Paruzzi Magazine

Technical Publication for the classic Volkswagen

19


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CLASSIC CAR PARTS


GO FG 984H

#55 Front axle

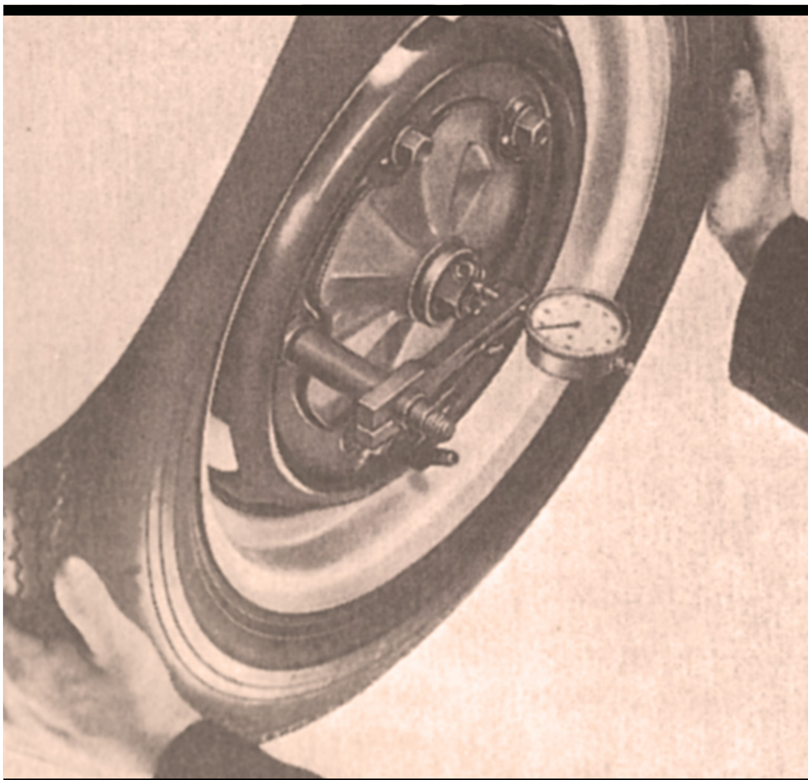
Introduction

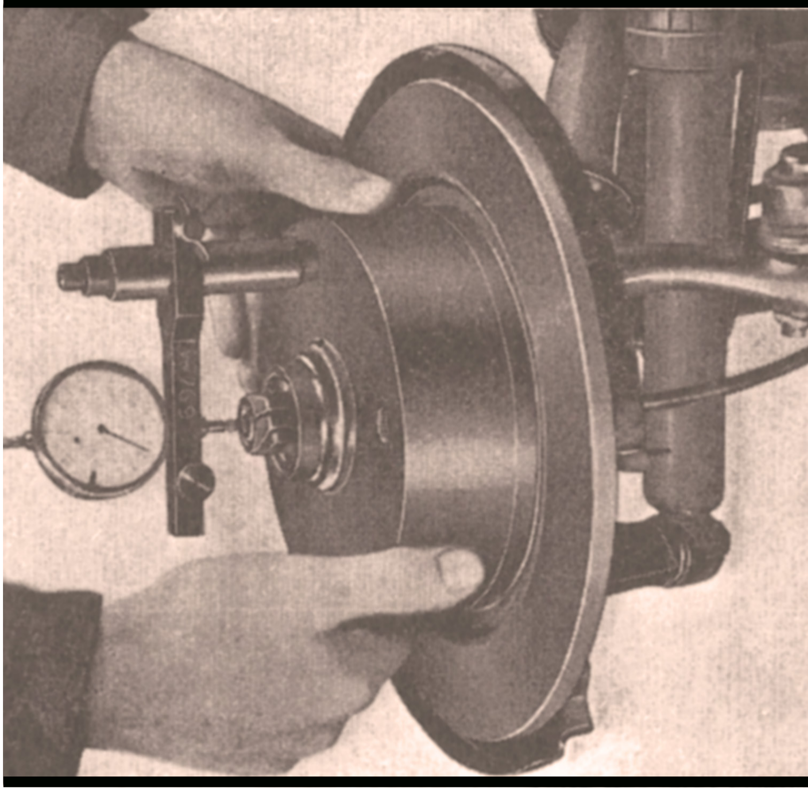
In edition 18 we explained why the wheel play of the front wheel axles needs to be accurately adjusted. We did that by feeling the play and using are years of experience. We are of course lucky to have an experienced VW mechanic in our team who could help us feel the correct wheel play. He confirmed during a coffee break that in the past the wheel play was always adjusted to the feeling.

But what if you have never done this before, when do you know if there is too much or too little play (pre-load) on the wheel bearings. You only know that when you have adjusted the wheel play several times together with an experienced colleague. If you don't trust your gut feeling, or if you want to measure everything accurately, then adjusting the wheel play with a dial gauge is something you will appreciate.

measure play with dial gauge

The adjustment of the wheel bearings pre-load with a gauge is only mentioned in the workshop manuals from 1966 onwards. On the right we show a picture from a 1966-1969 manual which shows how to adjust the wheel play on a VW with a drum brake. Bottom right a picture of the adjustment with disc brake from the 1970-1979 workshop manual.

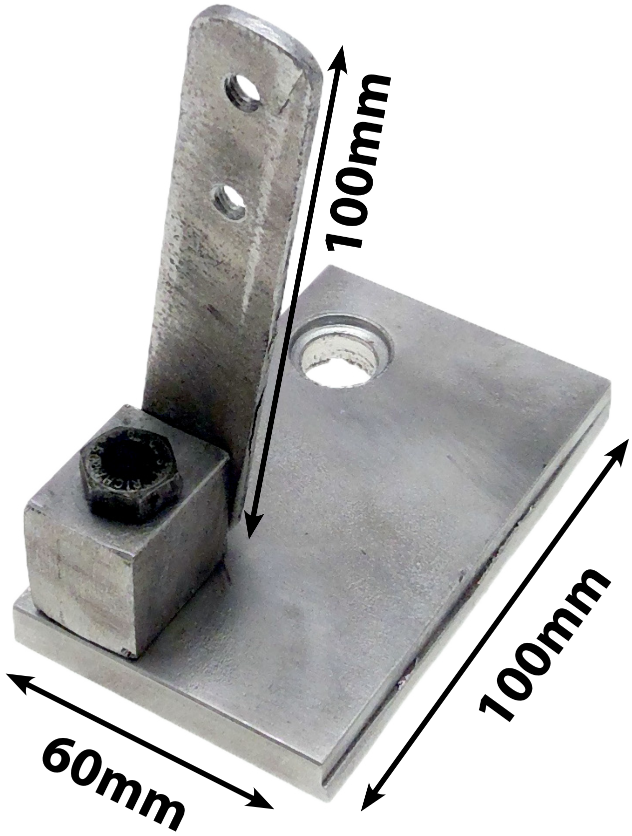




Therefore, the mechanics from the fifties and sixties will probably not be familiar with this method of adjustment. After decades of experience in adjusting to their feelings, the introduction of the dial gauge was probably not for them. But VW recommended it on all models from the mid-sixties onwards. With disc brakes, accurate adjustment of the wheel play is even more important (refer to edition 18 page 5).

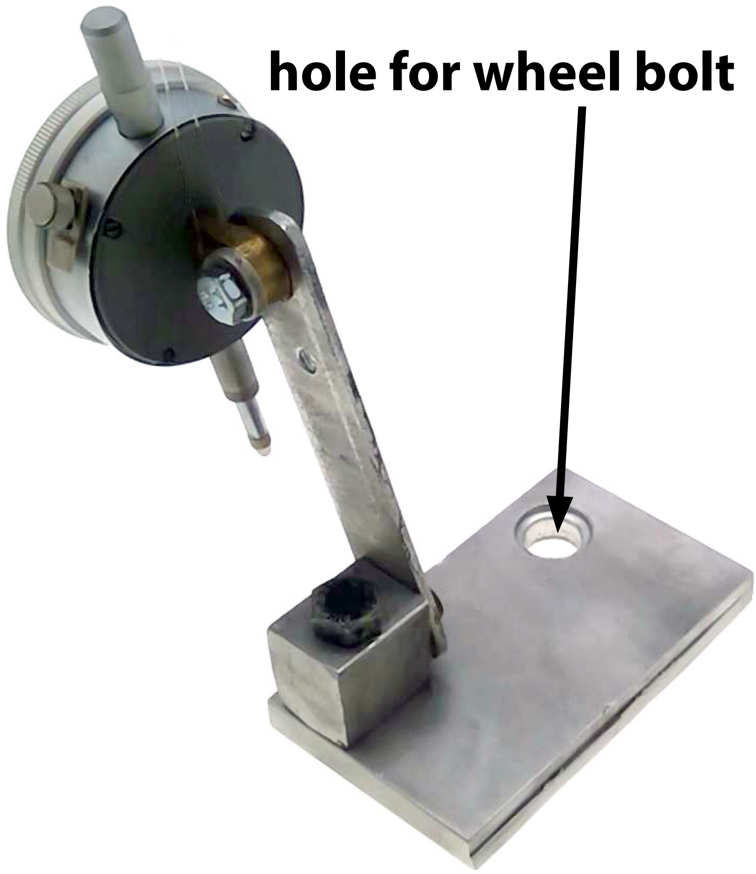
#55 Front axle

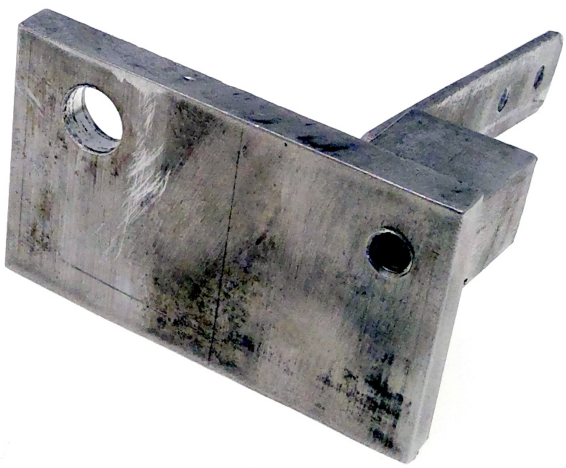
With special stand



Anyone who's a bit involved in car technology will have one of these gauges in a drawer. If you're not sure how such a measuring device works, read the article on page 20 and further of this edition.

There are several ways to attach a dial indicator, we have explained this on pages 28 and 29. With a magnetic stand it's always a bit of a search to find the right position, that's why my colleague made a special stand identical to the one shown in the VW workshop manual (see pictures page 5).

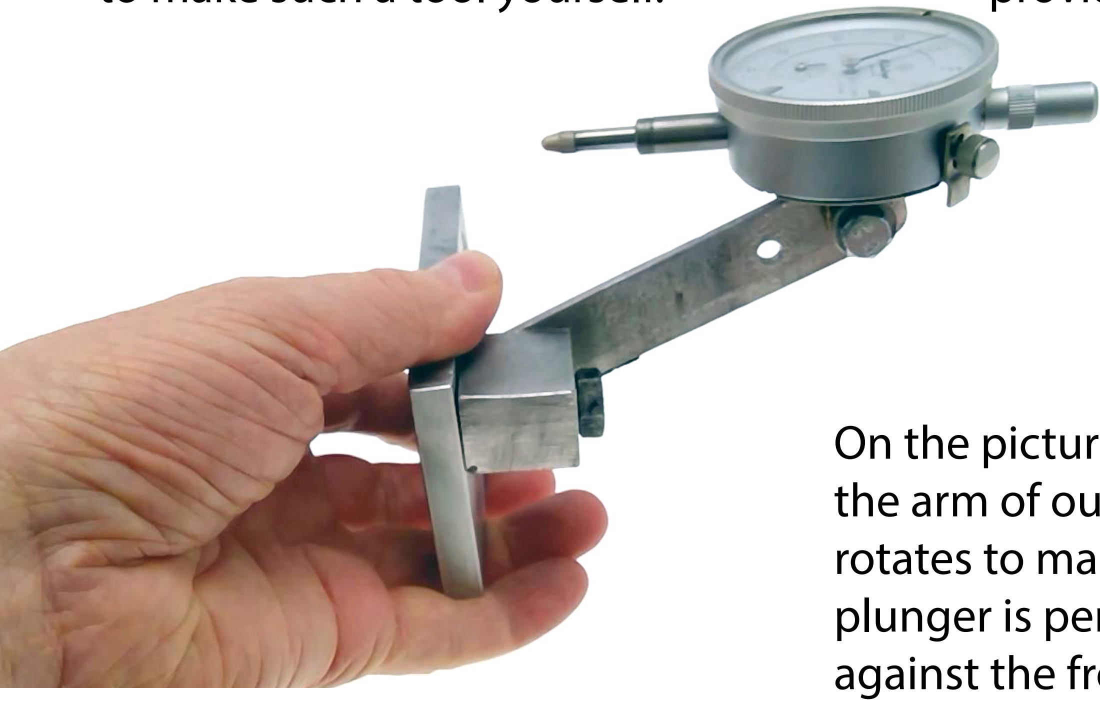




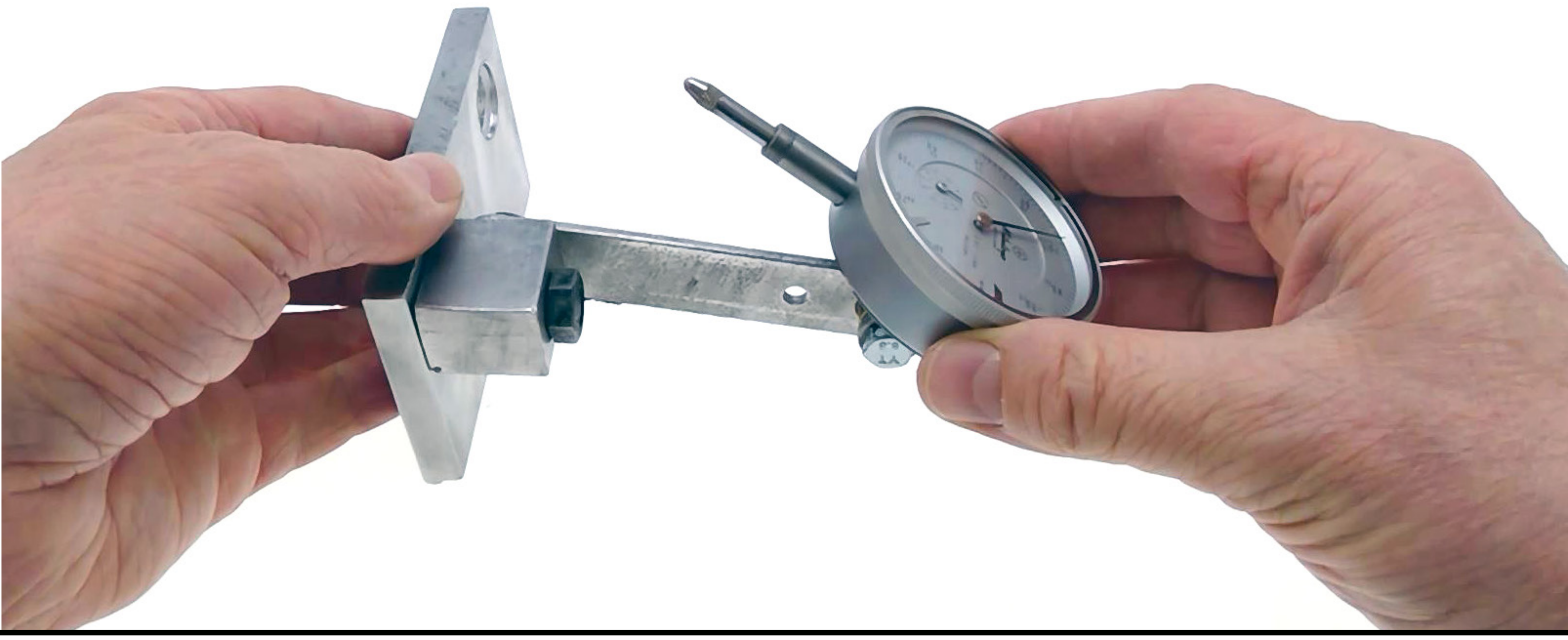
measure play with dial gauge

With this special standard, it is very quick to mount the dial gauge correctly. We have printed a series of photos with dimensions here in case you would like to make such a tool yourself.

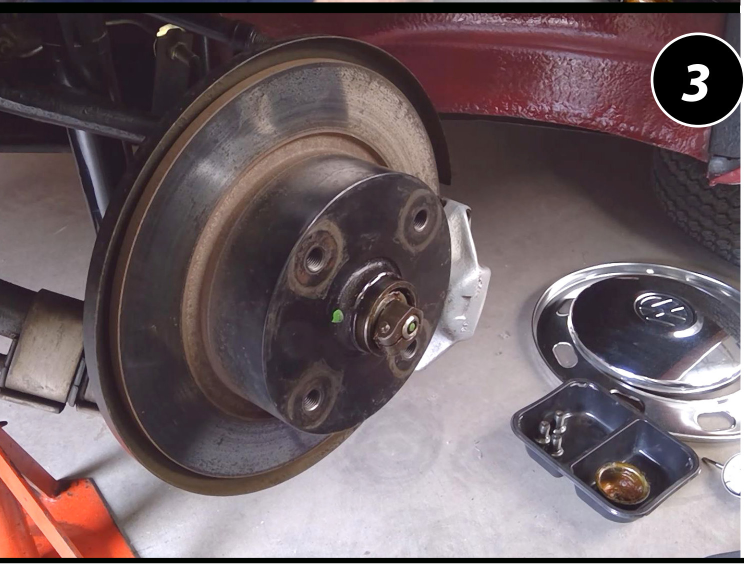
The hole for the wheel bolt should be made so that the wheel bolt just fits. We have drilled an extra recess to fit the head of the wheel bolt, this provides more stability when measuring.



On the pictures we show how the arm of our homemade tool rotates to make sure that the plunger is perfectly pressed against the front wheel spindle.



Measuring the wheel play

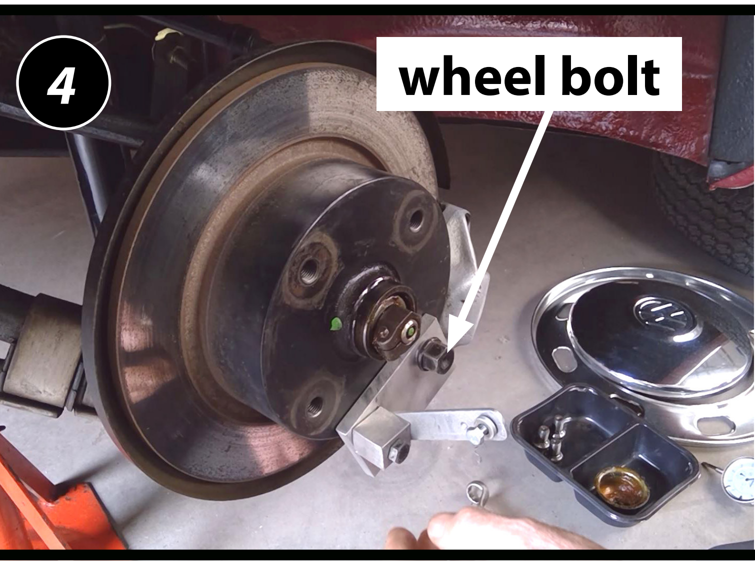


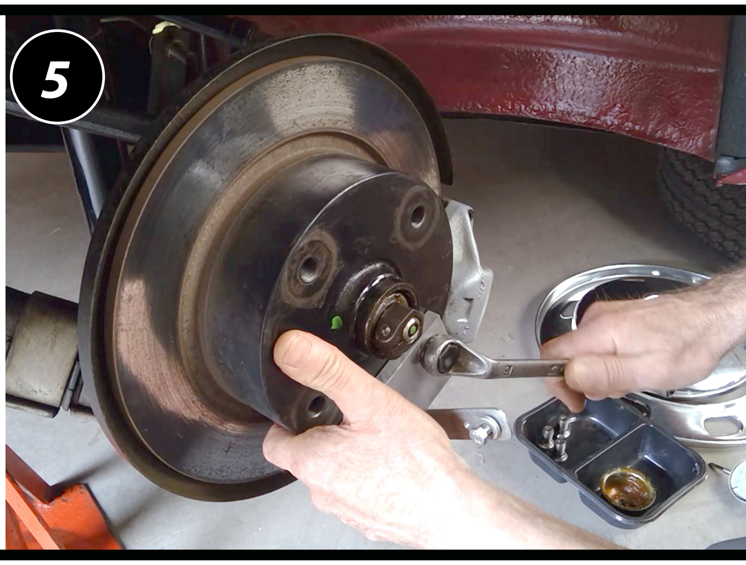
Now that we have found the right mounting for our dial indicator, it is time to position it on the front wheel spindle.

We first show the measurement using our homemade mounting tool. Jack up the car on the front (see edition 03 to learn how to safely jack up your VW). The wheel must first be removed (pictures 1 and 2) to be able to attach our special tool.

We do the measurement on the left side of our 1967 Karmann Ghia. Remove the dust cap (see edition 18 page 9). In the spindle there is a speedometer cable on the left side, so you have to loosen it by removing the locking clip on the dust cap (see also page 18). On picture 3 we show what you should see if you have VW disc brakes at the front. You can also use the method we show for drum brakes.

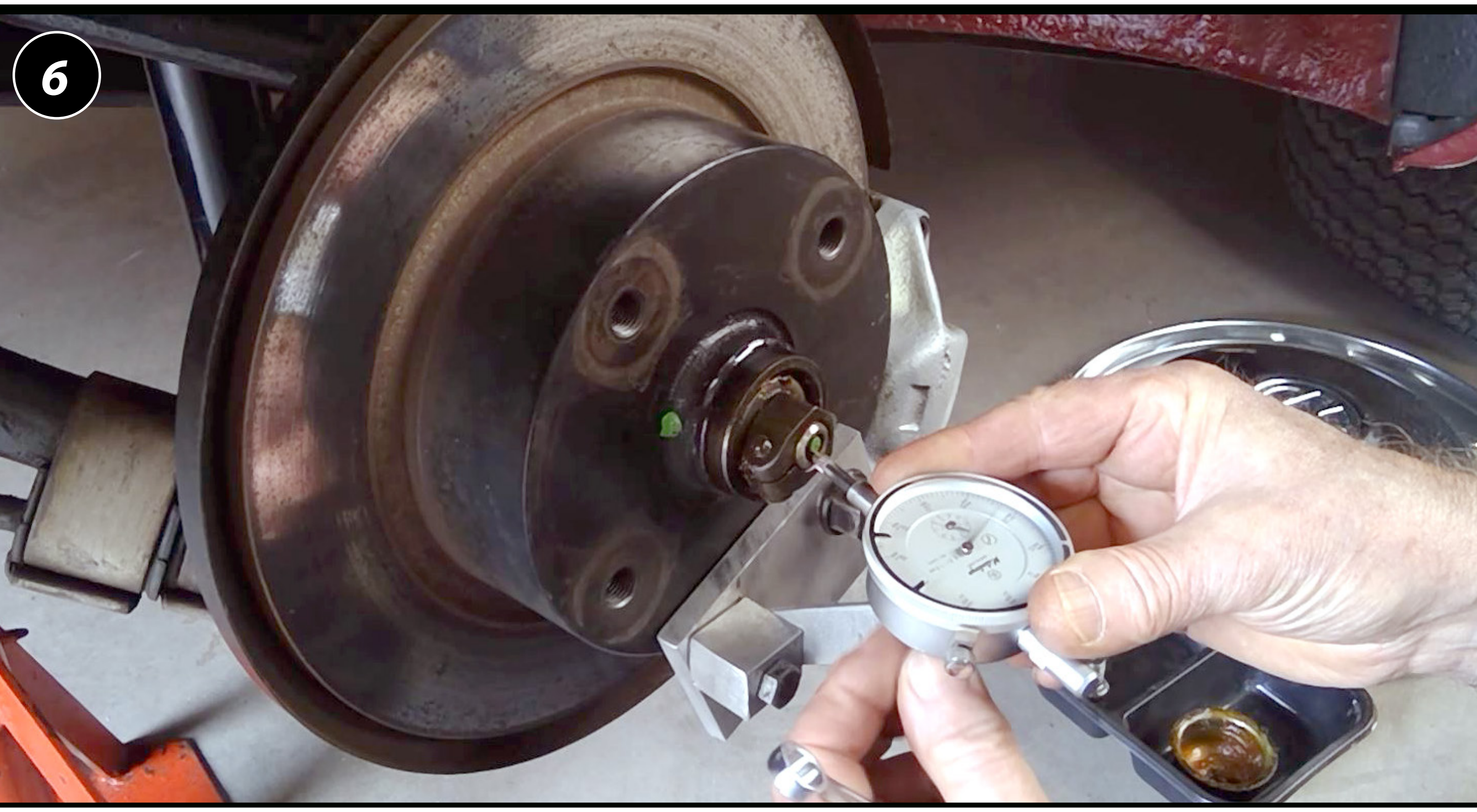
measure play with dial gauge





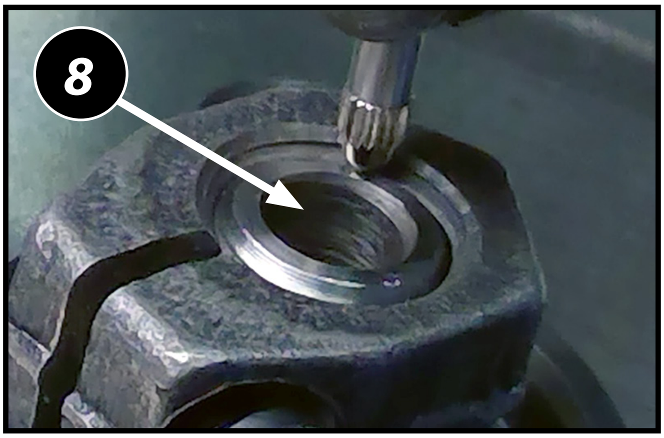
Use one of the wheel bolt holes to secure the dial gauge stand with an original wheel bolt (photos 4 and 5).

Attach the dial gauge to the stand and position the gauge head against the wheel spindle (photo 6, see also page 10).



Below (picture 7) is a close-up of a test setup with a lowered spindle of the left wheel. We show how to position the dial against the spindle in order to measure the wheel play correctly. The measuring head of the gauge must be pressed a little (preload) to measure correctly (see explanation on page 27). The scale is set to zero after the dial indicator is in place. In this setup we have used a standard with a flexible arm (see also page 29).

On picture 8 you can see the opening in the spindle through which the speedometer cable can be pushed. The opening is only present at the left stub axle.



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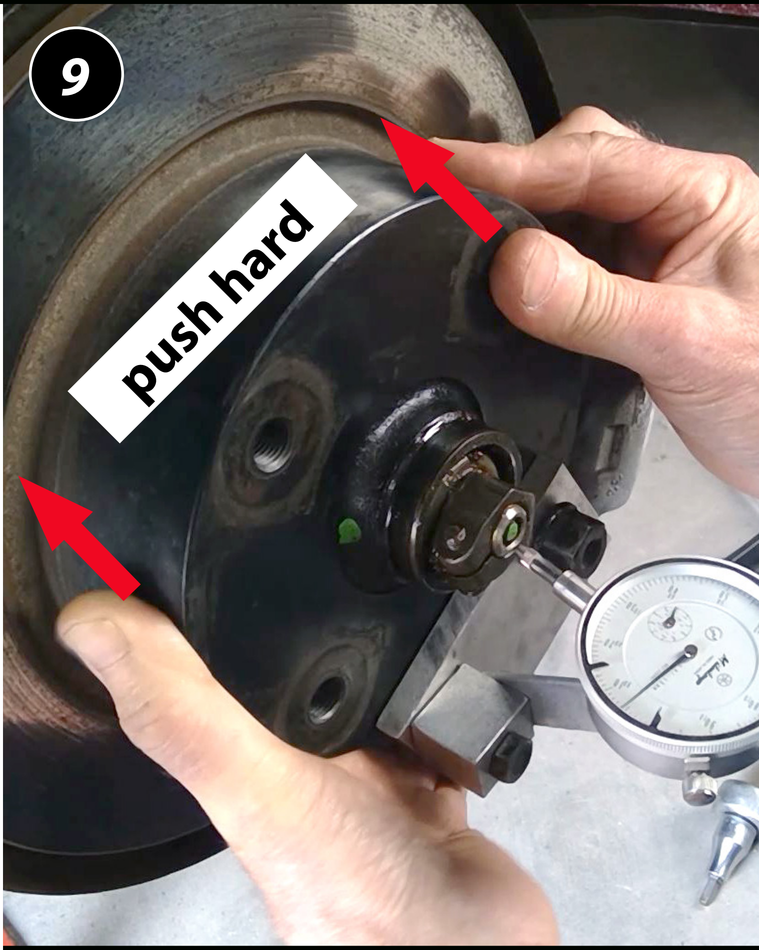
measure play with dial gauge

Make sure the car is stable, use an extra jack support to secure the car. Now first press the brake disc or drum all the way away from you by pressing it firmly (photo 9). With the wheel removed, you can hardly feel that there is any wheel play, so don't worry and push the disc or drum firmly inwards.

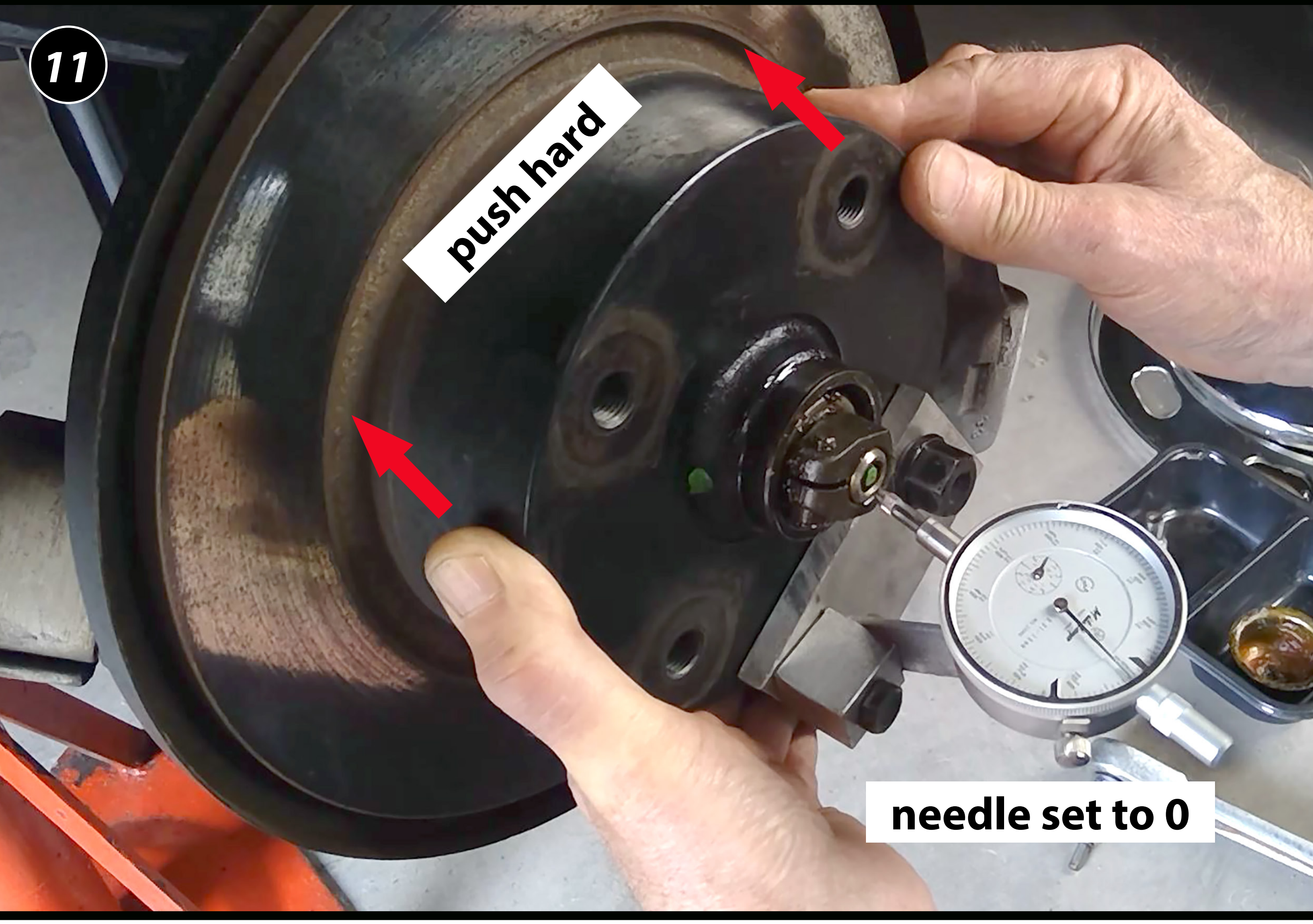
Make sure that the head of the gauge presses against the wheel spindle, and set the gauge so that the needle shows the zero position (picture 10). This is not mandatory, but it makes it easier to read the wheel play on the dial.

If you want to know more about the use of the dial gauge, please refer to the introduction article in this edition (see page 20).

Check if the gauge head still pushes against the spindle, and you're now ready to adjust the wheel play.



#55 Front axle

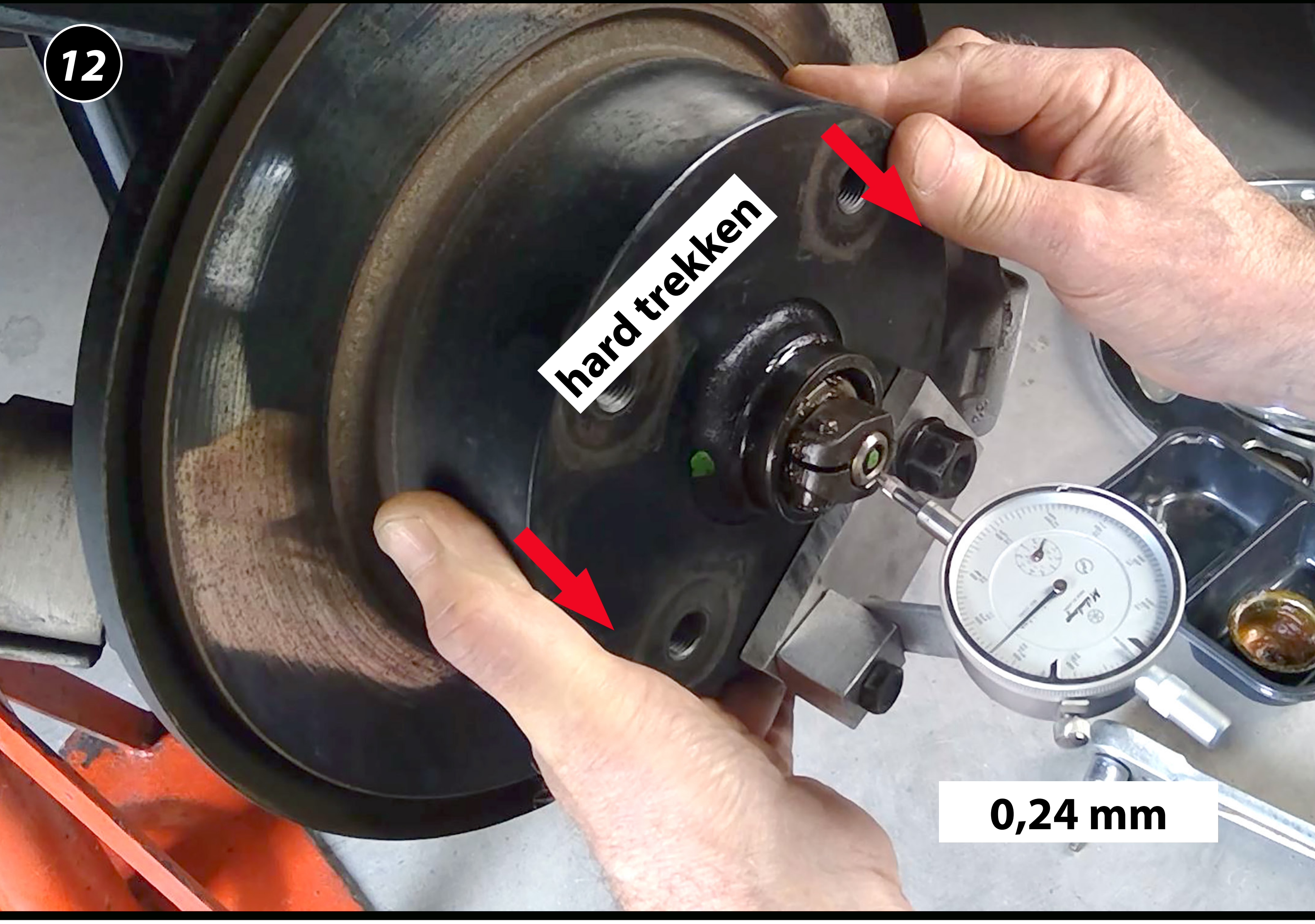


The setup is now ready to perform the measurement. When you push hard on the brake disc or drum (11), the pointer of the dial indicates the zero position. Make sure that only the head of the gauge moves when the brake disc is pressed, if the housing of the gauge moves, then the dial gauge stand is not attached correctly and the measurement will not be correct.

When pressing the brake disc, you bring the play, or preload, on the wheel bearings to zero. You will feel some resistance, that is normal.

needle set to 0

measure play with dial gauge



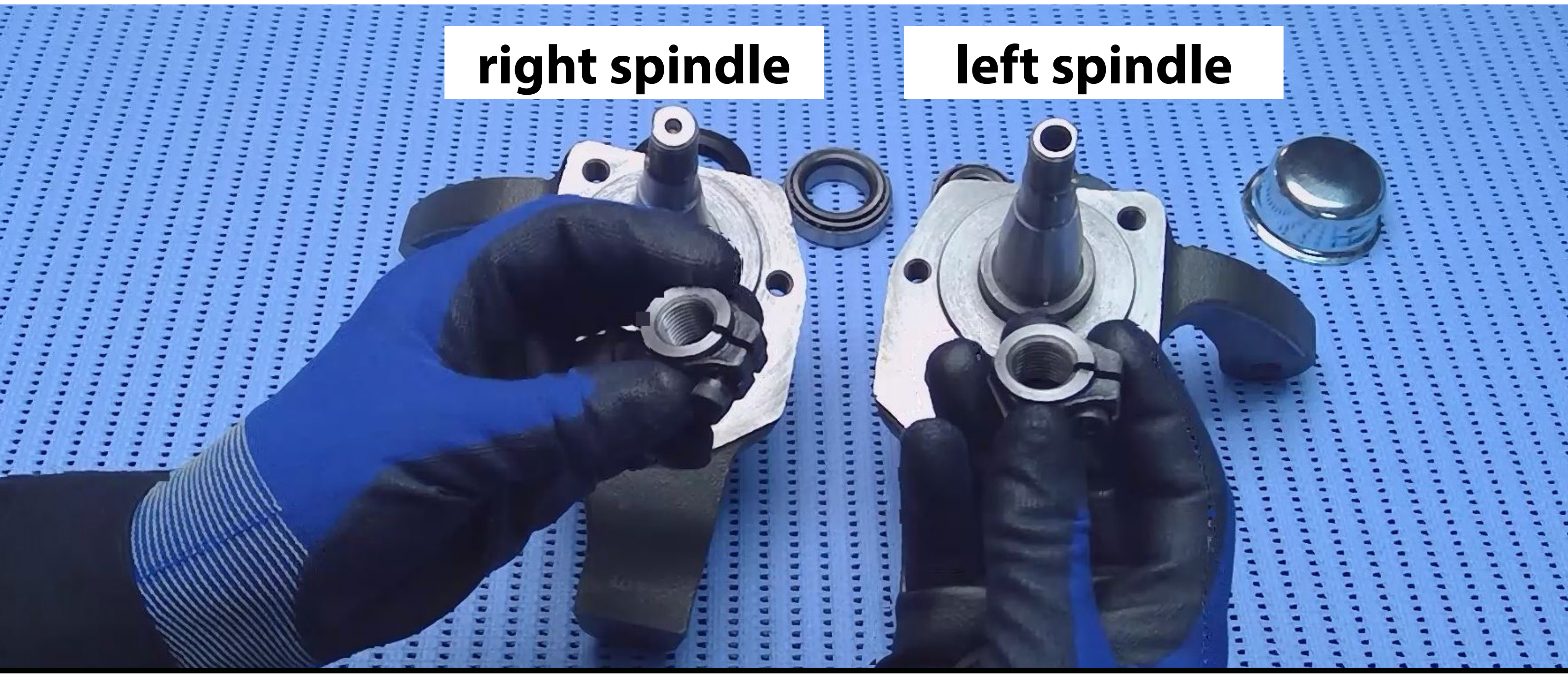
With the gauge at zero, pull the brake disc hard (12). The head of the dial will be pushed in and the needle will move.

Maybe not clearly visible in the picture, but we measure a wheel play of 0.24 mm. A look at the VW workshop manual tells us that for this type of Karmann Ghia the wheel play must be at least 0.03 mm and the maximum play must not exceed 0.12 mm. Our Ghia has double the play on the left wheel, which is not good.

Adjusting the wheel play

We measure 0.24 mm of wheel play on the left wheel of our 1967 Karmann Ghia, so that's too much. It is of course possible that your measurement indicates that the play is zero. Pressing or pulling the brake disc or drum does not affect the movement of the dial. Then you need to quickly adjust the wheel play. If the measurement indicates a value between the prescribed values, you can put everything back in place and start adjusting the right wheel play.

You can adjust the wheel play as explained on page 8 of edition 18. The right wheel uses a classic **clockwise clamping nut**, i.e. you tighten the clamping nut by turning it clockwise. The left wheel uses an **opposite threaded nut** (pictures below). So be careful when adjusting the wheel play! We work on the left wheel of our Ghia, so when adjusting the wheel play the clamping nut has to be turned the other way around than you are used to in daily life.

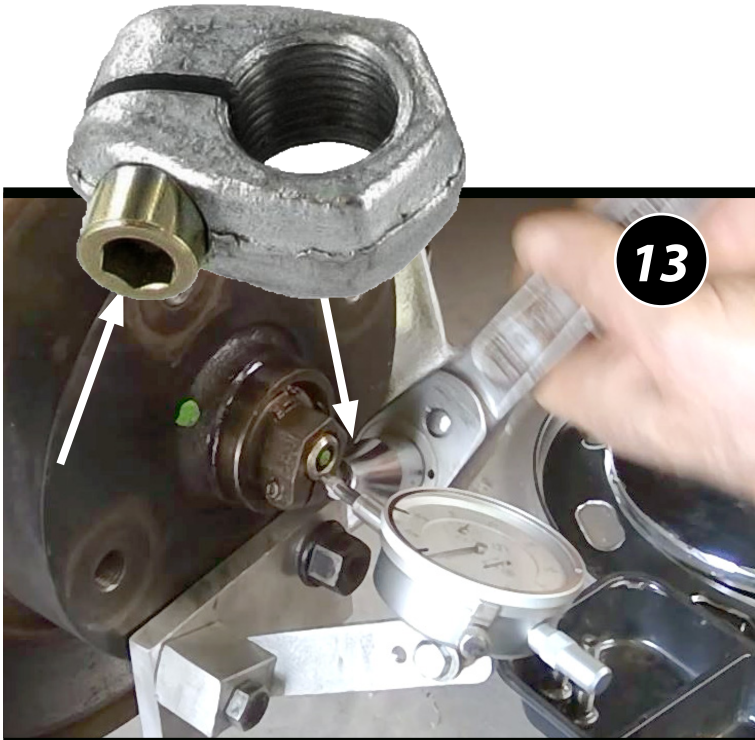


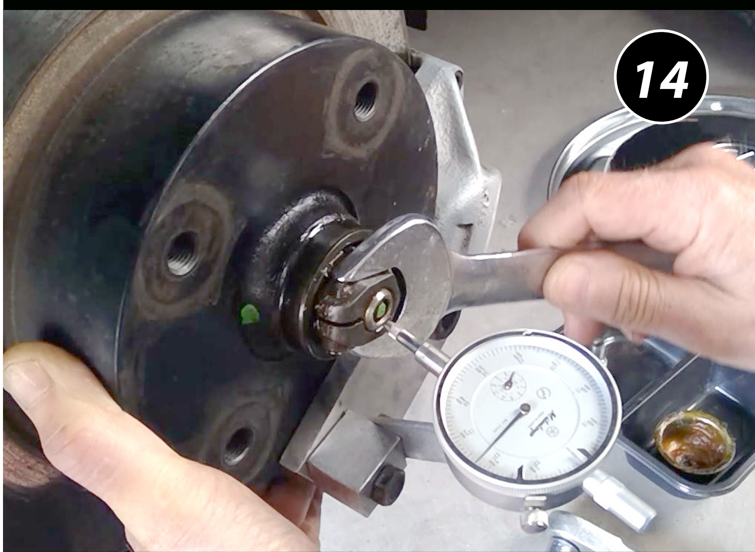
measure play with dial gauge

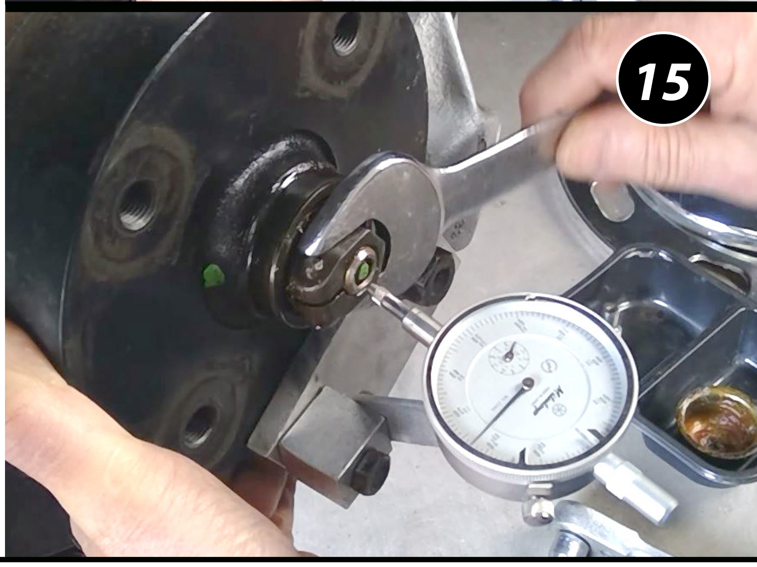
Our Ghia currently has a wheel play of 0.24 mm, so this is too much. We have to reduce the wheel play by tightening the clamping nut, so this is turning to the left (counter clockwise, we are working on the left wheel).

First loosen the Allen bolt that holds the clamping nut on the spindle (picture 13). Then you can tighten the clamping nut (pictures 14 and 15). Attention, the zero point of the gauge will shift when you tighten the clamping nut, first set the zero point again.

Pictures 14 and 15 show how much we had to turn the clamping nut (counterclockwise) to adjust from 0.24 mm wheel play to 0.04 mm. It was barely 1/8 of a revolution, so the adjustment is clearly very sensitive. When the wheel play is between the prescribed values, the clamping nut can be secured with the Allen screw as shown in picture 13.







#55 Front axle

After you have tightened the Allen bolt, you can measure the wheel play again just to be sure. Turn the brake drum or disc several times around, then press it all the way down to set the zero point and then pull it all the way towards you to take a new measurement. If the wheel play is still greater than 0.03 mm and less than 0.12 mm then you are ready for this side.

If this is not the case, the play may have changed during the tightening of the Allen bolt, or the measurement may not have been correct.

The left wheel can now be mounted. By holding the wheel firmly and pushing and pulling it, you should feel the wheel play (picture 16).

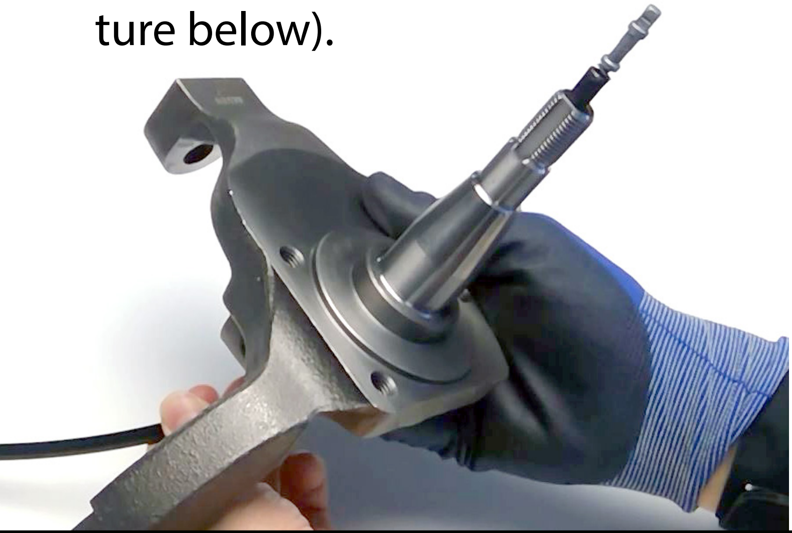
measure play with dial gauge

The dust cap can now be put back on. With the left wheel, don't forget to secure the speed-ometer cable on the dust cap. The whole time on all pictures the cable can be seen as a green dot (we have marked it with green paint). On picture 17 you can see that we pulled the cable out of the spindle, or rather pushed it on the inside of the spindle (behind the wheel).

It is easier to push out the cable from behind (behind the wheel). Once the cable is pushed out of the spindle, you can push it through the hole in the dust cap. The hole must be square (angu-lar), if it is no longer angular (very rounded), then the cable will not turn correctly with the wheel and may slip through.

Front axle

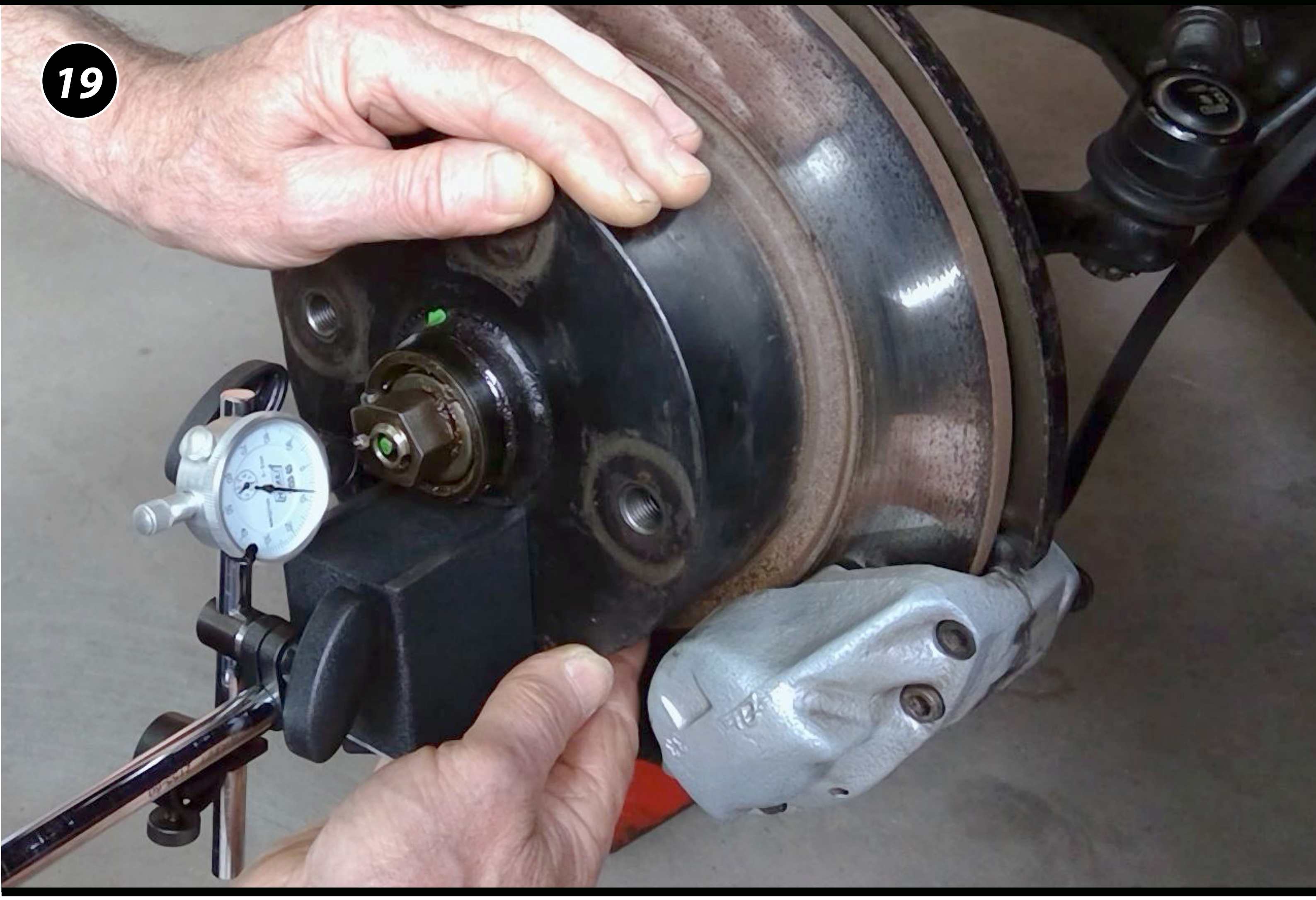
On the right we show a right dust cap and a left dust cap, the left side can be recognized by the hole that is provided to drive the speedometer cable. You can see that on this new part it is nicely angular. Of course the end of the cable itself has to be sharp and angular (picture below).



right dust cap

left dust cap

measure play with dial gauge



We made the same measurement using a standard magnetic dial indicator stand (picture 19). It was a bit more difficult to position the dial against the spindle, but with a bit of try and error it worked out pretty well. The value of the wheel play we measure now is 0.07 mm instead of 0.04 mm (see page 15). This is a very small difference of course, and will not affect wear or handling, the value is still within the prescribed clearance.

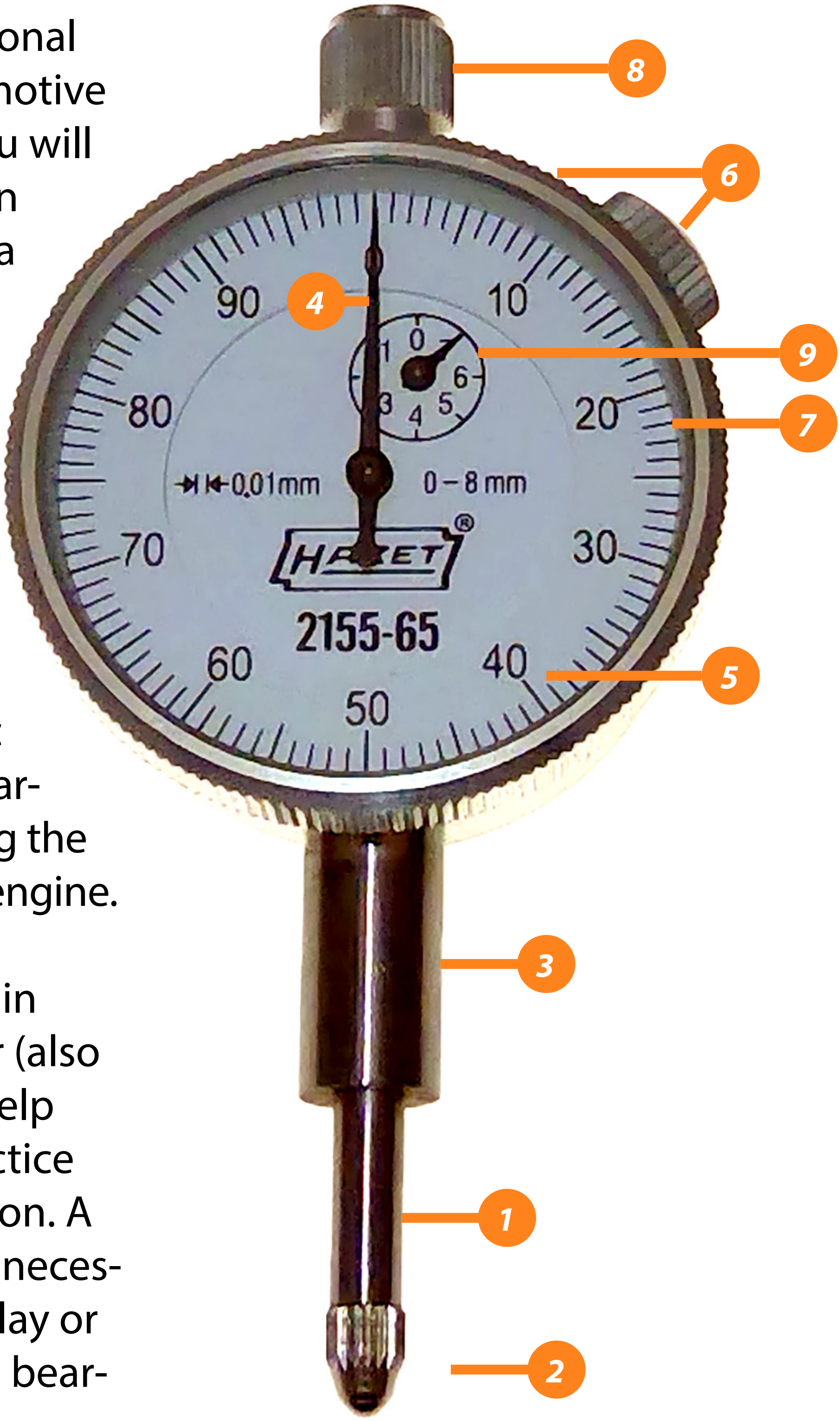
It is recommended to check the wheel play after a few hundred kilometers of driving, eventually without dial gauge, just manually, to make sure the wheel play didn't change because the bearings set. This will especially happen with new wheel bearings, we will discuss this in the next edition.

Introduction

A dial gauge is part of the basic equipment of the professional car mechanic. As an automotive technology enthusiast, you will soon need such a precision measuring tool. A caliper, a micrometer or a dial indicator will quickly find its way into your toolbox.

For example, to measure the axial crankshaft clearance (see edition 11), to measure the straightness of the disc brakes, the front wheel clearance (see page 4), or during the complete overhaul of the engine.

In this article we will explain how to use a dial indicator (also called dial gauge), it will help you to better put into practice the first article in this edition. A precision measurement is necessary when adjusting the play or preload of the front wheel bearing on a classic VW.



Dial gauge parts

For this article we use a measuring clock from Hazet. On the left we show all the parts that make up our gauge. Each brand will have a different construction, but the basic parts and the use of each dial gauge will be identical.

1. **plunger or dial gauge spindle**
2. **gauge head**
3. **stem**
4. **long pointer or needle**
5. **rotating graduation plate**
6. **outer frame**
7. **graduation**
8. **fine tune knob**
9. **small graduation with small pointer**

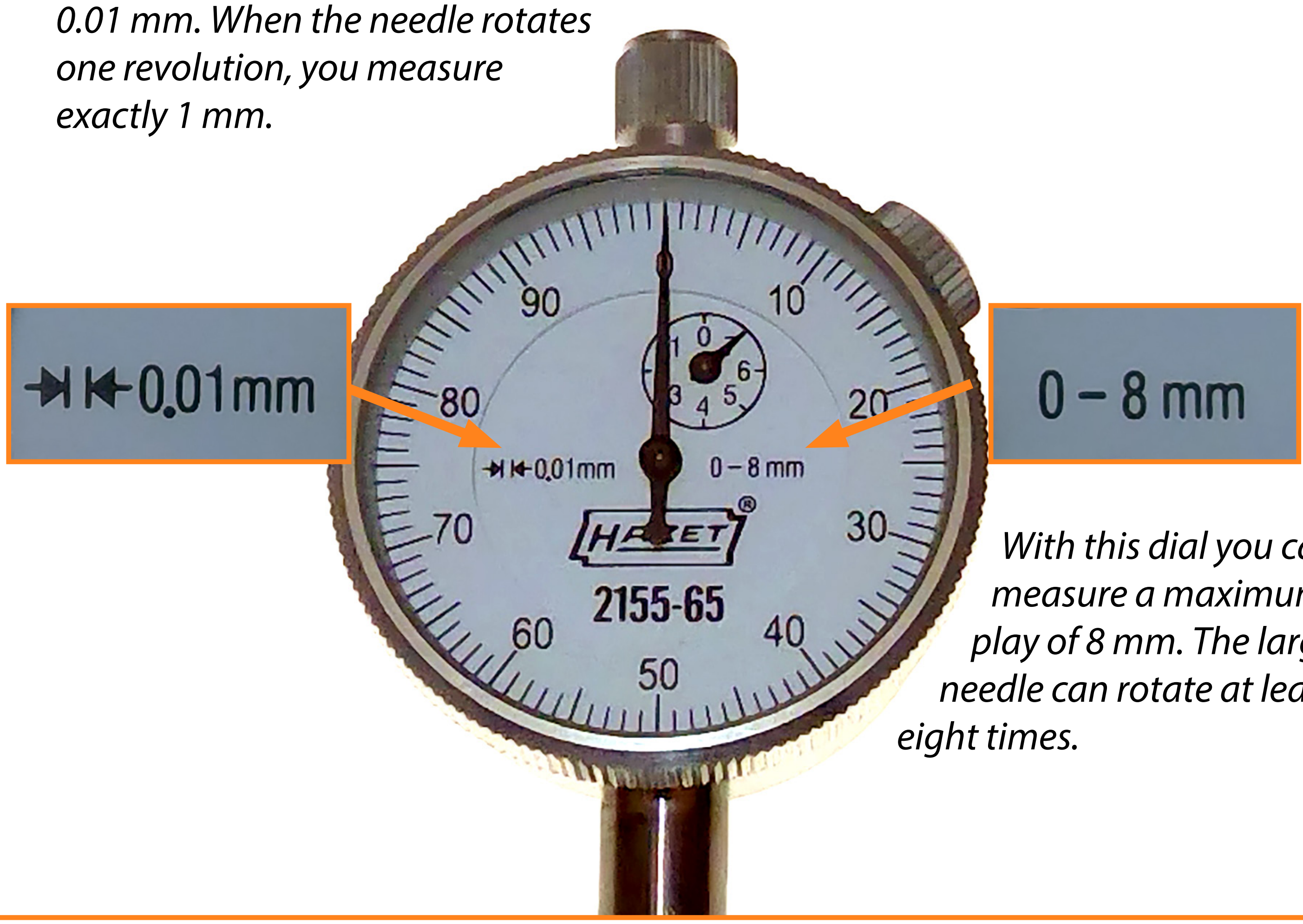
You can remove the gauge head and replace it with a new or a different type for a special application. You can easily remove it by carefully unscrewing it (see page 25). If the head is damaged or deformed, it is advisable to replace it to avoid measurement errors.

The scale

The first thing to check when using a new dial indicator is the scale. Maybe you bought the dial second hand and the scale is in inch. Keep that in mind, otherwise you will make a wrong measurement! There are different versions with different precision and range.

Our measuring device indicates that each graduation of the outer scale is 0.01 mm (i.e. 1/100th of a mm). When the big needle moves from 0 to 10, you have a measurement of 10 hundredths of a mm, or a tenth of a mm. When the big needle rotates all the way around, you measure exactly 1 mm.

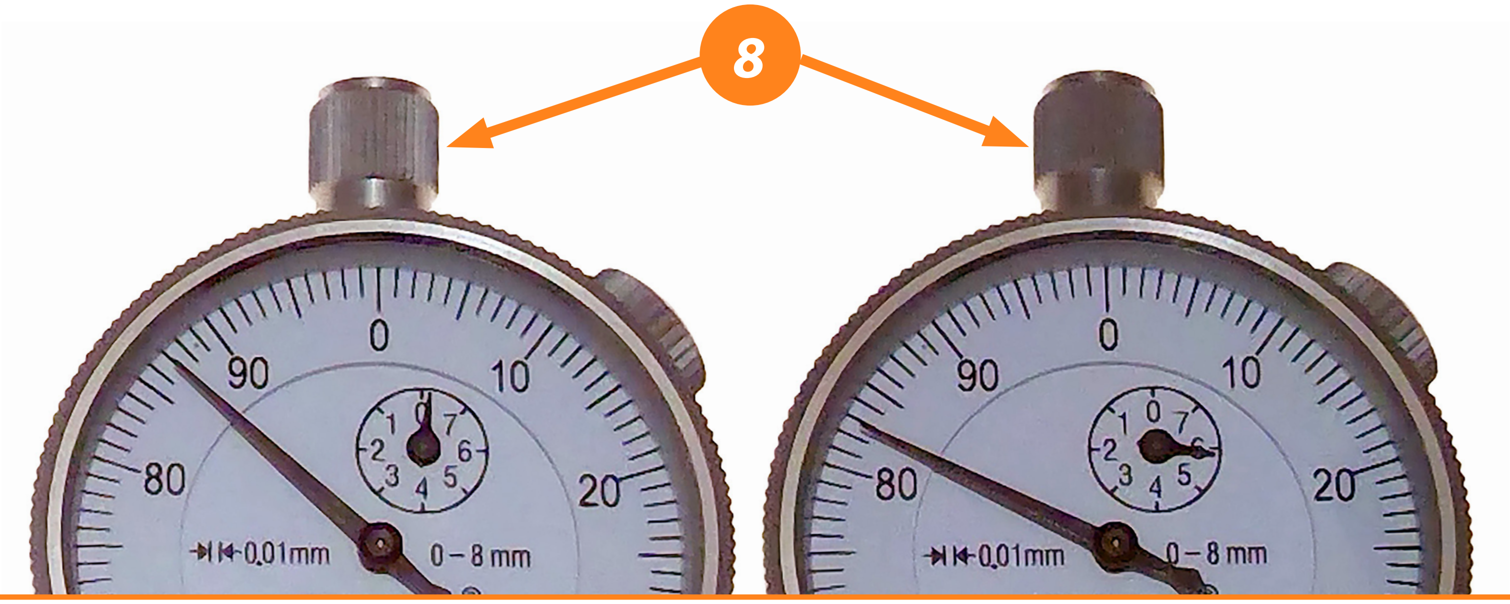
The smallest scale of this dial is 0.01 mm. When the needle rotates one revolution, you measure exactly 1 mm.



With this dial you can measure a maximum play of 8 mm. The large needle can rotate at least eight times.

The maximum range of this dial indicator is also indicated, which is 8 mm (see photo page 22). You can also see that on the small dial, the scale goes from 0 to 7. For each full revolution on the large dial scale, the small dial will rotate one revolution. For most measurements on our air-cooled VW, you will not need the small scale. We will not see much deviations of more than one complete rotation, that is more than 1 mm. For example for the flywheel we measure a maximum of 0.40 mm (see edition 11), for the wheel play of the front wheels it is 0.12 mm (see article page 4). So we will mainly use the large dial scale to carry out our measurements.

At the top of the dial gauge you can turn the big needle with the control knob (8). With this dial we can adjust the small needle of the small dial from almost zero to six. We set the small needle in the middle, namely to seven. With this setting you can adjust the gauge head with the knob a full millimeter in both directions, if necessary during your measurement.



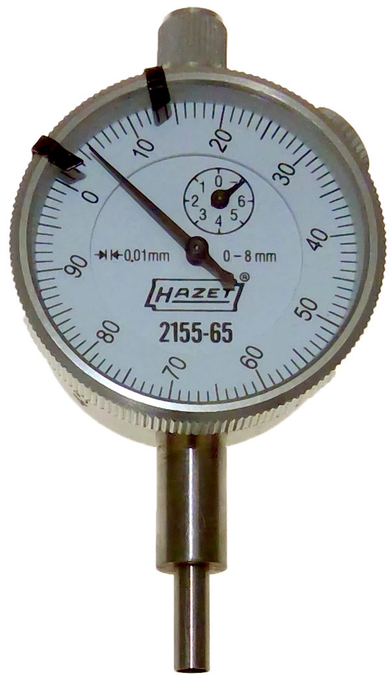
An additional measurement function is provided by the clips (photo below, also called markers or limiters) attached to the metal outer ring. For example, you can set one to the zero position, and the other to the maximum desired deviation. If you want to adjust the wheel play, you would slide the second clip to 0.12 mm. This extra function helps you to find out more quickly whether the play is within specs.

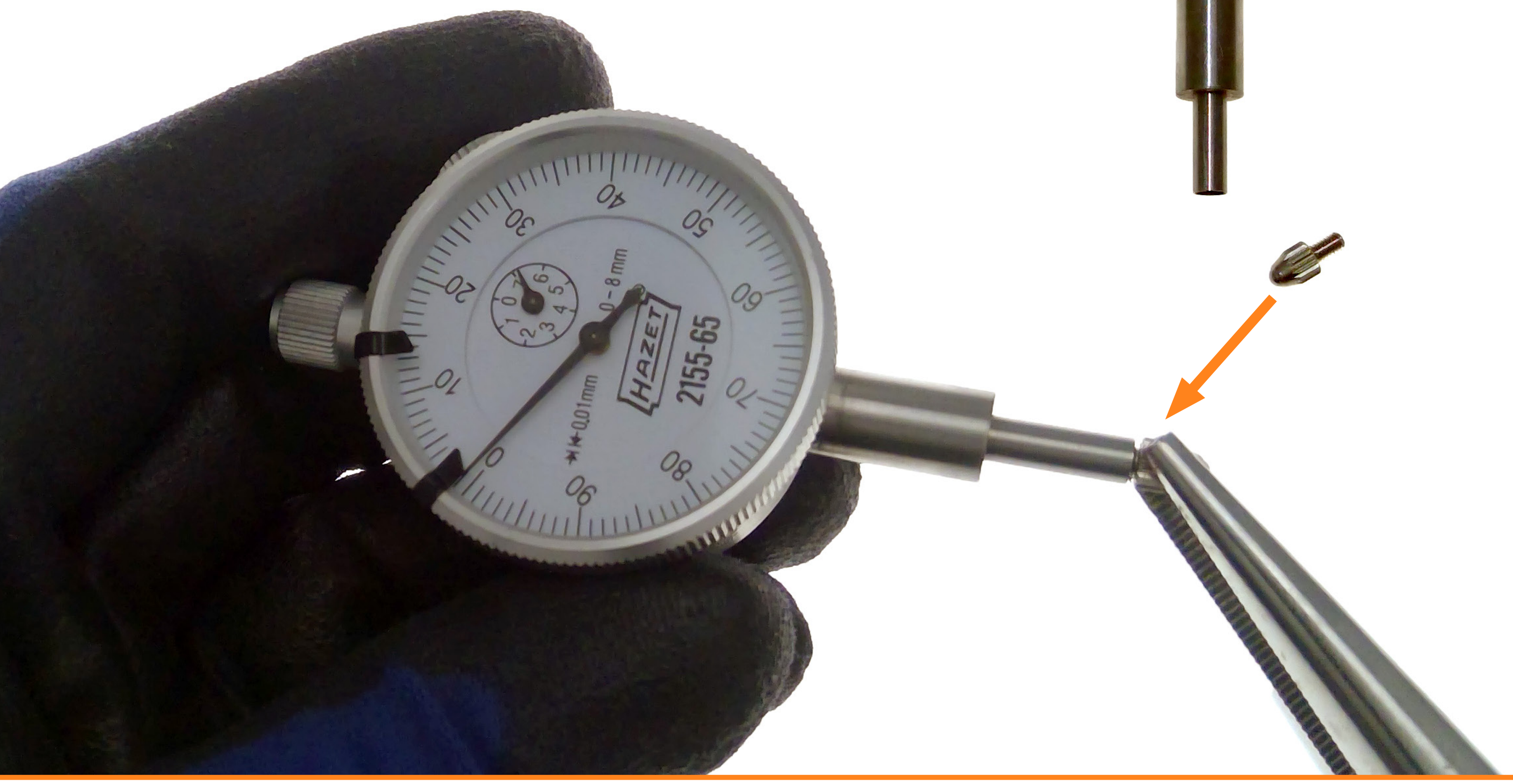
The clips are used when several parts have to be measured in succession for example, to quickly see if the part is within the specifications.

The large dial is rotatable (photo above). You can rotate the metal ring, to which the protective glass is attached. This feature is often used to set the large needle to the zero position in order to obtain a start setting.

You can remove the gauge head and replace it with a new or a different type for a special application. You can easily remove it by carefully unscrewing the head with a gripper (picture below).

If the head is damaged or deformed, it is advisable to replace it to avoid measuring errors. On some models you can also replace the head with a longer version, please note that this can lead to inaccurate measurements if you do not follow the manufacturer's instructions.





How to use the dial gauge

In order to obtain an accurate measurement with a dial indicator, there are a number of guidelines that need to be followed closely.

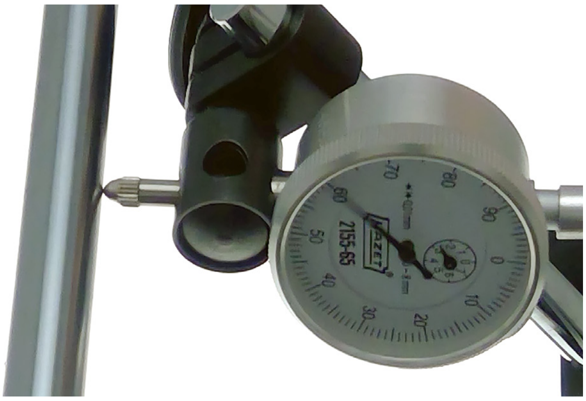
1 If you want to measure a part that is quite uneven, you have to make sure you don't damage the dial plunger or head. So first make sure that the surface you are measuring is clean without burrs or irregularities that could damage the dial indicator head.

2 The gauge is a precision instrument, this tool does not belong between hammers or gripping pliers. It must be handled with care during use. When not in use, always store in the original box or bag, away from big and heavy tools.

3 The measuring head has to be positioned perpendicular to the surface to be measured. A slight deviation will result in a serious measurement error. For example, if we use the gauge on a part that has 1 mm of play, the gauge will show 1.41 mm if the pin is 45° oblique with respect to the part to be measured.
45° is an extreme example, but it proves that the gauge will no longer measure correctly if the gauge plunger does not move perpendicular to the part to be measured.

using the dial gauge

4 The measuring head may be pushed in a large part, it may be up to half, to ensure that it has a continuous measurement. On the pictures below we show how this works.



Once the gauge head is in place, you can turn the rotating dial plate so that the big needle is at zero.

5 If you want to measure the play or a deviation then it is not necessary to set the scale to zero. You can measure the initial value and the final value, and substract them from each other. The rotating dial allows you to zero the large needle, the deviation or play is then easier to read (see page 24).

6 The stand may not influence the measurement, so it may not move along with the part to be measured. Use a suitable stand for your application, if necessary make a special mounting as on page 6 to measure the wheel play.

On the next page we will explain more about the choice in mounting hardware.

Dial gauge stands

The challenge when using such a dial indicator is the way you secure it. There are different fastening methods depending on the situation. One of them is a magnetic stand, with which you can fix the dial gauge in most situations, but you must have a flat and clean metal surface at your disposal close to the part to be measured. A stand can be equipped with fixed arms or with a flexible arm.

1. magnetic base with fixed rod
2. spring clamp fixed / movable rod
3. two-part movable rod
4. spring clamp with dial gauge

With fixed arms

This type of stand consists of four parts. A magnetic base with fixed rod (1), a spring clamp to connect the vertical rod to the movable rod (2), a two-part movable rod (3) and a spring clamp (4) to attach the dial gauge. The movable rod is made of two parts, both parts can move relative to each other to position the plunger. The spring clamp for the dial indicator has holes with different dimensions to be able to attach various dial indicators.

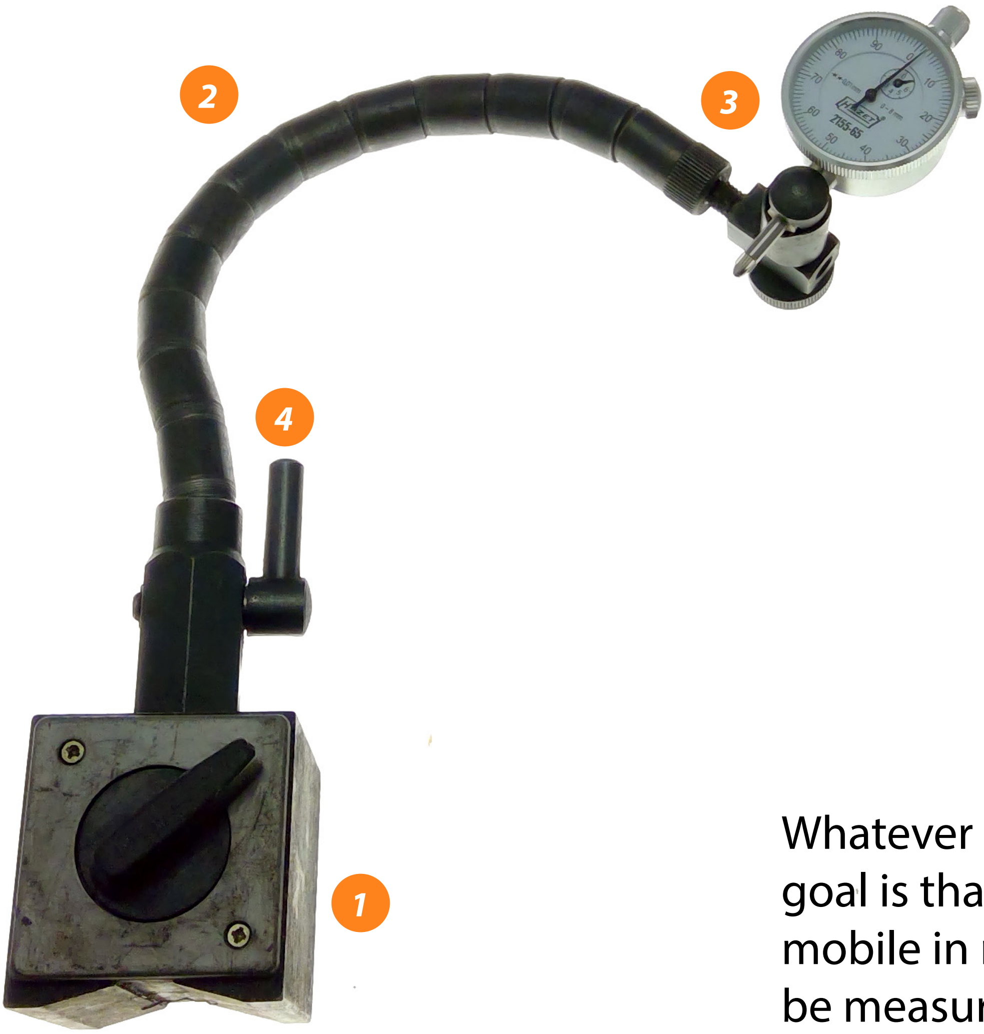
using the dial gauge

With flexible arms

This type of stand also has a magnetic base (1) but has only one arm that is set up flexibly (2). You can tighten or loosen the arm by turning the nut (3). When the arm is in place, you can lock it with the lever (4).

Special stands

For occasional use, commercially available stands are useful. If you need to make regular identical measurements, you will have to look for special mounting methods such as those for the flywheel (edition 11), or for the wheel play (see page 6).



1 **magnetic base**

2 **flexible arm**

3 **adjusting nut**

4 **locking lever**

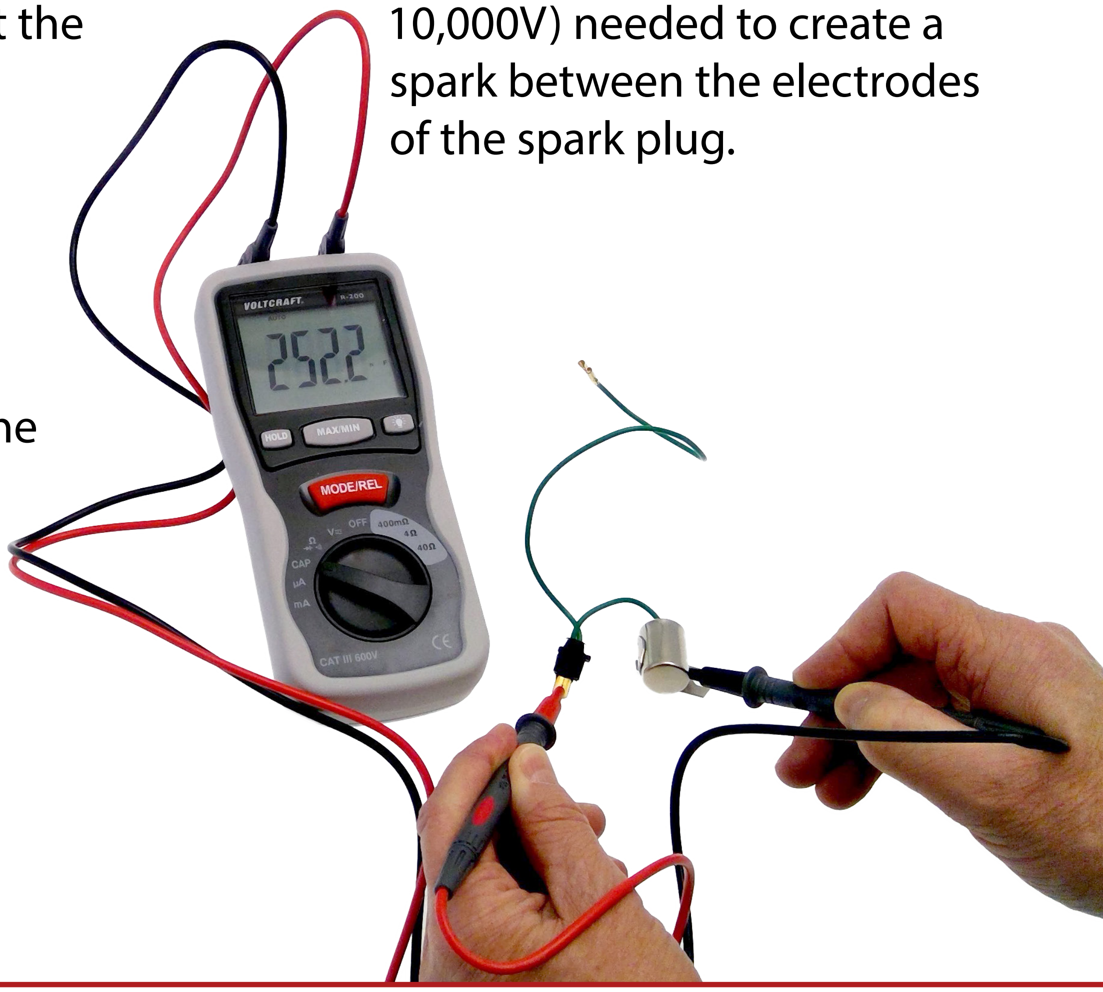
Whatever stand you use, the goal is that the dial gauge is immobile in relation to the part to be measured.

Introduction

In the previous edition we explained what a condenser is, and what it is used for in our air-cooled Volkswagen engine. The versions for different types of engines were placed next to each other and their value was written down in micro farad. The measurement was done with a capacitance meter (see picture below).

It became clear that the condenser plays an important role in the creation of the spark between the electrodes of the spark plugs. We will now measure the ignition coil and see how much influence the condenser has on the ignition.

We will start by measuring the ignition coil, there we will study the role of the condenser in the ignition circuit. Everyone knows that the condenser will protect the contact points from burning in. But what few people know is that the condenser also plays a very important role in transforming the low voltage of the battery (6V or 12V) into a high voltage (more than 10,000V) needed to create a spark between the electrodes of the spark plug.

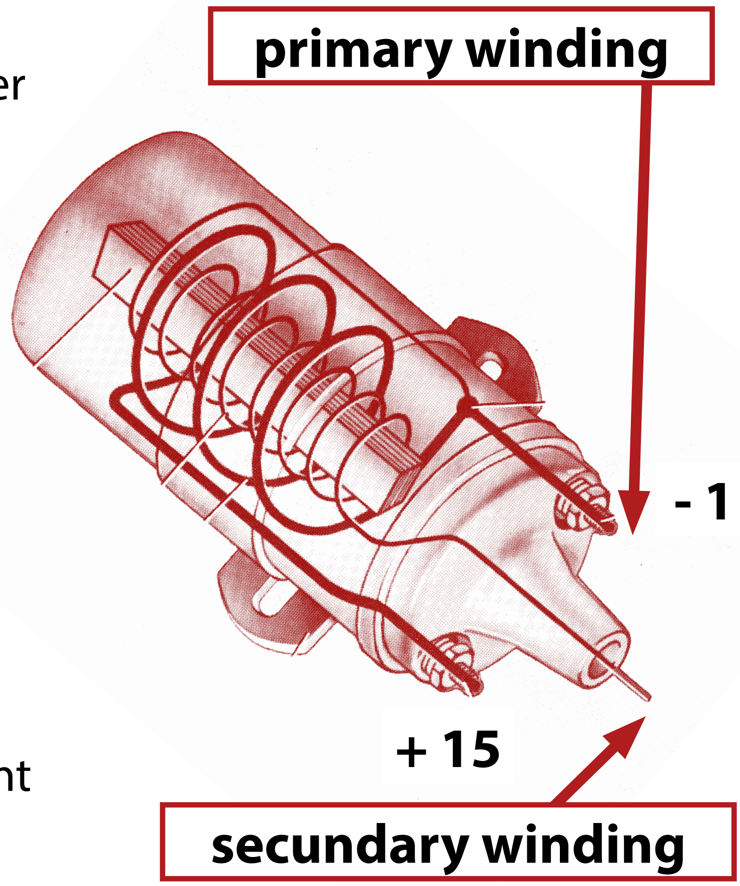


Measuring the coil

In edition 08 we tested the ignition coil while it was connected, which already gave us a good indication of how it works. Now we will measure the coil on the workbench, with an ohmmeter.

An ignition coil can be compared to a voltage transformer, it has a primary coil (primary winding) and a secondary coil (secondary winding). On the one hand you connect a voltage and on the other hand you get a voltage that is so much smaller or larger.

On the pictures on the right we show an ignition coil like you will find in an air-cooled VW. Terminal 15 (positive terminal) is connected to one side of the primary winding, terminal 1 (minus terminal) is connected to the other side of the primary winding. Terminal 1 is also connected to one side of the secondary winding. This is important to know when we will measure the resistance of the coil.



#57 Electrical

Primary winding

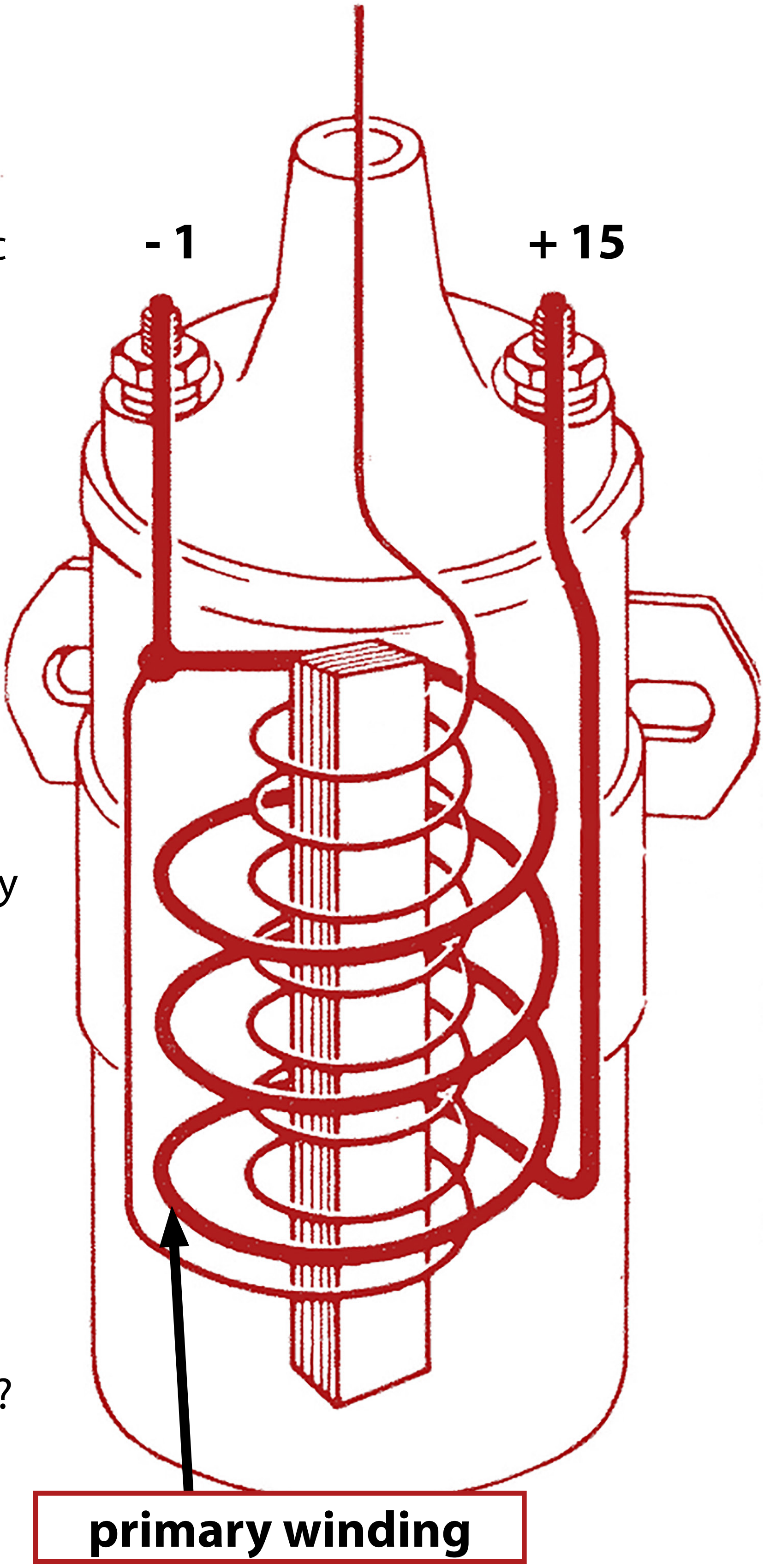
The coil used for a motor has a primary coil with few windings of thick copper wire. From this we can conclude that the ohmic resistance is very low between the terminals of the primary winding. When we consult old schoolbooks, an electrical resistance (ohmic resistance) of just 1 ohm is mentioned.

If we now connect the battery voltage (in this example 12V) at the primary side of the coil, a current of 12 amperes should flow through the primary winding. You can calculate this with Ohm's law:

U / R = I

12V /1Ω = 12A

But we don't measure 12A but 3.48A, so what do we do wrong?



An average DC generator or alternator (AC) gives a maximum current of 30A, if the ignition coil would absorb almost half (12A) this is not good news. 12A through the primary winding will also cause the coil to warm up quickly and the contact points will be damaged more quickly.

Therefore a ballast resistor is used, a resistor in series with the primary winding, typically 2Ω to 3Ω (depending on 12V or 6V ignition coil). With our VW ignition coil, this resistor is not visible, and therefore not so well known, it is built into the ignition coil. For other brands, the ballast resistor is mounted separately in the engine compartment.

3Ω plus 1Ω is 4Ω, so the resistance between terminals 1 and 15 of the ignition coil should be about 4Ω.

Below we show the current measurement (4.03A), we put the ammeter in series with the battery and the coil. Attention, we used short cables with a sufficient diameter for this measurement, otherwise the resistance would be too high and the current would be even lower. Don't let this measurement take too long, the ignition coil will get warm and the battery will quickly run out. The current drops rapidly when we continue the measurement, the battery discharges quickly because of the strong current flowing through the ignition coil.

Electrical

We will now measure the ohmic resistance of the primary winding of the coil. Connect terminals 1 and 15 to your ohmmeter. We measure 2,96 Ω. With 2.96 Ω resistor a current of 4A should flow through the primary winding of the coil. On page 33 we measure about 4A, the value can differ due to the condition of the battery and the quality of the cables:

12V /2,96Ω = 4,0A

We repeat the measurement, this time with a 6V coil from Beru. The ohmic resistance of the primary winding is 1.38 Ω, this is half of the value of a 12V ignition coil. The 6V and 12V ignition coils are designed to draw the same current:

6V /1,38Ω = 4,35A

We carry out the measurement with a resistance meter that uses four cables, this provides a very accurate measurement of small resistance values.

12V coil

6V coil

measuring the coil

12V coil | **6V coil**

The value of the coil is expressed in henri (H). This is a measure of self-induction, a coil of 1H will induce a voltage of 1V by a current change of 1A per second.

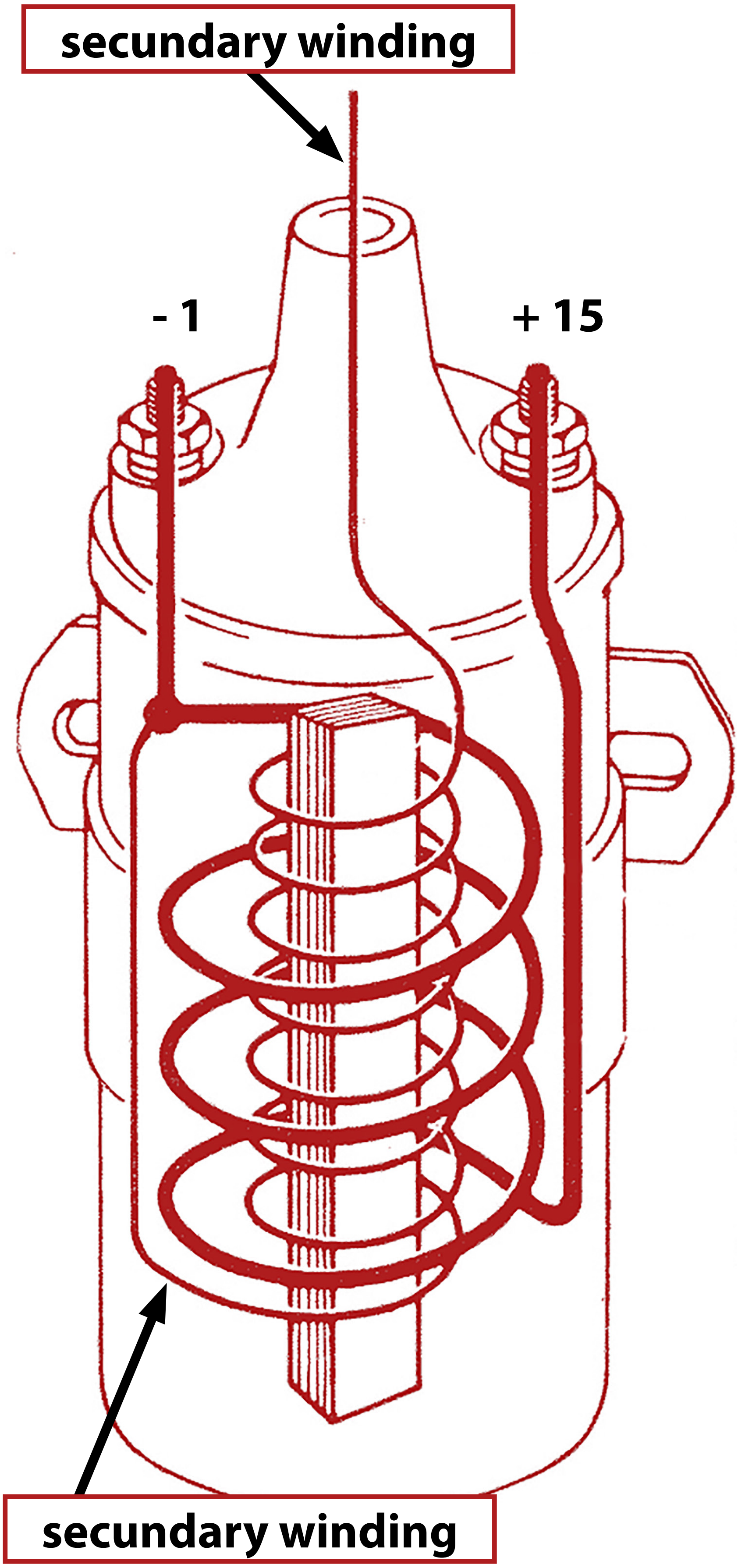
The value for our coil is not documented in the VW books, schoolbooks mention a value of about 8 to 10 mH for the primary winding.

Measuring a coil can be done with a special L-meter. The average VW enthusiast does not have such a device in house, measuring the value of the coil can give you an indication of the condition of the coil. We measure 8.43mH for the 12V coil and 3.91mH for the 6V coil (pictures above).

Secundary winding

The secondary coil is made of thin wire and contains more windings than the primary coil, typically a ratio of 1/100, so 100 secondary windings per 1 primary windings. The drawing does not give an exact reproduction of the windings! The secondary circuit also has a much higher ohmic resistance due to the small diameter of the copper wires.

You can measure the resistance by connecting your ohmmeter to the high voltage side of the coil and terminal 15 or terminal 1. If you measure at clamp 1 you have the exact value, if you measure at clamp 15 you add the low resistance of the primary winding (less than 4Ω), but you won't see that on your ohmmeter.



measuring the coil

Be careful not to touch the Multimeter measuring probes with your fingers, use gloves if necessary, you could influence the measurement by measuring your own body resistance in parallel with the secondary coil.

According to Bosch specifications, the secondary winding should have a resistance of about 8000 Ω. For our 12V coil (picture right) we measure the resistance of the secondary winding, this is 7.6k Ω or 7600 Ω.

We repeat the measurement with a 6V coil and measure 6900 Ω.

The current in the primary winding is high (4A), from the measurement of the resistance of the secondary winding we can conclude that the current in the secondary winding will be very low.

The coil value of the secondary in henri is 110H for the 12V coil and 35H for the 6V coil. This is 10.000 times larger than the primary winding.

#57 Electrical

High Voltage

The voltage transformation of an ignition coil (which actually works as a voltage transformer) is according to theory equal to the ratio of the number of windings, and that is on average 100 for a VW ignition coil.

So, if we connect 12V between terminals 1 and 15, then a voltage of 12V times 100 should be measured over the secondary winding, being 1200V.

But, we need a minimum of 10.000V to overcome the air resistance between the electrodes of spark plug to obtain a spark. It doesn't add up.

Because a high voltage measurement with a standard multimeter is not possible, we connect a spark plug to the secondary winding of the ignition coil (and to the minus terminal) to see when a spark can be seen between the electrodes of the spark plug.

In a test setup we connect the ignition coil to a 12V battery, the ground at terminal 1 and the plus at terminal 15. There is no spark, so no voltage increase? It is only when we disconnect the battery that sparks occur at the clamps and between the spark plug electrodes.

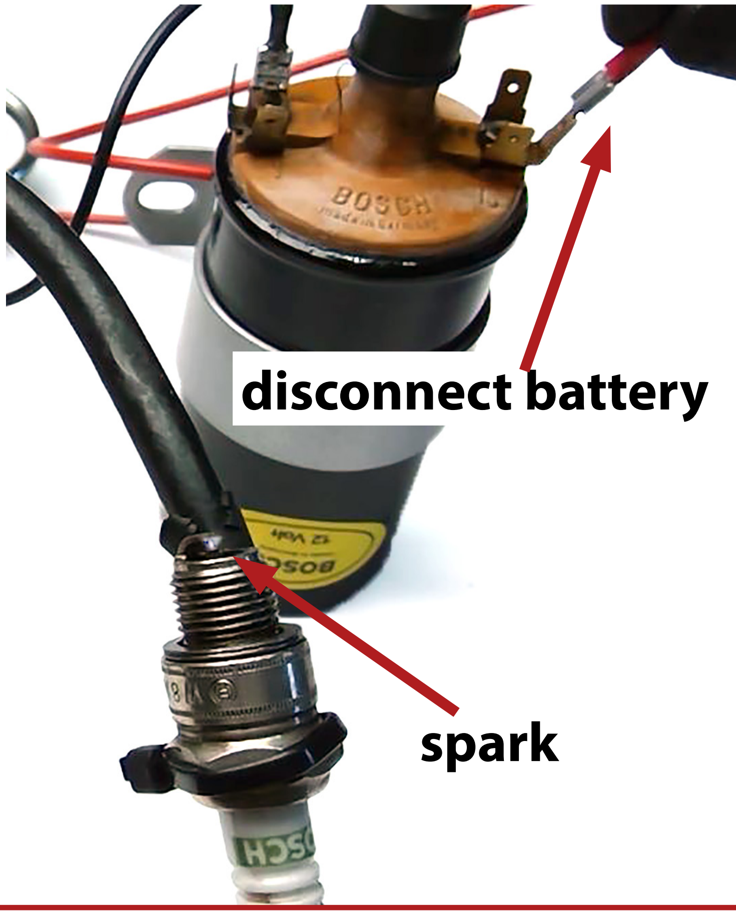
What really happens?

Be careful not to connect the Multimeter to the secondary side of the coil when the contact points open or when the battery is disconnected, this will damage your multimeter!

measuring the coil

On the pictures we show the setup. When everything is connected, nothing happens. When we disconnect the battery, a small spark occurs between the electrodes of the spark plug. When the voltage in the primary winding disappears (when the contact points of the ignition circuit open), a high voltage is built up in the secondary winding. It is a small spark, it is the condenser that will improve the spark between the electrodes.

How do we explain this? A bit of theory follows to explain this.



Faraday's law

I will forgive you if you skip these two pages and jump directly to the practical information. For those who would like an explanation of why the condenser plays a role in the ignition circuit, some theory is now explained to show why the contact points have to interrupt very quickly.

The ignition coil consists of two coils (windings). A coil is the counterpart of a condenser, it has all the opposite characteristics of a condenser.
While a condenser is a storage for voltage (electrical voltage difference), the coil is a storage for current or energy.

Michael Faraday 1791 – 1867 © www.famousscientists.org

A coil will try to maintain the magnetic field caused by the current flowing through it, or counteract an emerging magnetic field caused by a current. In other words, it will try to maintain the current situation.

Let's assume that the coil is connected to a 12V battery, through the primary winding (terminals 1 and 15) a current of 4A runs, there is a magnetic field present as Faraday predicted it.

When the voltage suddenly drops (after opening the contact points), the magnetic field would suddenly collapse, and that is what the coil wants to avoid. It will develop a counter-voltage to maintain the lost battery voltage (and the current and magnetic field associated with it).

So it does just the opposite of a condenser, the ignition coil forms a blockage for a current that is lost. The opposite voltage will be higher as the current change is greater and faster.

The opposite voltage generated by the coil is called **ElectroMotive Force** or **EMF**. The EMF will be higher as the current change increases, as the coil has more windings and as all this happens very quickly, this formula defines the proportions:

$$EMF = - L \times \Delta I / \Delta t$$

ΔI= change in current in ampère
Δt= speed of change in seconds
L= coil value in henri

#57 Electrical

ElektroMotive Force (EMF)

The theory on the previous pages explains why a spark occurs when opening the contact points. Do you like practice more than theory? Then you will enjoy what follows.

The ignition coil will try to maintain the magnetic field in the primary winding and will develop an EMF for this purpose that is many times greater than the battery voltage.

We want the highest possible voltage in the primary winding when opening the contact points, at least 200V, with a coil ratio of 100 this would give 20.000V in the secondary winding, enough to cause a spark between the electrodes of the spark plugs.

According to the formula on the previous page, the current change, the primary coil and the rate of loss of the magnetic field have an influence on the strength of the EMK, as follows:

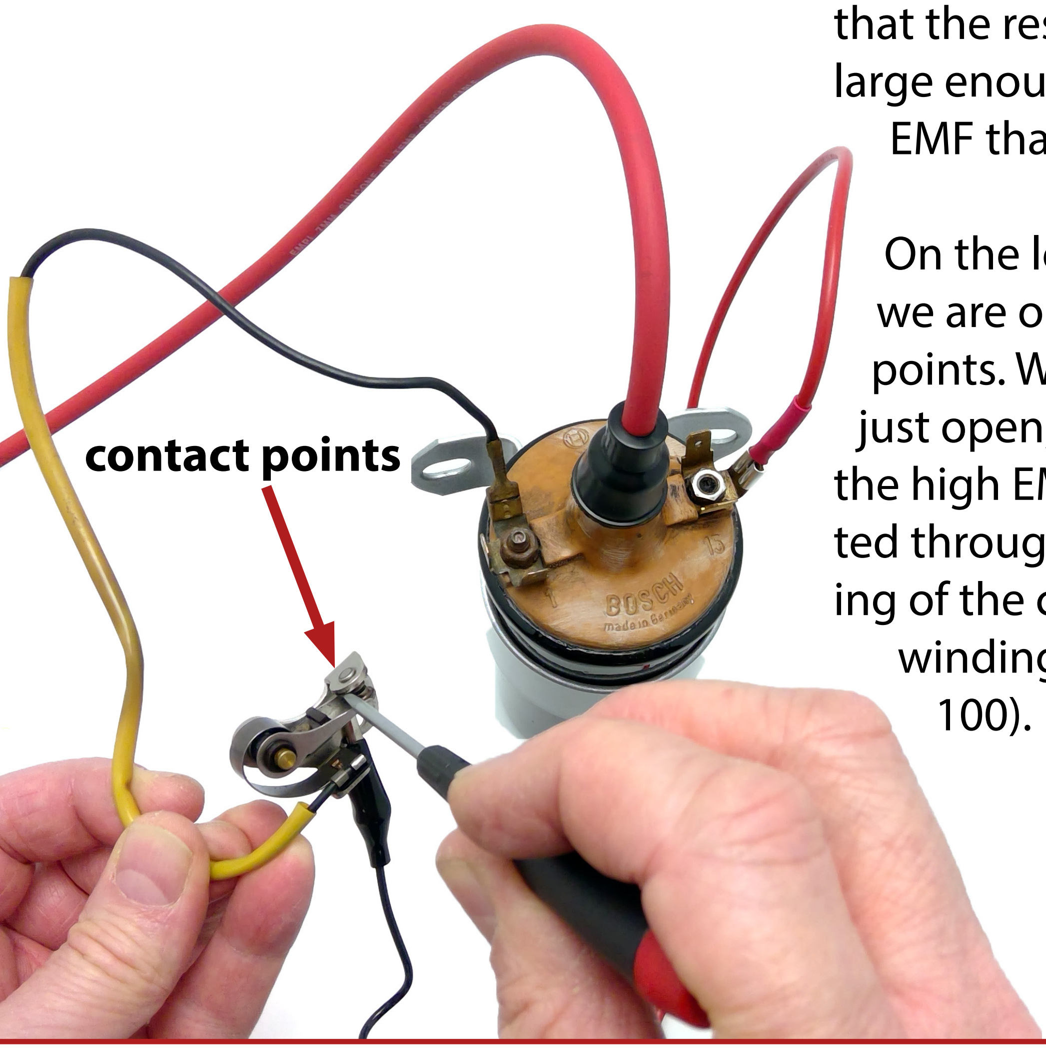
$$EMF = - L \times \Delta I / \Delta t$$

The value of the coil is fixed, which is about 10mH. The current flowing through the coil is also fixed, which is determined by the resistance of the coil, the current is about 4A. The only thing we can influence is the speed at which the current is dropping through the coil. Let's assume that by opening the contact points under ideal circumstances the current will go from 4A to 0A in 0.1 ms. Then the EMF:

$$EMF = - 0{,}01H \times 4A / 0{,}0001s$$

measuring the coil

According to this formula, an opposite voltage is created at the battery that is 400V. If we now succeed in making the current drop even faster, say in 0.01 ms, then the generated EMF is 4000V. This is very good news, so we have to make sure that the contact points open quickly to interrupt the current through the ignition coil.



The good news is also the bad news. The larger the EMF, the stronger the spark between the contact points. In the beginning the air gap between the contacts is a tenth of a millimeter, a voltage of more than 400V will cause a spark between the contacts without any effort. It is only when the contacts are the full 0.4 mm (see edition 12) apart that the resistance of the air is large enough to resist the high EMF that is generated.

On the left you can see that we are opening the contact points. When the points are just open, a spark is caused by the high EMF which is transmitted through the primary winding of the coil to the secondary winding (primary EMF times 100).

#57 Electrical

Below you can see the voltage drop when the battery voltage drops. When you open the contact points (O) you see a hesitation (t1), these are the contact points that spark. The current does not disappear immediately, the Δt of the formula increases, which has a bad influence on the primary voltage.

The scale is at 50V per distribution. When the contact points are closed, the voltage across the coil (terminals 1 and 15) is equal to the battery voltage, i.e. 12V. The voltage rises to more than 200V for 0.5 ms after opening the contact points and then quickly drops away. In total, the pendulum motion takes 1 ms (t2).

measuring the coil

Below you can see the result of a measurement with the same test setup as on the previous page, but this time with a condenser connected in parallel with the contact points. The hesitation (t1) we saw earlier after opening the contact points is now almost gone, less time is lost because the condenser short-circuits the spark.

The proof is provided, by interrupting the current, the ignition coil generates a (counter) EMF that is many times greater than the battery voltage. The voltage rises to more than 300V and also lasts longer (t3) than without a condenser, now about 2 ms.

RLC resonance circuit

But where does the pendulum movement come from? It is due to the interaction between the resistor (R) of the coil and the ballast resistance, the coil itself (L), the condenser (C) will amplify it (by RLC resonance). For an exact explanation a lot of mathematics would be needed. In practice, you're not much with these calculations either.

So, the conclusion is simple, we have to make sure that the contact points open as soon as possible to interrupt the current through the primary winding almost immediately.

In practice, this does not work very well. When the contact points open, the EMF will make sure that current flows between the points (sparks), although they don't touch anymore. This is done by the air gap between them. The air ionizes and becomes a good conductor.

This phenomenon is interesting and positive between the electrodes of the spark plugs, but less desirable between the contact points. We must therefore ensure that when the contact points open, the current is diverted as quickly as possible away from the contact points.

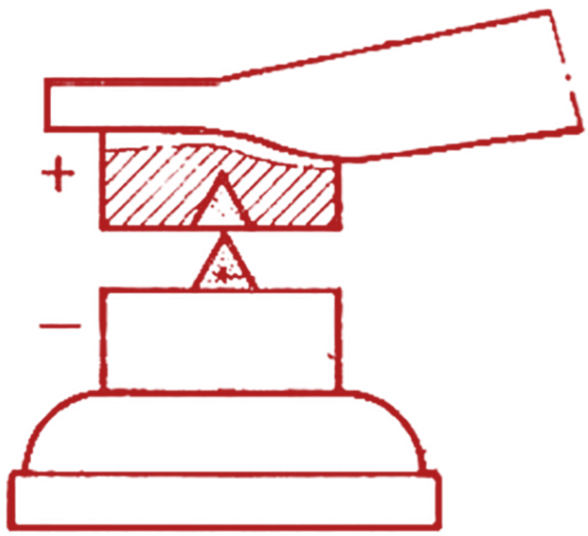
How do we do this? By short circuiting the contact points with a part that does not contain any mechanical contacts, the condenser. The operation of the condenser is discussed in detail in edition 18.

Another problem we have to take into account is that the spark for each of the four spark plugs has to occur within a certain period of time. If too much time is lost due to sparking contact points, it is possible that the pendulum movement is not over when the contact points close again, which would mean a loss of energy and therefore a weak spark between the spark plug electrodes.

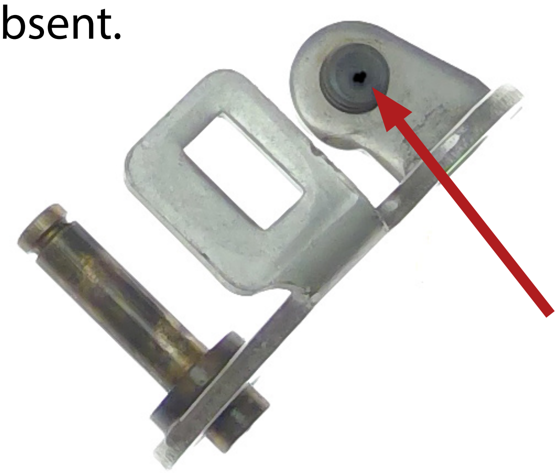
Above we show a simulation of multiple opening and closing of the contact points. The primary winding generates a voltage of more than 300V, which would mean that the secondary winding would give 30.000V (1/100 ratio). 30.000V is good, it certainly allows us to bridge the distance between the electrodes of the spark plugs to generate a strong spark.

Of course, attentive readers will notice that the condenser has a positive effect on the ignition. So, why not mount an extra large condenser, so you can get rid of all the misery and contact point sparks in one go?

Well, an oversized condenser won't have a good effect on your contact points, they'll burn in even more. From a too small (or no) condenser we know that it is not healthy for the contact points. They will burn in as shown in drawing A below.



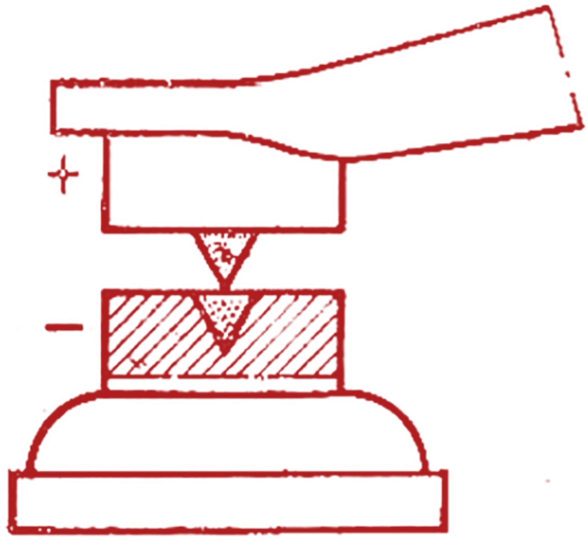
Carbon will settle on the minus side of the contact points and a crater will be formed on the plus side. On the picture below we show the minus side of a set of new contact points that have been running for half an hour without a condenser. You can clearly see carbon accumulation on the contact. The other contact is burnt in. This is the most common scenario and happens when the condenser is defective or absent.



Due to the accumulation of carbon, the ignition will be disturbed (this is explained in edition 18).

The plus side of the contact points is the movable part that is connected (with the usually green cable) to the distributor.

But an oversized condenser, so instead of 0.2µF (see edition 18) for example 0.5µF, will have the opposite effect. On the drawing on the right side we show the effect on the surfaces of the contact points.

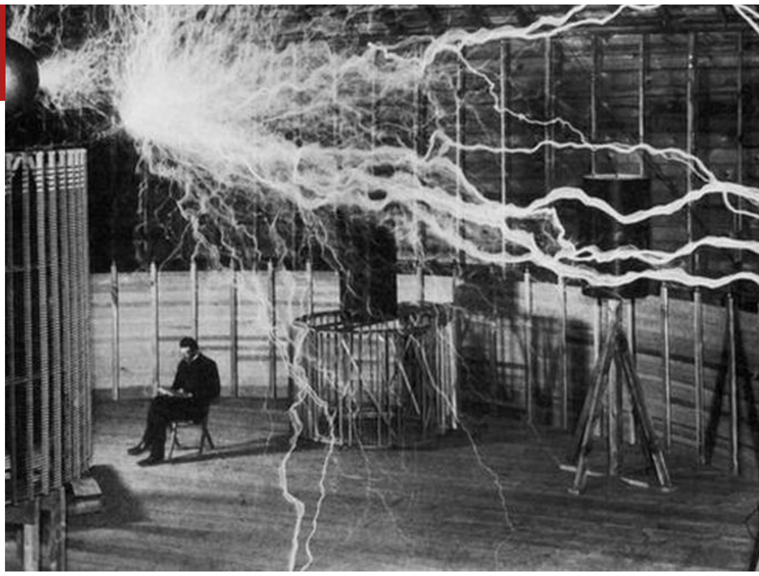


Carbon will settle on the plus side of the contact points and a crater will be formed on the minus side.

Conclusion

It is clear that an ignition circuit without condenser is not an option. The condenser does more than just protect the contact points from burning in, it plays an active role in increasing the voltage on the primary and secondary side of the coil.

So running an engine without condenser installed is devastating for the contact points but also for the engine.



We owe this technology to Faraday and Tesla (picture Tesla experiment below), without them our cars would probably have looked completely different.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