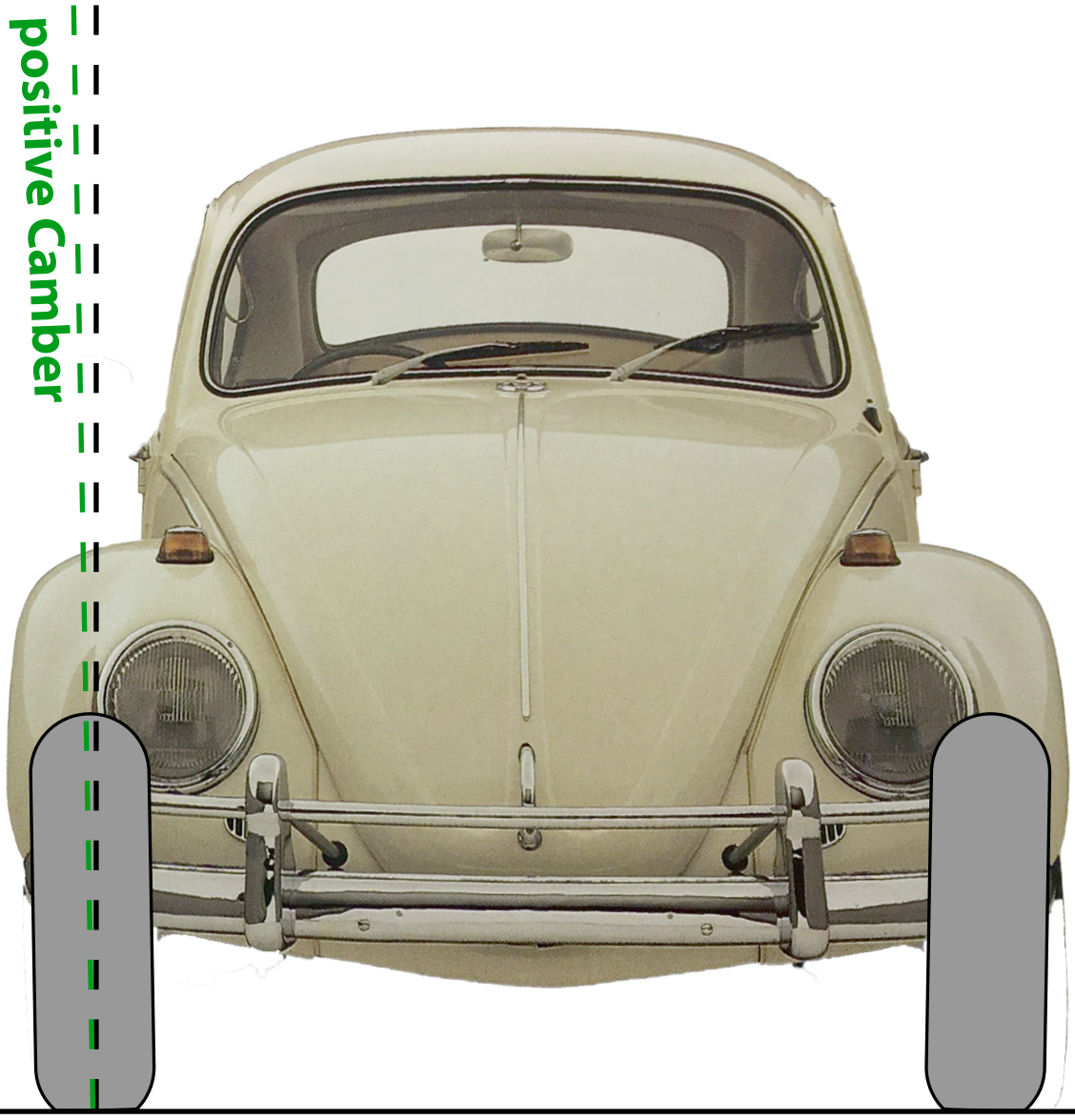
Below we show the rear end of a VW Beetle with swing axles. At rest and empty, the rear wheels will show positive Camber, the top of the rear wheel tilts outward.
The positive Camber is in the order of magnitude of 1° to 3°.



Camber and King Pin

At the front of a VW Beetle with the classic front axle setup with torsion leaves, positive Camber can also be observed. Although the number of degrees is much smaller than at the rear, less than 1°. The inclination at the front is not only caused by the Camber setting, but the King Pin Inclination also plays a role here (we will explain this later).

Camber is the tilt of the wheel relative to the road surface.



#75 Front and rear axle

Wheel Camber will change when the car moves up or down. This can be due to an irregularity in the road surface, more or less occupants, or cornering. You can clearly see this when driving behind a VW Beetle or Karmann Ghia going into a pit, especially with the older models with pendulum axles.

This is also very noticeable when you put the car on the garage lift. Less load will increase the positive wheel Camber (photo below), more load on the rear axle will decrease the positive wheel Camber. This ensures that the Camber is always optimal, both loaded and unloaded, in a straight line and when cornering.

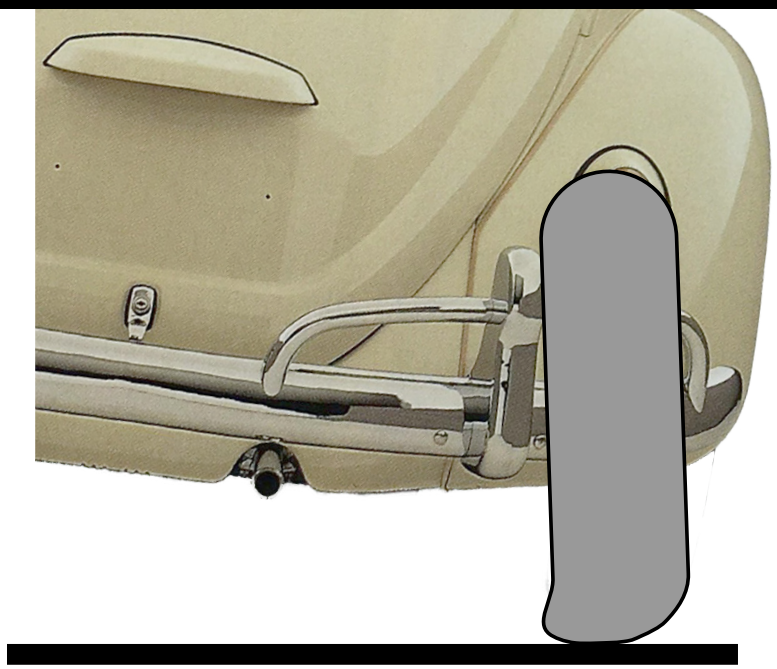
On the VW with swing axle, the positive Camber at the rear is relatively large. This arrangement can be used because the suspension clearance is quite large, and the Camber angle reduces when the rear end is pushed down by more weight (passengers or luggage) or by driving on bad roads.

Camber and King Pin

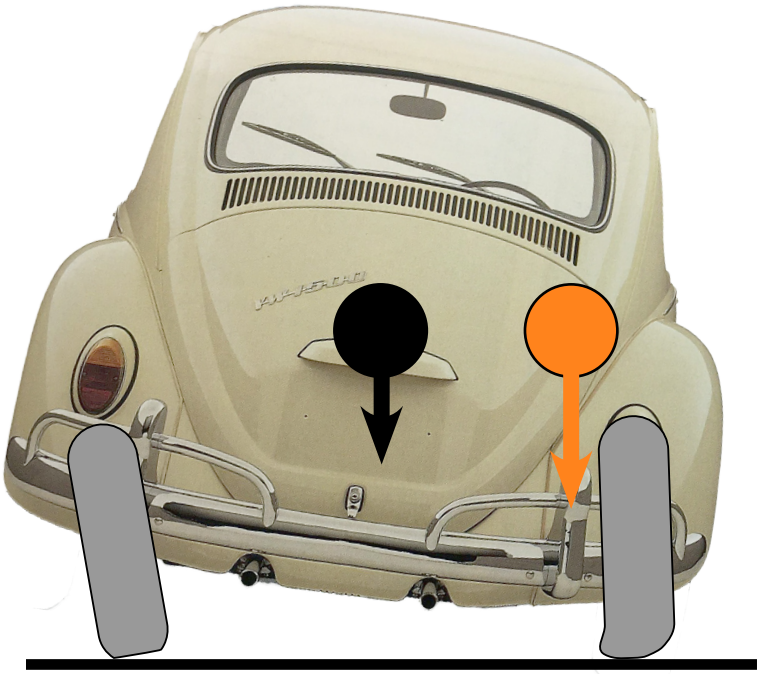
But why is wheel Camber necessary. Why can't you set the wheels all neatly perpendicular to the road surface?

When taking a right turn, for example, the car's center of gravity will shift from the center (black circle) to the right (orange circle), the body tilts in the turn (body roll). As a result, more force will be exerted on the right wheels, pushing the suspension down on the right, compressing and deforming the tires at the bottom. In the drawing above right, you can see how the right tire at the bottom takes on a different shape, so the contact surface with the road surface is not optimal.

By giving the wheel less positive Camber (to negative Camber) (drawing on the right), the contact surface with the road surface will increase, the available tire surface (contact patch) will be better utilized and provide more grip on the road.



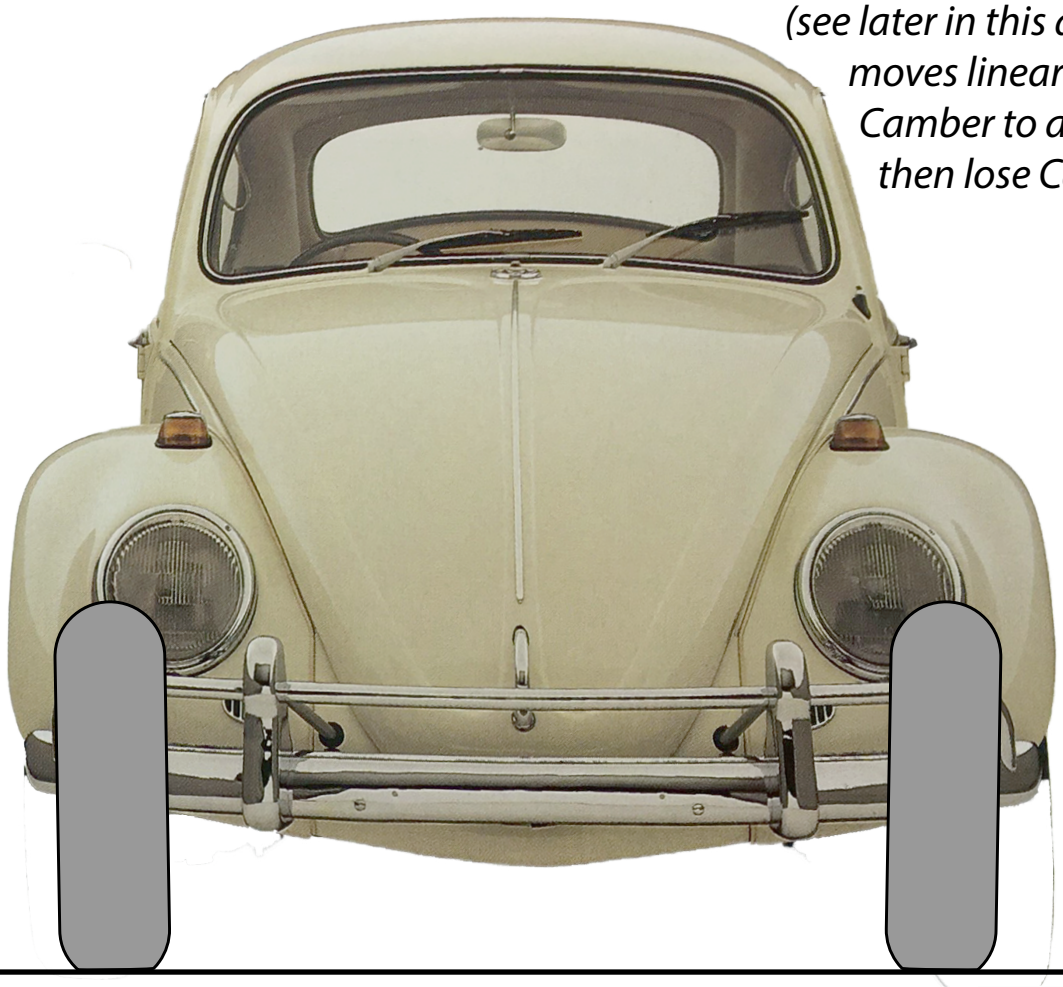
The left wheel will lean even more than at rest, and thus will make even less contact with the road surface. The forces on that wheel are much smaller than on the other side, extra positive Camber on the unloaded wheel is an acceptable compromise.



#75 Front and rear axle

Due to either negative or positive Camber, the contact of the tires with the road surface will never be optimal when driving straight. This is a compromise made, to ensure that the car has more grip in a corner, by compensating for the deformation of the bottom of the tires, by positioning the tires at an angle to the road surface. This compromise will promote tire wear, unfortunately.

If you should drive only straight ahead, as in the "quarter mile sprint," then 0° Camber is optimal from start to finish, because the maximum tire surface is used to transfer the power from the engine to the road surface. If the pressure at the bottom of the tires is equally distributed, then the temperature of the tires will be the same everywhere.



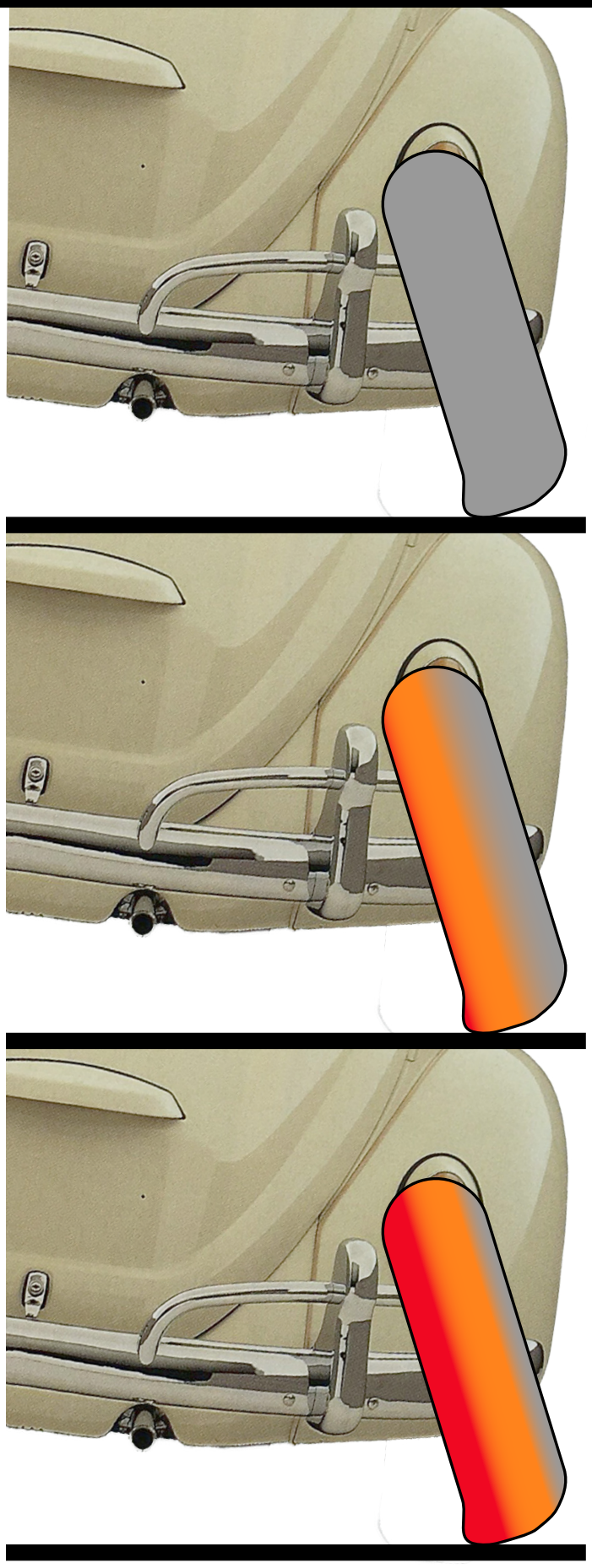
With the MacPherson front, Camber changes are minimal with body roll (see later in this article). The strut moves linearly, the tire will gain Camber to a certain extent and then lose Camber.

Camber and King Pin

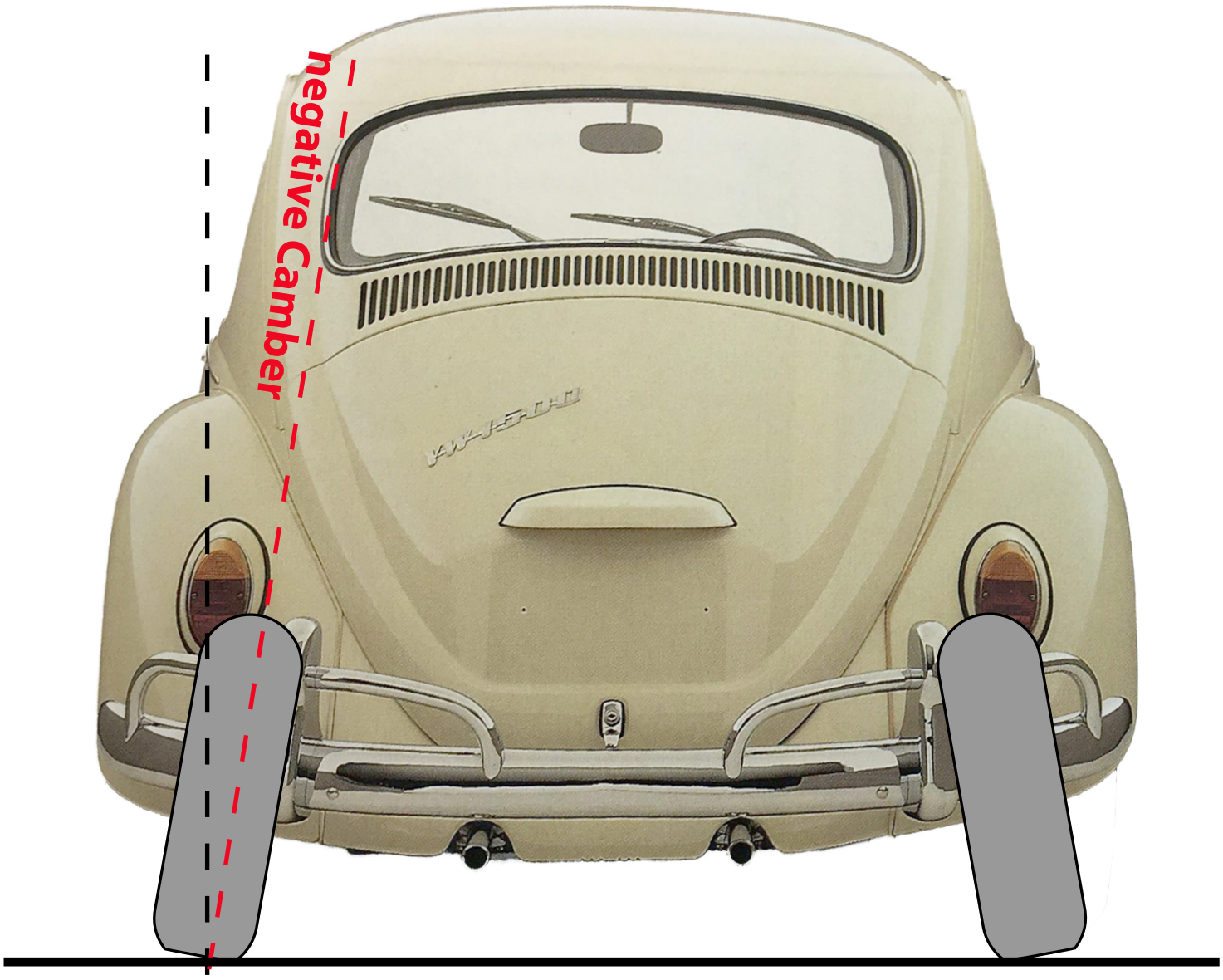
In the drawing on the right, we show extreme negative Camber. When cornering at high speed, the forces on the contact surface of the tire will be mainly on the inside of the tire. Due to the extreme forces on one side, the tire will get warmer on the inside than on the outside, as illustrated in the drawings on the right.

This is not desirable, as overheating on one side will cause the tires to deform, weaken and eventually rupture or blow.

By studying Camber, it also becomes all the more clear that correct tire pressure is crucial to handling, and tire wear. Too hard tires will deform less but also reduce the contact area with the road surface, too soft tires will increase the contact area, but the tires will deform more.



#75 Front and rear axle



With negative Camber, the wheels will be closer together at the top. When lowering the car, the Camber will become less positive to extremely negative.

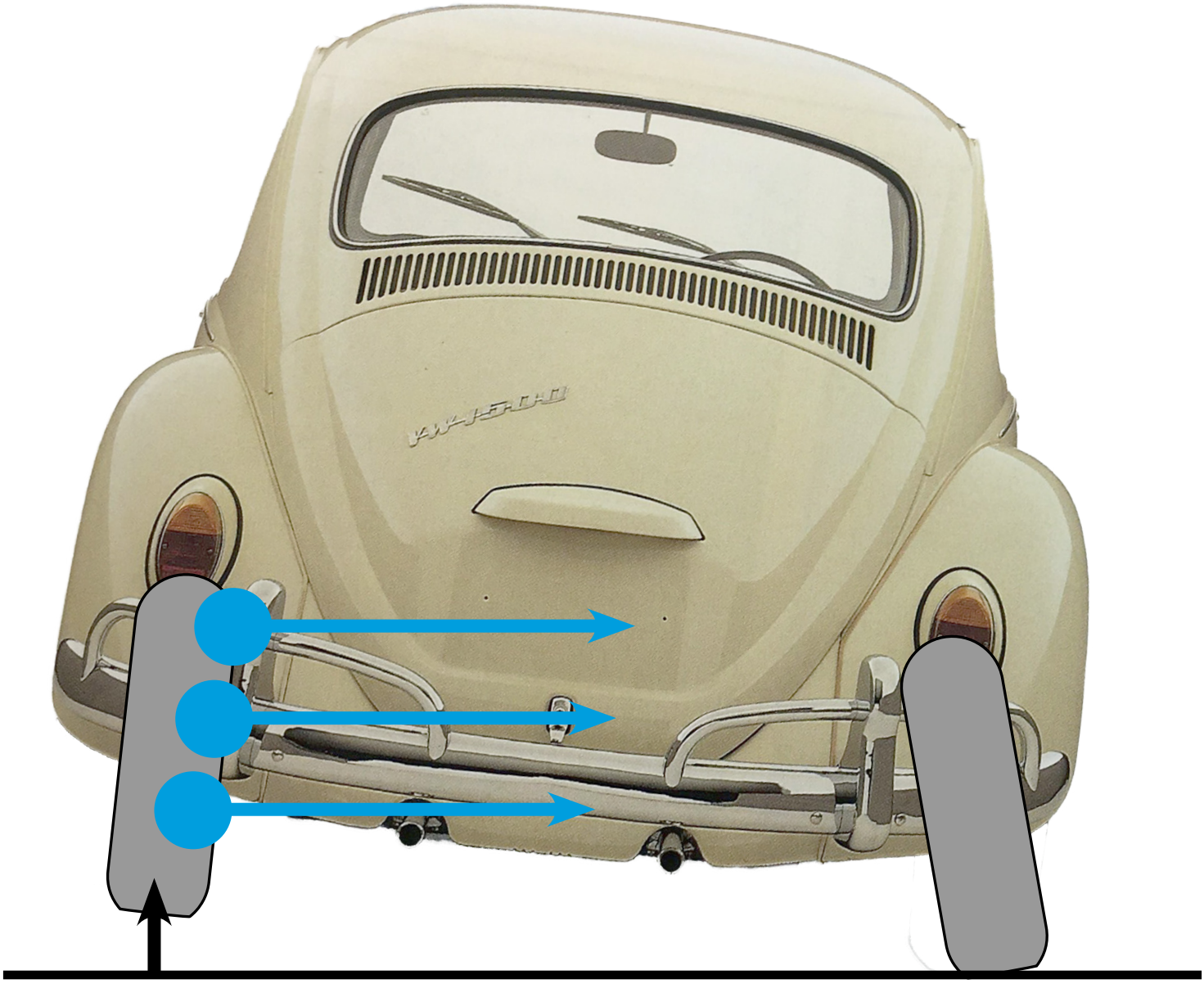
This is done mainly for aesthetic reasons, handling and comfort will not always improve.

A particular disadvantage of negative Camber is Camber-thrust on the wheels. Due to the position of the tires on the road surface, the tires will deform, creating a pressure on the tires that will push the wheels towards the center.

Camber and King Pin

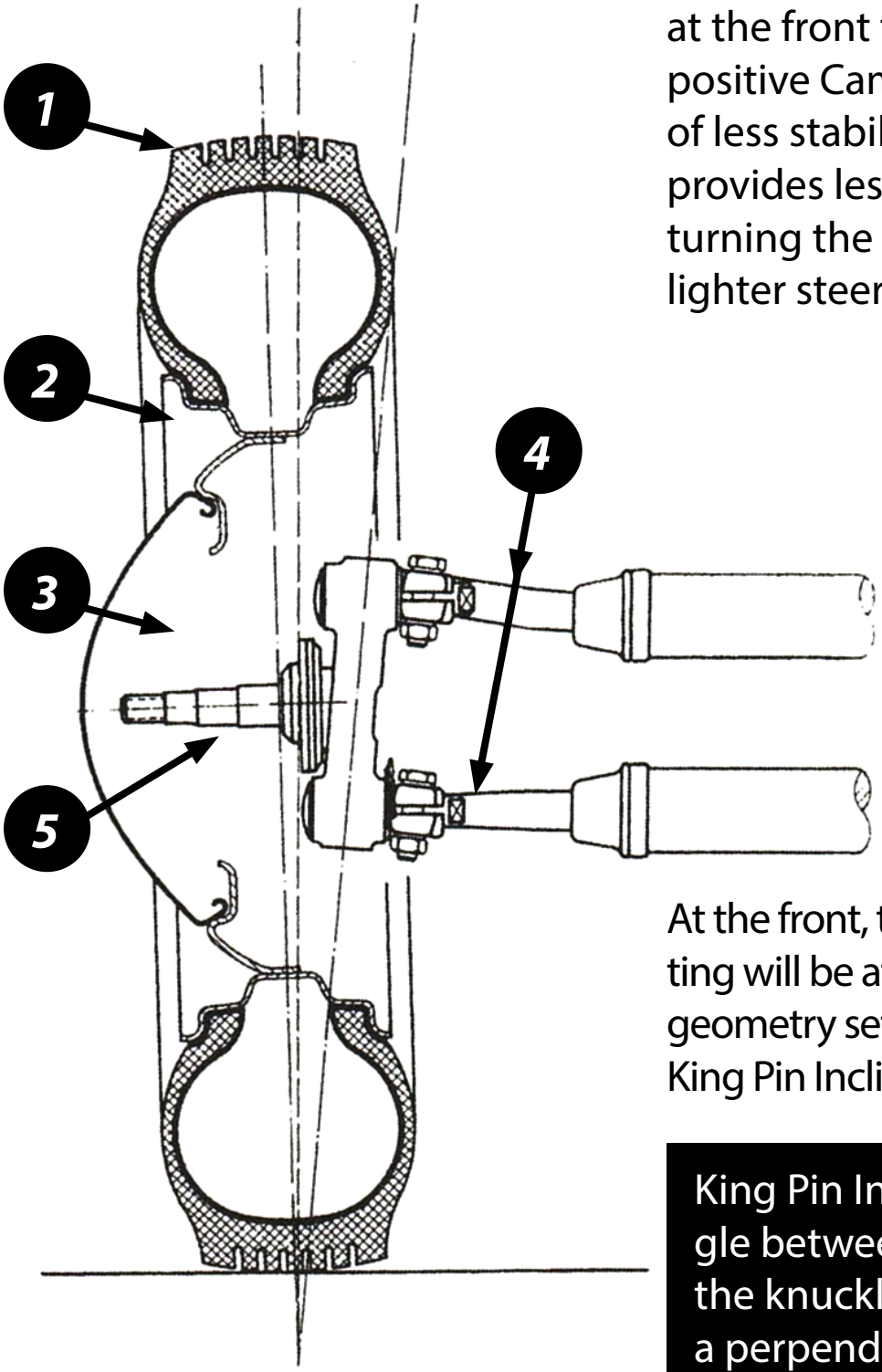
It offers the car more stability, but if one wheel loses grip, the car will be pushed to one side (blue arrow below). That lateral force will feel like a solid thump, as if your car was pushed away by invisible forces, like in strong crosswinds.

We don't have to tell you that this can lead to very dangerous situations. The average road car does not have negative Camber, because of the difficult to control Camber-thrust effect. Negative Camber will also cause faster tire wear. In a future edition, we will explain how Camber is set.



#75 Front and rear axle

King Pin inclination



1. tire
2. rim/wheel
3. hubcap
4. torsion arms
5. steering knuckle

Camber is as important, or even more important, at the front as it is at the rear. This is because at the front the wheels can turn, positive Camber is the cause of less stability in turns, but it provides less resistance when turning the steering wheel, i.e. a lighter steering wheel.

At the front, the wheel Camber setting will be affected by other wheel geometry settings, particularly King Pin Inclination and Caster.

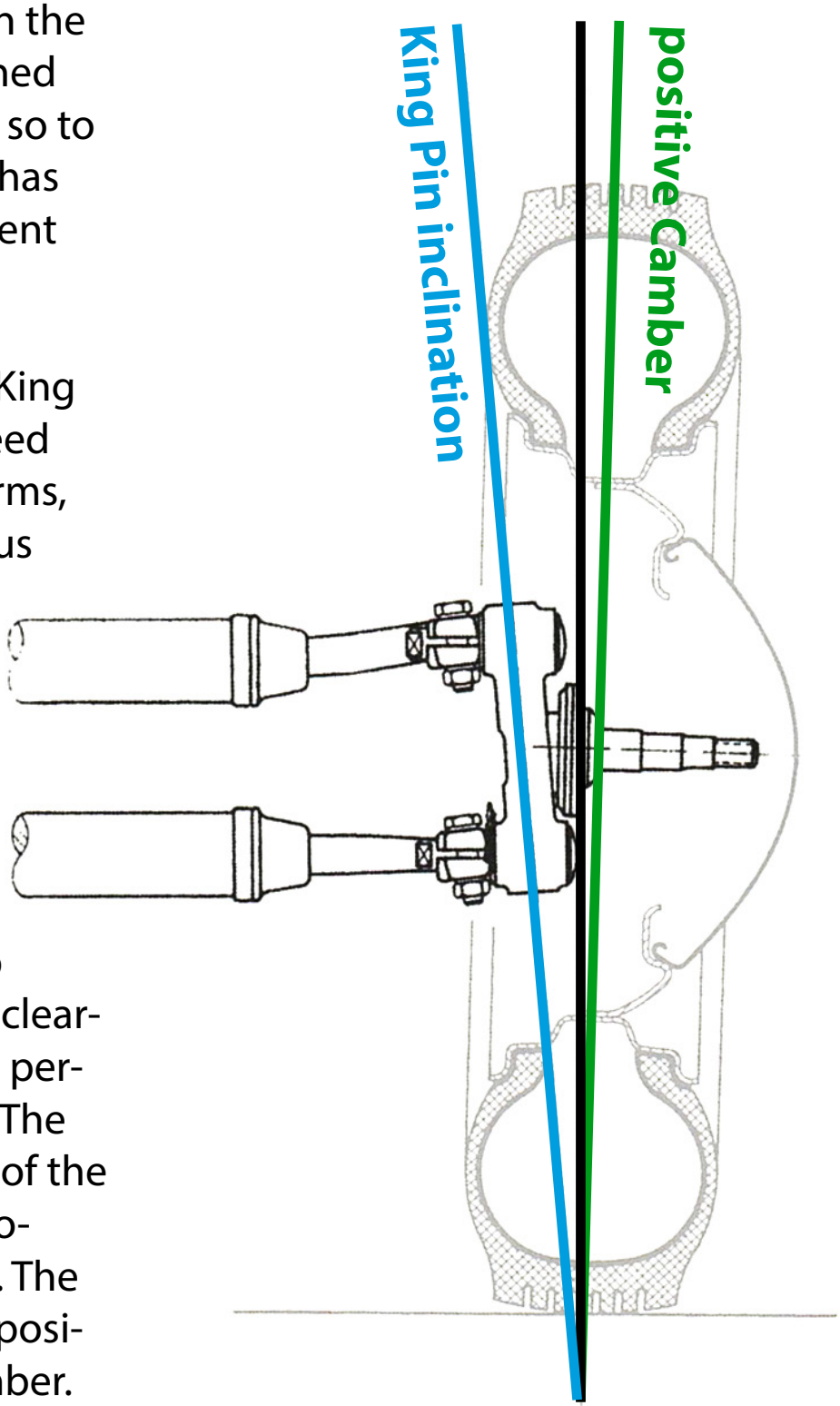
King Pin Inclination is the angle between the line through the knuckle pivot points and a perpendicular line on the road surface.

Camber and King Pin

The King Pin designation dates back to the beginning of the automotive industry, when the front wheel was still attached with one pin, a master pin so to speak. The name King Pin has persisted as the arrangement changed.

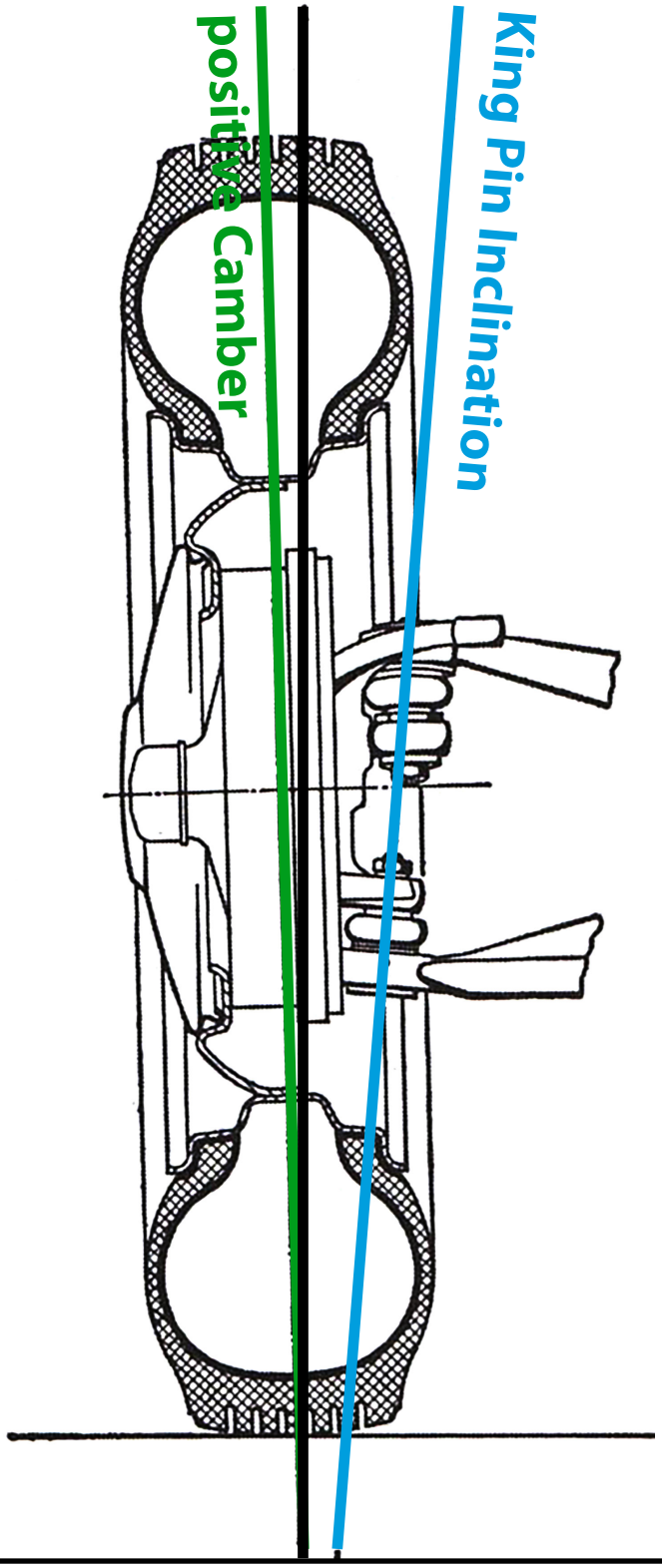
To explain the concept of King Pin inclination (KPI), we need a drawing of the torsion arms, with King Pins. The previous page shows a front suspension of a VW Beetle with stub axle (until July 1965).

In the drawing on the right, we have isolated the torsion arms with stub axle, to show things more clearly. The black vertical line is perpendicular to the ground. The blue line is the inclination of the stub axle pins, this is the so-called King Pin Inclination. The green line is the resulting positive Camber or wheel Camber.



#75 Front and rear axle

On the VW Beetle after 1965, the King Pins disappeared, to be replaced by ball joints (drawing below).



Here the blue line is drawn through the steering ball joints and is referred to as "Steering Axis Inclination" or "SAI." SAI and KPI are actually two different names to represent the same thing.

In a future edition, we will explain how the wheel geometry of the classic Volkswagen is set. What we can already say here is that King Pin or Steering Axis Inclination is a fixed feature on our old VWs. It is determined by the torsion arms and King Pins or ball joints.

Due to wear of the balls or pins, due to deformation from shock, for example a collision, setting of the KPI or SAI can change. A deviation of the inclination will affect wheel Camber and handling.

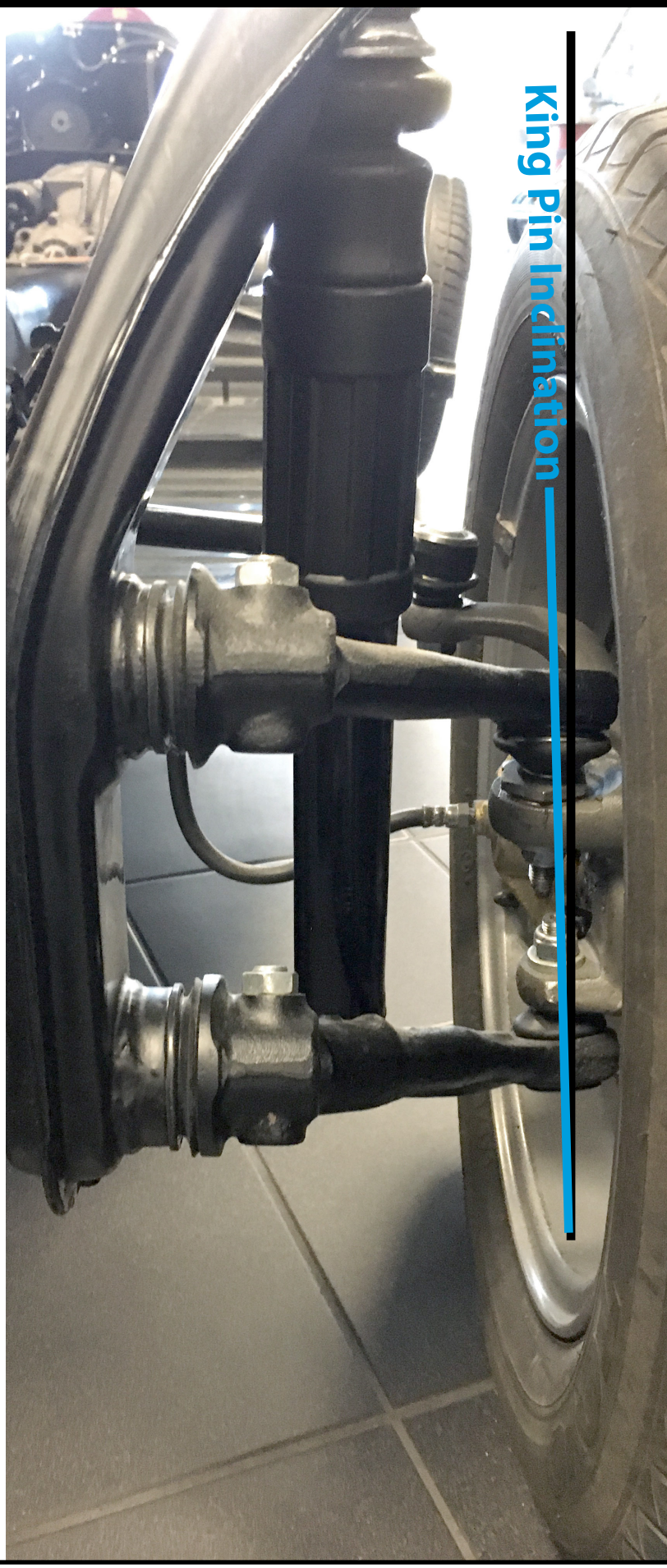
Camber and King Pin

In the front of the car, KPI causes a change in Camber angle when the wheels turn to take a corner. The change in Camber angle is detrimental due to KPI, which is why Caster angle is introduced (see later in this article) to compensate for it.

You can see the effect of KPI when you turn the wheels when the car is stationary, and see the front of the car go up and down. That is the effect of KPI or SAI.

The car's own weight forces the wheels back into the straight-ahead position. The Caster angle also plays an important role in this. The bumps from the road surface are also transmitted less forcefully to the steering wheel as a result.

The car is lifted when turning in, which of course requires extra power, or heavier steering. Fortunately, in our air-cooled VW, most of the weight is at the rear.



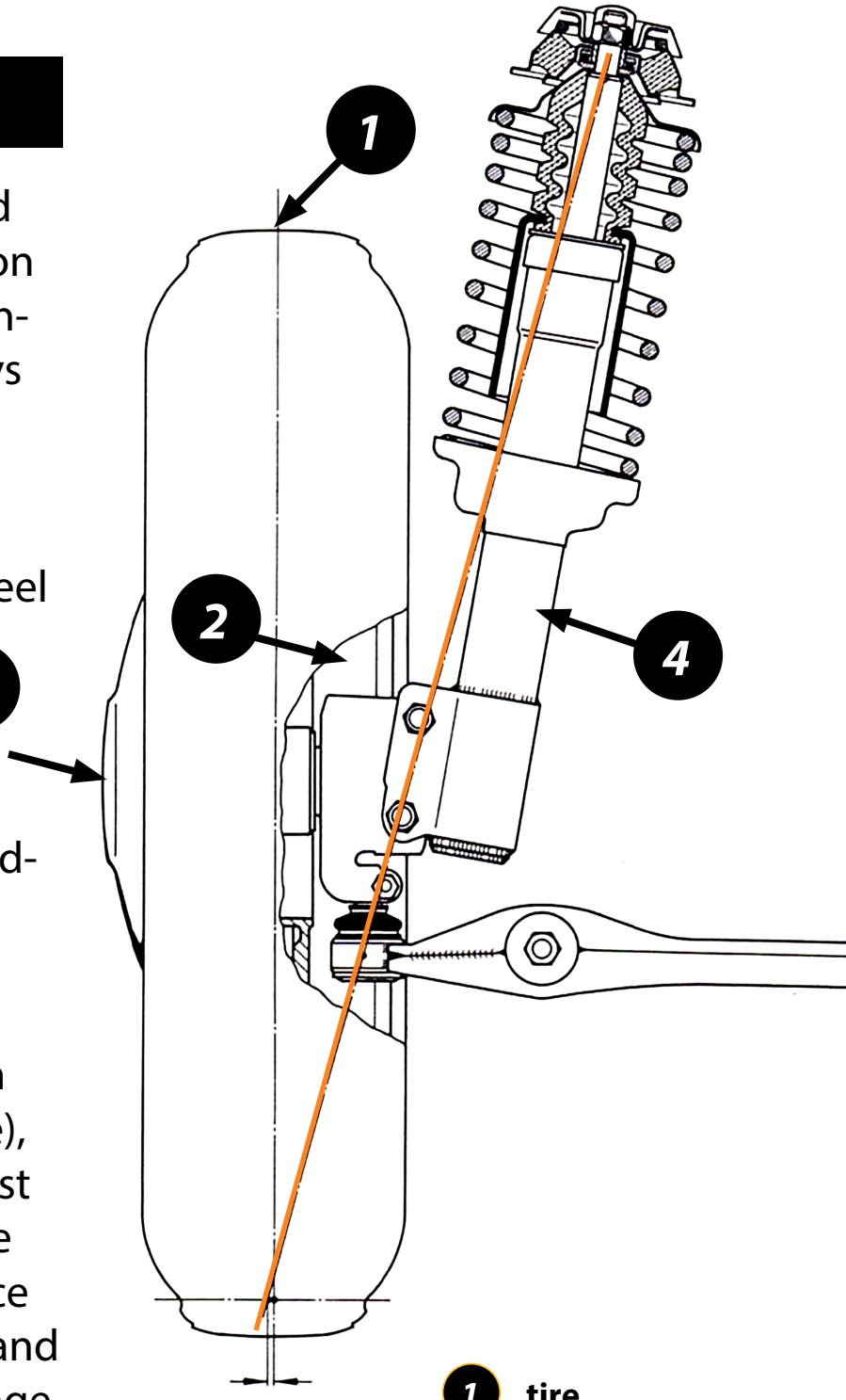
#75 Front and rear axle

Scrub Radius

The Scrub Radius is influenced by both the King Pin Inclination (KPI or SAI) and the Camber angle. Wheel geometry also plays an important role here.

Fitting a wider wheel, with a modified ET value, or/and wheel spacers, will affect the Scrub Radius.

We show this on the drawing to the right, using a second-generation MacPherson front suspension fitted to the VW 1303 from 1974. If we draw a line in the extension on which the wheel rotates (orange line), we end up at a point that is just beyond the perpendicular line of the wheel itself. The distance (a) between the center point and the tangent point of that orange line is the Scrub Radius.

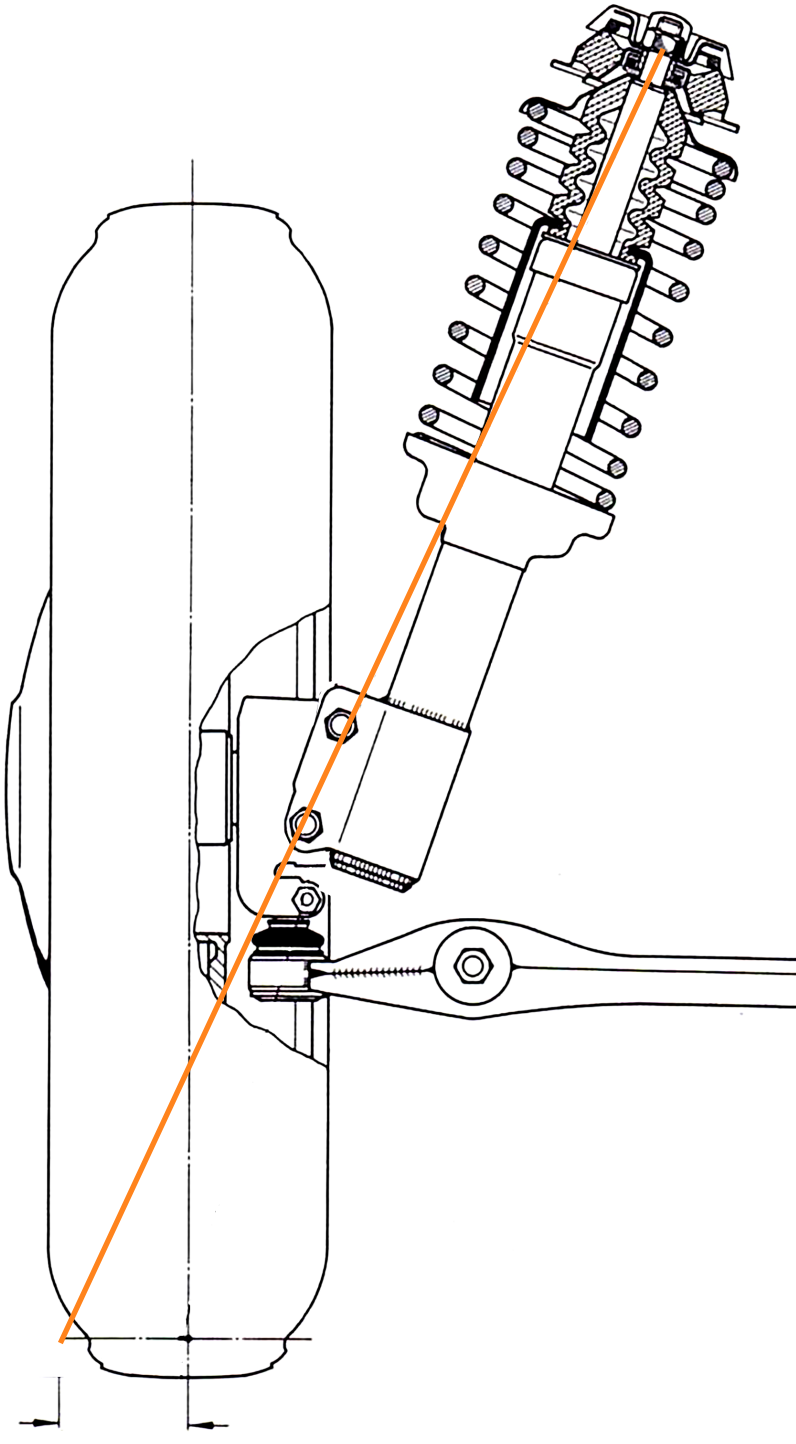


1 tire
2 rim/wheel
3 hubcap
4 MacPherson

Camber and King Pin

A small negative Scrub Radius, is typical of a MacPherson suspension. A positive Scrub Radius is used with a double suspension arm setup, such as the VW's with leaf springs up front. With any type of front suspension, a small positive or negative Scrub Radius is desired. Too large a Scrub Radius is never desired, for a variety of reasons.

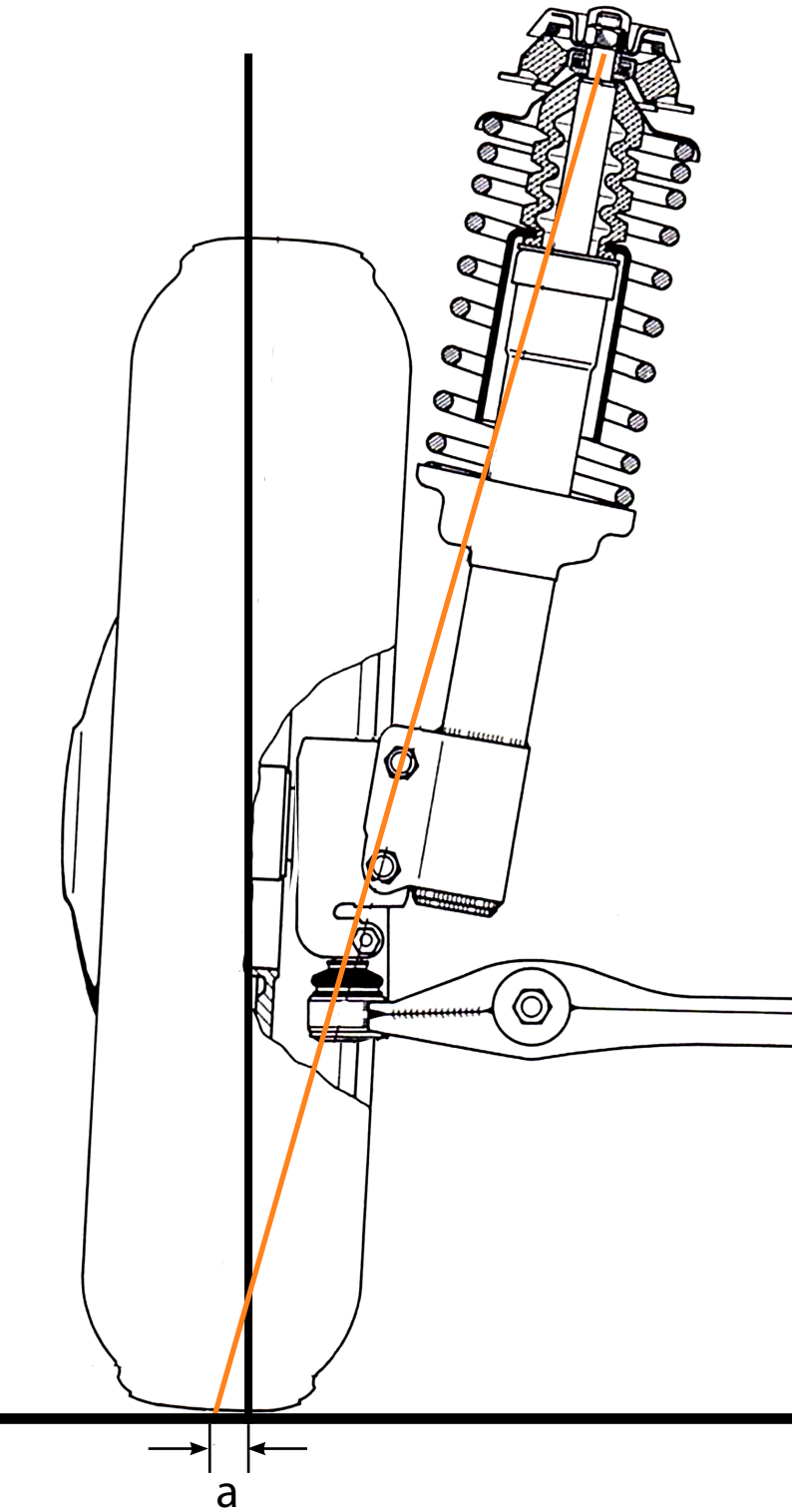
Imagine we have the setup as shown in the drawing on the right. Due to a hard blow, or incorrect mounting, the KPI or SAI is too large. This results in the orange line shifting to the outside of the tire. When turning the wheels, the tire will want to rotate around the orange line on the road. The tire will rub on the road surface instead of rotating freely. With wide tires, you can even hear the friction.



By changing the King Pin angle, the rotation point of the wheel will change. Extreme forces in the suspension parts can occur when the Scrub Radius is too large.

#75 Front and rear axle

A larger Scrub Radius will make steering heavier. The result is that more forces are applied to the tires and to the suspension components, such as the torsion arms and the steering ball joints or King Pins. The heavy steering is dominant mainly at low speeds. Once the car is up to speed, the influence of the Scrub Radius largely disappears, and another setting takes over, namely Caster. Too large a Scrub Radius will also exert excessive forces on the mechanical parts of your chassis during acceleration, braking and turning.



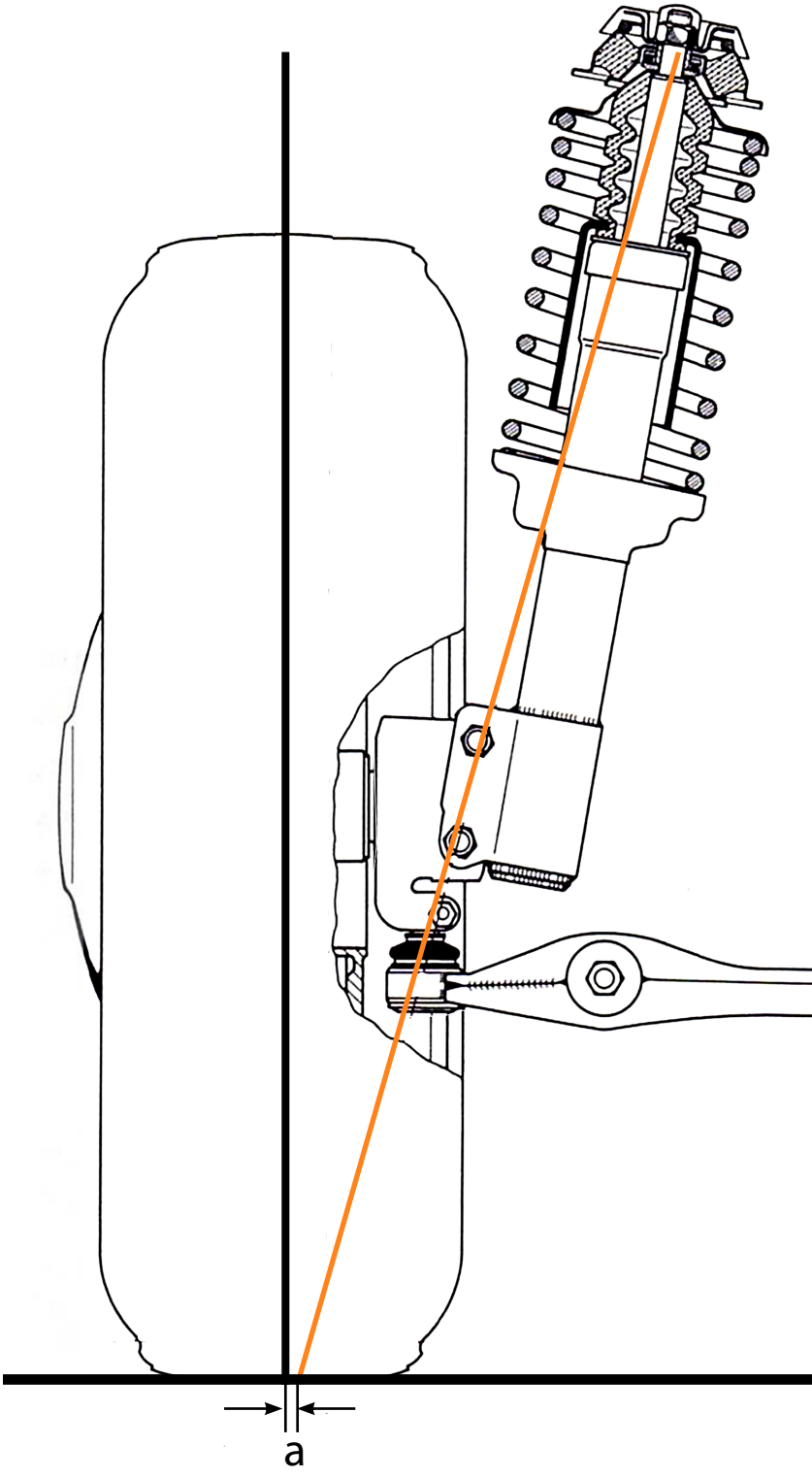
The Scrub Radius is also affected by the Camber angle. We show this in the drawing on the left. We have given the wheel some more negative Camber while the MacPherson is adjusted correctly. In this case, the Scrub Radius is negative, but the value is too large versus factory specifications. This setup will put greater forces on the components, and make steering heavy.

Camber and King Pin

Adjusting the rims and/or tires, can also have a big impact on the Scrub Radius. In the drawing to the right, we show wider tires with wider rims than factory standard. Because wider rims usually also have a different ET value than factory standard, the center of the rim, in this case shifts outward, thus changing the Scrub Radius. The orange line shows that we now have a positive Scrub Radius, when we should have a negative value.

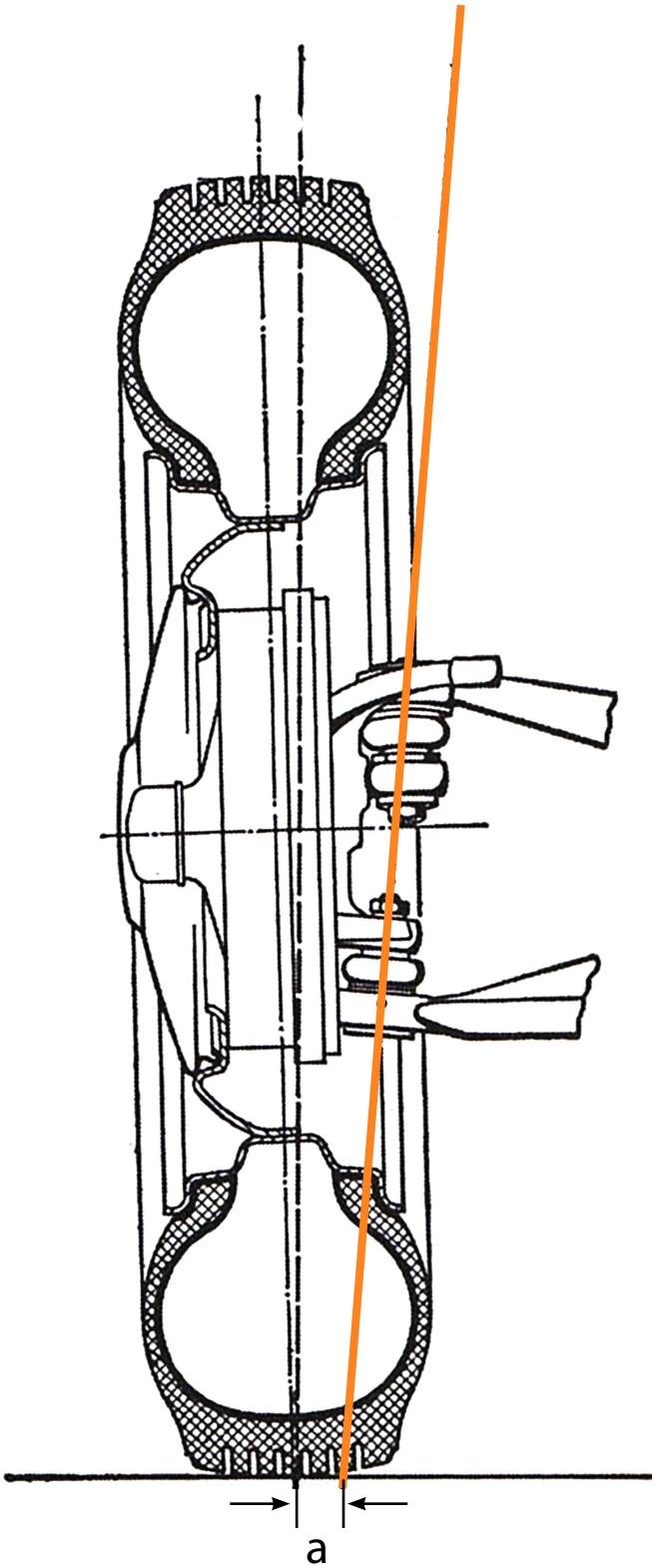
In modern cars, you will feel the effects of the Scrub Radius less, because the strong power steering takes over heavy steering from the driver. The excessive forces on the components do remain present with an incorrectly adjusted Scrub Radius and will cause both tires and suspension components to give up faster.

After replacing the narrow tires with wide tires, steering sometimes feels very heavy without power steering. The reason can be found in the larger Scrub Radius.



#75 Front and rear axle

Below we show the older front suspension type, with double torsion arms and ball joints.



The orange line shows the SAI (or KPI) angle. The distance between the center of the tire and this line is the Scrub Radius (a). In this case, a small positive Scrub Radius as prescribed by the workshop manual.

To be continued

We have discussed Camber and King Pin in this article, and the Scrub Radius as a logical consequence. In the next edition, we will explain Caster and Toe.

With this basic knowledge, we will explain how each setting is performed on a classic VW in further editions of this Magazine. We will concentrate mainly on the factory settings of our classics.

With this information you can drive to the tire center to correctly adjust your newly restored classic, or to detect symptoms of poor handling.

Camber and King Pin

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