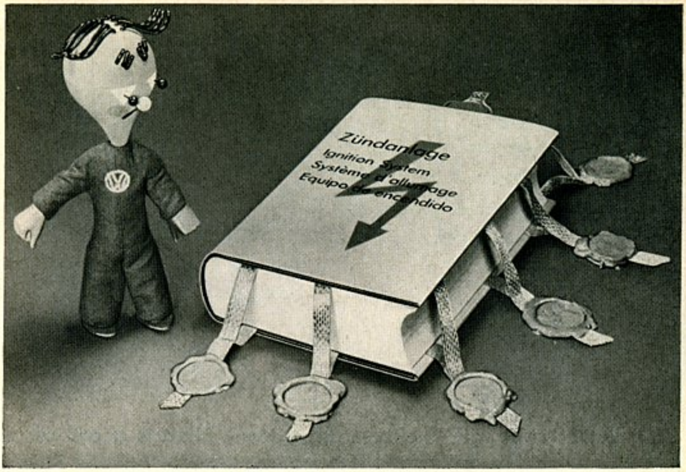
LOOK
LISTEN
DO IT BETTER

IGNITION SYSTEM

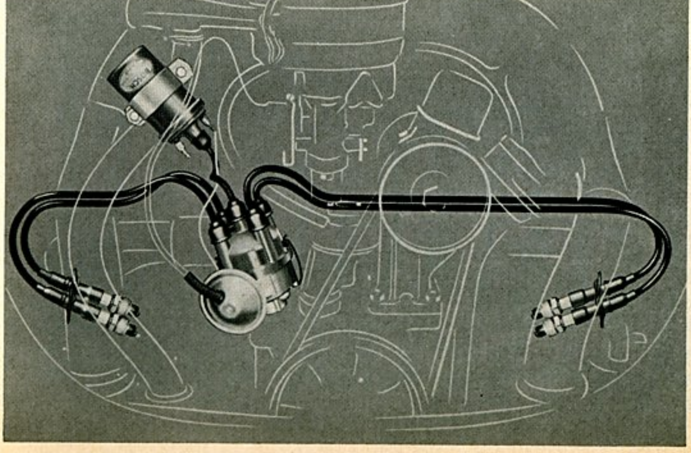
Slide Series № 27

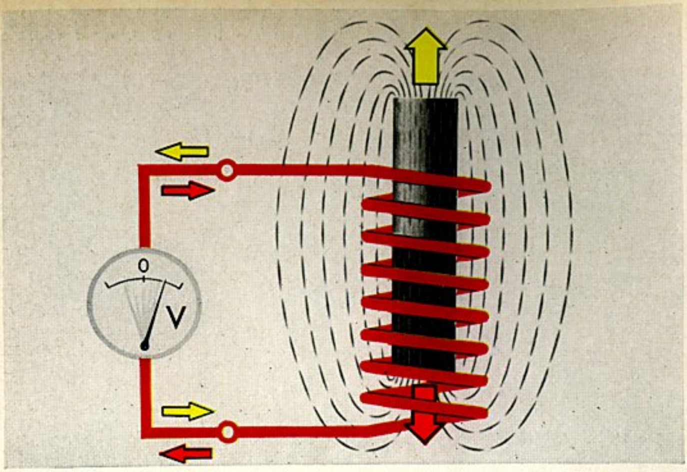
IGNITION SYSTEM



27/1 Some motor mechanics still regard the electrical system of an automobile as a sort of sealed book. The slides which you are about to see will help you to trace and rectify faults in the ignition system of the Volkswagen. We could not avoid bringing in a certain amount of theory but in order to be able to work properly, you must understand the basic principles.

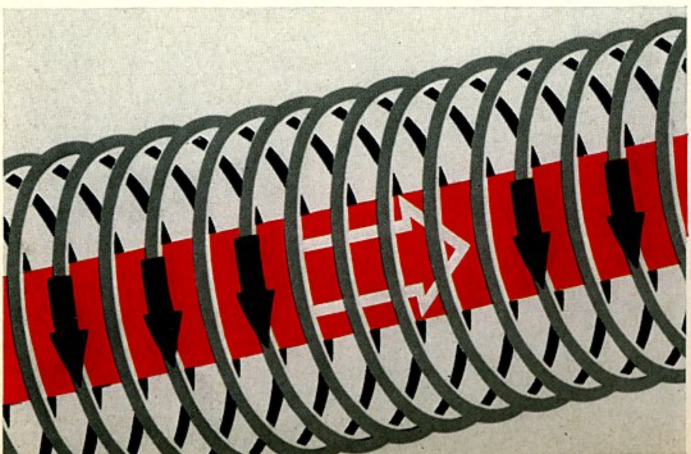
27/2 You all know these parts of the ignition system, but what takes place inside them. How does the ignition coil work for example? As one cannot see electricity, we have had to demonstrate the processes with diagrams.



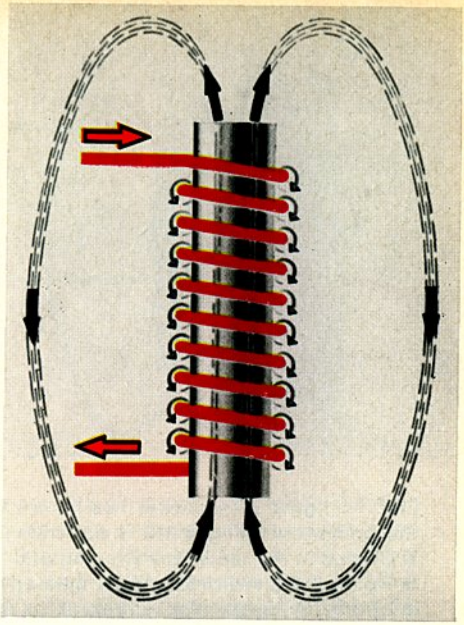


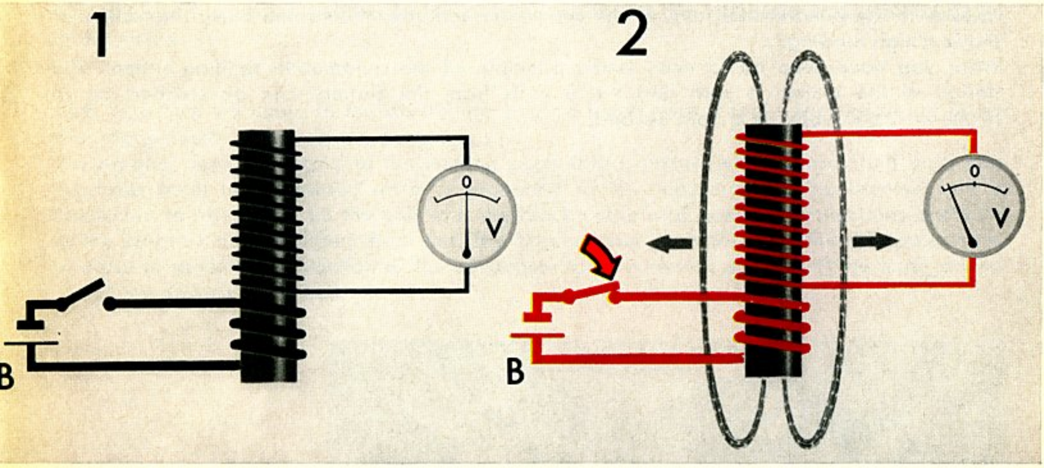
27/3 Let us start with a simple experiment. Here is a coil of copper wire connected to a voltmeter. A bar magnet can be moved up and down inside the coil. If you move this magnet, the lines of magnetic force which are shown dotted, move past the loops of wire. This will generate an electric current in the coil as shown by the voltmeter needle. Please bear in mind that the quicker the magnet is moved and the more turns of wire there are in the coil, the greater the voltage will be.

27/4 It is also possible to create magnetism with electricity just as it is possible to create electricity with magnetism. This is done as follows. An electrical current is passed through the coil of wire in our sketch. This sets up a magnetic field round the wire. The direction of flow of this magnetic field is shown by the circles.

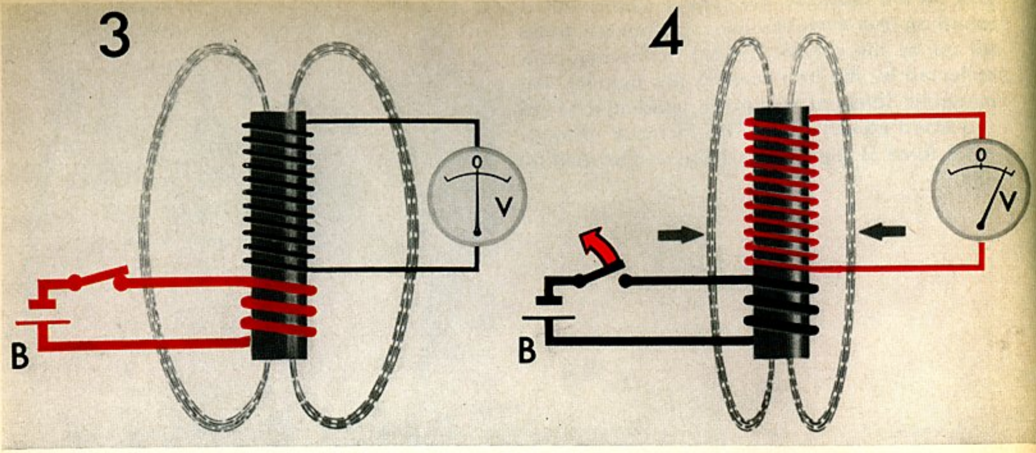


27/5 In this diagram, the copper wire is coiled round an iron core. The lines of magnetic force set up by the electric current in the coils are collected by the iron core. In this manner, the magnetic force of a electric winding can be increased considerably. This increase in magnetic force is put to good use in the ignition coil.





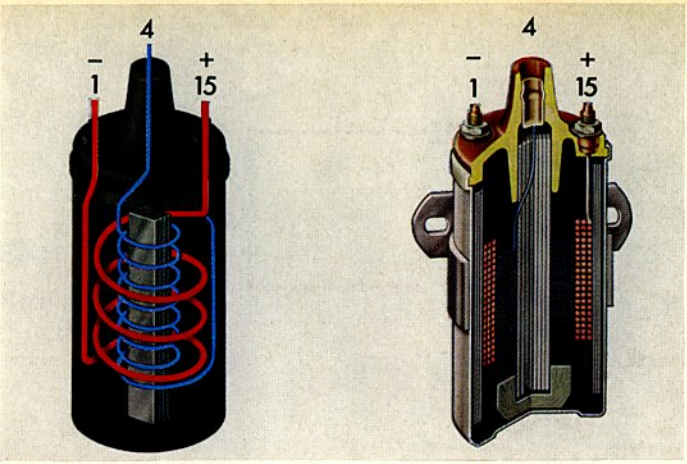
27/6 Figure 1 in this picture shows an iron core with two separate windings. One consists of a few turns of thick wire, known as the primary winding and the ends of the wire are connected to a battery B. The other winding which is made up of numerous turns of very thin wire is called the secondary winding and is shown here connected to a voltmeter. In figure 2, the switch has just closed. The current flows through the primary winding and creates a magnetic field. This magnetic field spreads through the two windings shortly after the current is switched on and sets up an electrical current in the secondary winding as shown by the voltmeter reading. This only applies, however, as long as the current and thus the magnetic field is changing.



27/7 In figure 3 the switch has been closed for some time. Current is still flowing through the primary winding but it is not changing any more. This means that no electrical current is created in the secondary winding and the voltmeter reading is zero.

In figure 4 the switch has been opened suddenly. The magnetic field shown in the previous diagrams collapses. All references to time used here are meant in fractions of a second and this also applies here. The rapid change in the magnetic field creates a very high voltage in the hundreds of turns in the secondary winding, shown thin here. The voltmeter shows a high reading.

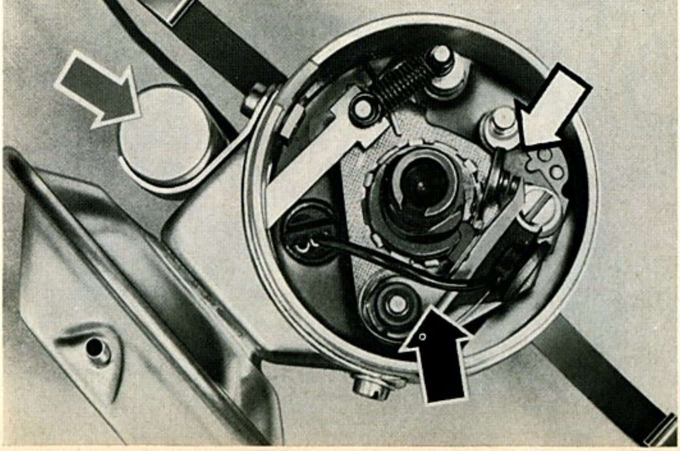
What you have seen up to now, is the principle of the automobile ignition system. The design of the system is such that the 6 volts from the battery can be stepped up to 10 000 — 20 000 volts in a split second.

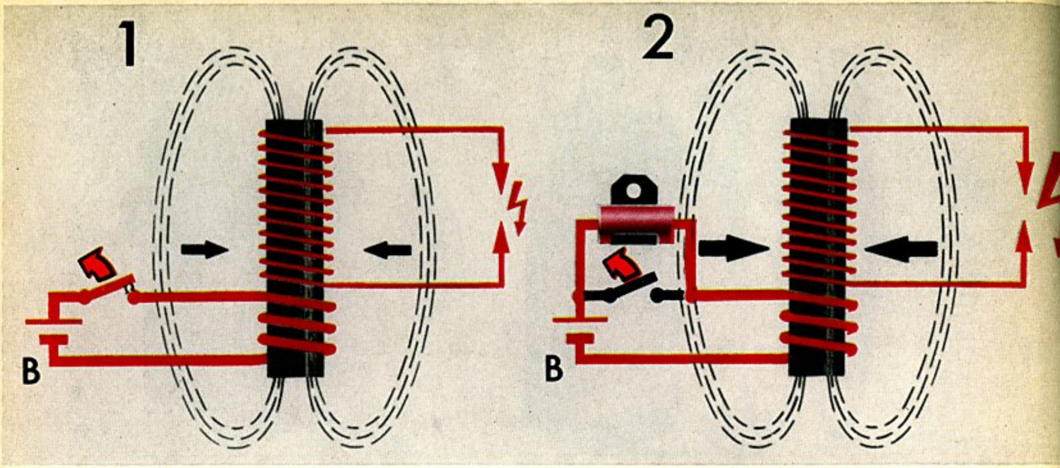


27/8 This is exactly what takes place in an ignition coil the construction of which is shown here. The coil is made up of primary and secondary windings, wrapped round an iron core, one over the other, just as shown in our first few diagrams. One end of the red primary winding is connected to terminal 15 together with one end of the blue secondary winding. The remaining winding ends are connected separately. Terminal 1 is the point at which the low-tension cable for the distributor is connected and the high-tension current is taken from terminal 4 in the center and led to the distributor cap. On the right is a cross section of an ignition coil.

27/9 And now we come to the distributor. You all know what it looks like inside but let us look more closely at the various parts.

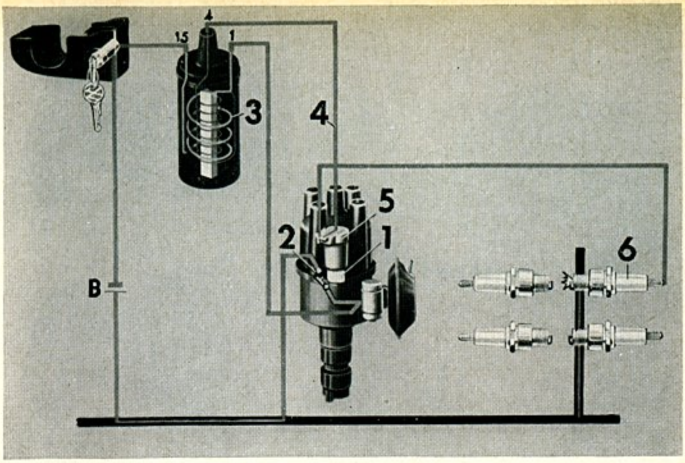
The breaker contacts consist of the moving point (black arrow) with its insulating bush and the fixed point (white arrow) which is grounded to the vehicle mass. The breaker arm is connected to terminal 1 on the coil with the black cable and push-on connections and acts as the switch in our simplified diagrams. The breaker arm is operated by the distributor cam. In order to explain the function of the condenser (grey arrow at upper left) we must remind you of the process in the coil.





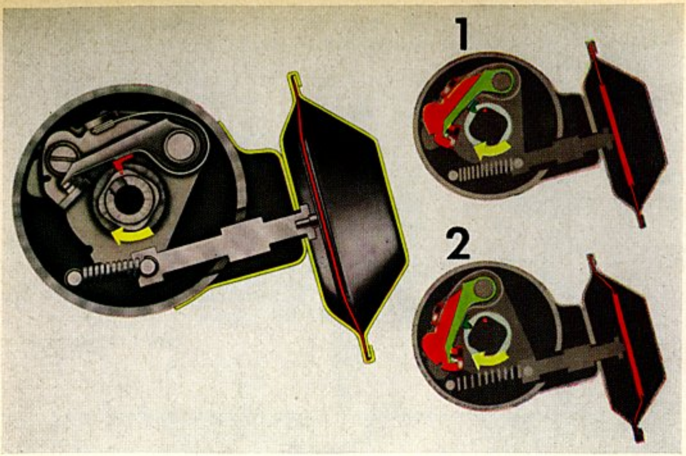
27/10 In figure 1 the breaker contact is just opening. The magnetic field collapses and the ignition current builds up in the secondary winding. Unfortunately, the same collapsing magnetic field also affects the primary winding and creates a new surge which can be anything up to 100 — 200 volts and results in heavy sparking at the breaker points. This spark formation is undesirable because it delays the rapid fall-off of the magnetic field and causes burning of the contact points. You will remember that earlier on we said that the quicker the magnetic field collapses the higher the voltage will be in the secondary winding. And that is just what we want.

In figure 2 we have bridged the breaker contacts with a condenser. A condenser can absorb lots of electrons quickly like a sponge absorbs water. This almost completely stops the sparking at the points just mentioned and speeds up the break down of the magnetic field. As we have already seen, this means that the voltage produced by the coil is considerably higher and it also shows how important a part the condenser plays in the ignition system.



27/11 This drawing shows you how the sparks get to the cylinders in the correct sequence and at exactly the right moment. The black line at the bottom is the vehicle mass. The breaker cam (1) is driven from the crankshaft and opens the points (2) shortly before the piston in the cylinder to be fired has reached top dead center. This interrupts the current in the primary winding of the coil (3). The current now built up in the secondary winding passes via the high-tension cable (4) to the distributor rotor arm (5) which at this moment is opposite the correct contact in the distributor cap so that the current flows to the spark plug (6) of the cylinder to be fired. A spark then jumps across the plug electrodes and fires the compressed fuel/air mixture in the cylinder.

27/12 The firing point is of great importance to the operation of the internal combustion engine. It depends to a large extent on the speed and loading of the engine. In the early days of motoring, all automobiles were fitted with levers so that the driver could select the correct firing point himself. Nowadays this method would hardly be adequate. An automatic spark advance is used to alter the firing point to suit all driving conditions.

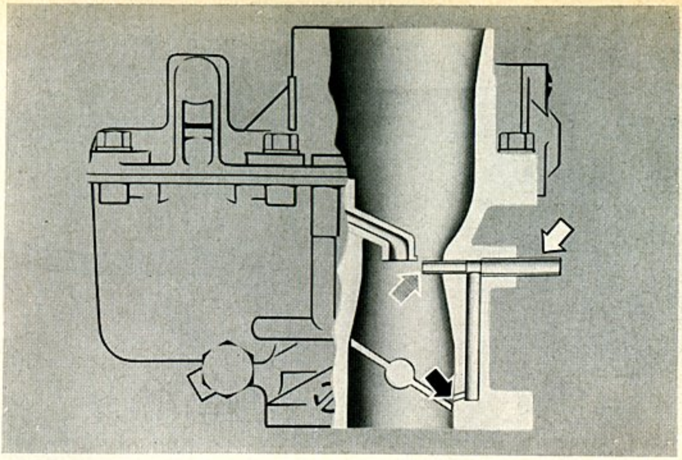


27/13 The automatic spark advance is operated by vacuum which is taken from the carburetor. This mechanism works as follows:

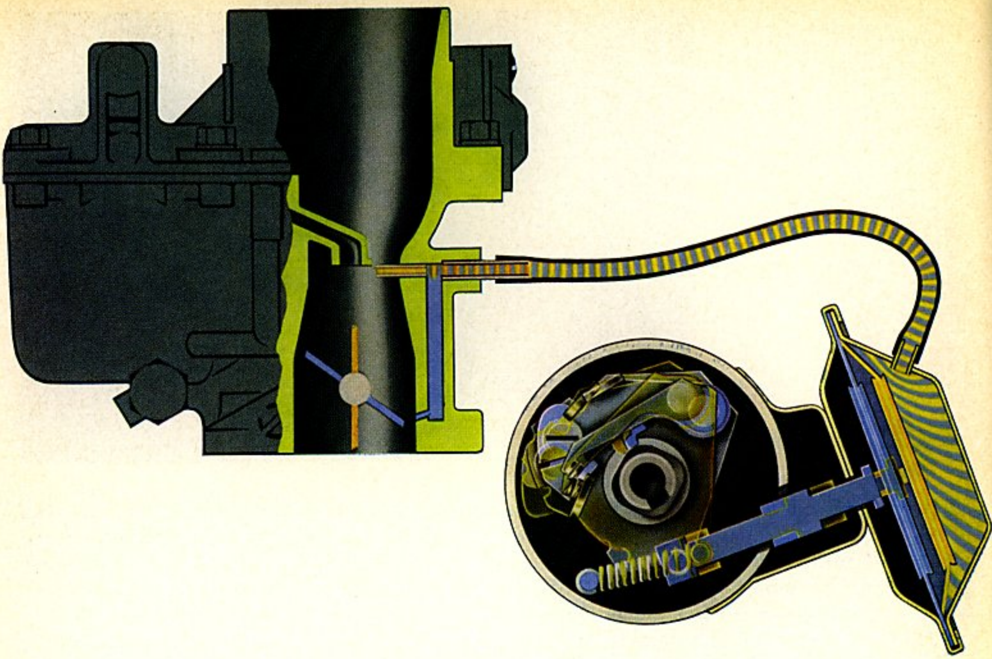
The large sketch on the left shows the rest position. Diaphragm and contact breaker plate are on the stops; the breaker contacts have just opened. The yellow arrow shows the direction of rotation of the distributor cam.

The small sketch 1 shows the partly advanced position with the diaphragm in the center. The breaker plate has been moved against the direction of rotation of the cam so that the next cam lobe lifts the breaker arm earlier.

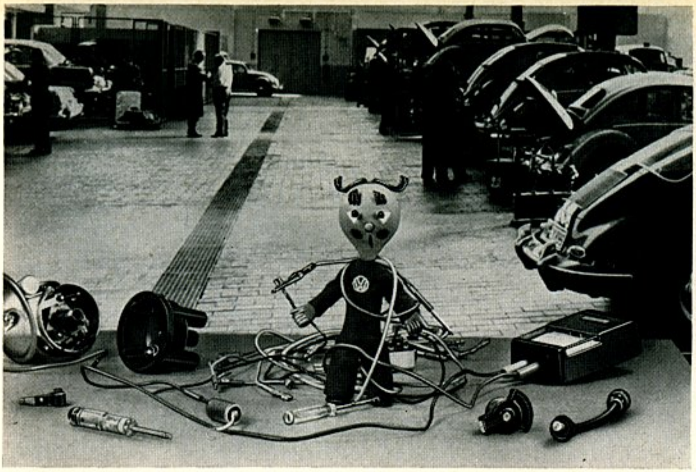
Sketch number 2 shows the fully advanced position with the diaphragm at the end of its travel. The cam lobe now reaches the breaker arm even earlier. With reference to the engine crankshaft, this means fully advanced ignition.



27/14 The vacuum which controls the movement of the diaphragm in the distributor is created in the carburetor. As the control of the firing point must be dependent partly on the engine speed and partly on the load on the engine, there are two vacuum drillings in the carburetor. The drilling for engine speed control of firing point (grey arrow) is at the narrowest part of the venturi under the fuel discharge arm. The black arrow points to the second drilling near the throttle valve. The amount of vacuum here depends on the engine loading and on the position of the throttle valve. Both drillings are connected to one another inside the carburetor body. The small hose leading to the vacuum unit on the distributor is attached to the connection indicated by the white arrow.

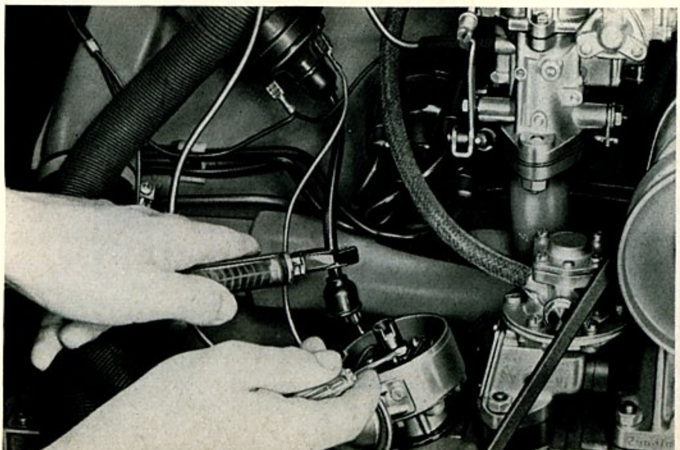


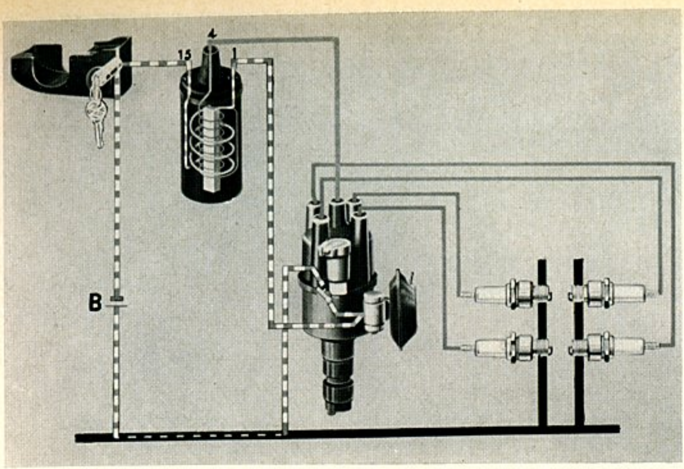
27/15 The vacuum at the throttle valve is only slight when the engine is under full load, but at part load there is a very high vacuum. In the venturi, the amount of vacuum depends on the quantity of air being drawn in by the cylinders. It is therefore higher at this point when the engine speed is high.
The vacuum influences the diaphragm in the vacuum unit on the distributor. The diaphragm moves outwards a varying amount in accordance with the amount of vacuum and turns the breaker plate. The throttle valve and breaker plate positions shown in blue indicate the part load conditions and those in yellow the full load positions at high engine speeds.
The vacuum proportions are shown in blue or yellow accordingly.



27/16 Well, so much for the basic principles. It wasn't really so bad, was it? We shall now go on to see how we can put this knowledge to good use in actual practice. Before we start, however, just a word to you, as mechanics. Always work systematically and think when searching for defects. Just haphazardly replacing parts will probably cure the trouble eventually but it takes time and time is money for you and for our customers.

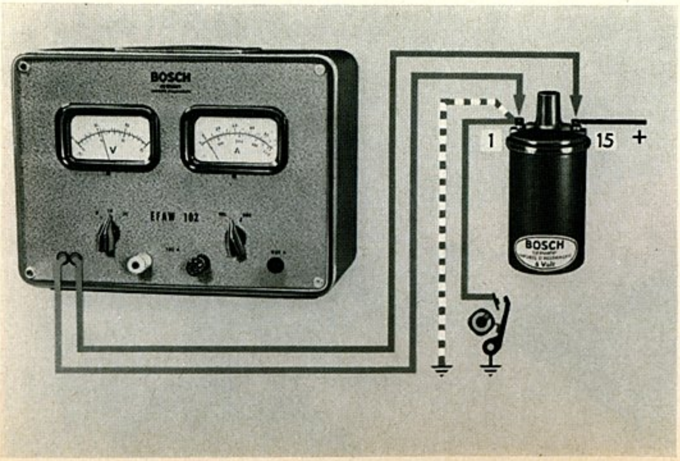
27/17 Just assume that you have to examine an engine which will not start.
To check if the ignition system is in order as far as the coil, take the high tension cable out of the center of the distributor cap and hold it about 10 mm (.4") from a suitable ground. Be careful how you hold the cable as otherwise you will get a shock. The best way is to use a pair of insulated pliers.
Switch the ignition on and open and close the points quickly with a small screwdriver. Every time the points are opened, a spark should jump from the cable to ground. If this is so, it can be taken for granted that the ignition system up to the coil, and the coil itself, are in order. The fault must be in the ignition cables or spark plugs but we shall come back to this point again later. It is advisable to check, at this stage, that the points are actually being opened by the distributor cam.

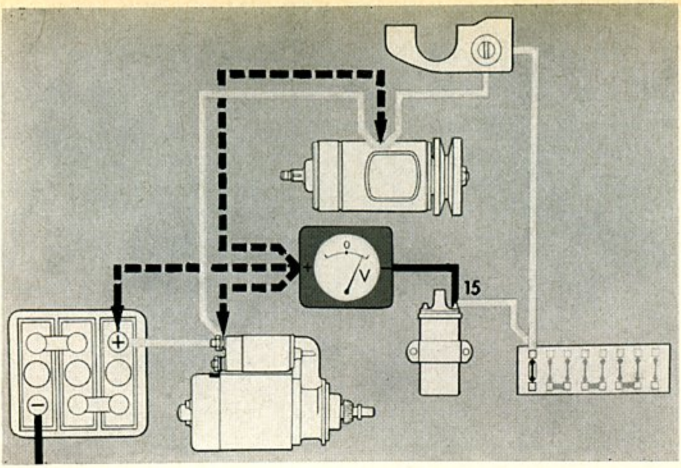




27/18 If there was no spark in the previous test, we can assume that the fault is in the low-tension circuit and it must be located by working systematically. Here is the wiring diagram to remind you. The low-tension ignition circuit is shown dotted. On the next few pages we shall show you some possible defects.

27/19 First we must know if there is current at terminal 15 on the coil. This can be checked with a test lamp, but it is better to use a voltmeter so that we can see if the voltage is not less than 5.5. The ignition must be switched on of course. Just in case the points are open, bridge them by fitting a piece of cable from terminal 1 on the coil to ground as shown here by the dotted line. Then get someone to operate the starter. The engine cannot start because the contacts are shorted by the extra cable. You thus have plenty of time to check the voltage while the starter is working. It must not drop below 4.5 volts, for a 6 volt system that is.

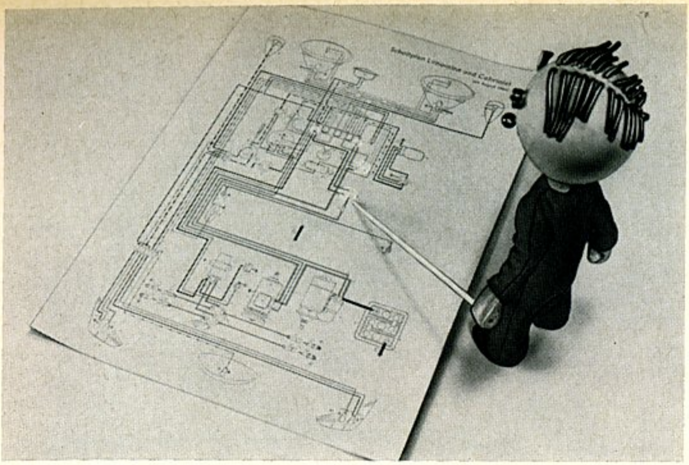




27/20 If the voltage is too low, it can be the battery, but in our case we shall assume the battery is o.k. This leaves only the notorious voltage drop in the cables to the coil. To locate the trouble, proceed as follows:

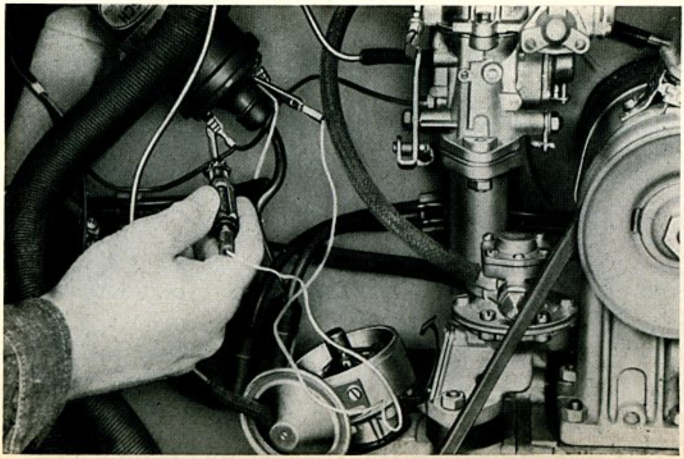
Switch the voltmeter to the smallest measuring range (3 volts for example) then connect the negative cable of the meter to terminal 15. Fit an extension cable to the positive side and measure all the connections through which current passes to the coil, starting with the battery positive terminal. The faulty connection has the largest voltage drop. For example, you have a reading of 0.7 volt at the battery positive, 0.5 volt at the starter and 0.1 volt at the regulator. The last but one connection, the starter, is faulty.

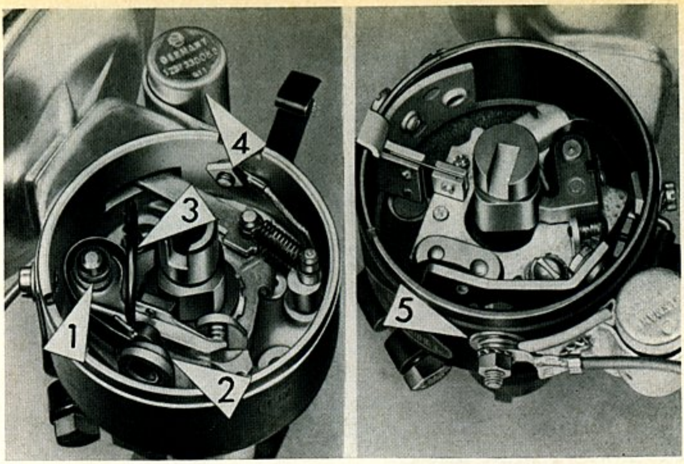
Do not forget that the checks can only be made with the ignition switched on.



27/21 The wiring diagrams in the workshop manuals are useful when searching for faults like this. In our VW 1200 wiring diagram we have circled all the possible sources of trouble, that is to say, the connections which may be loose in the cables leading to terminal 15 on the coil. You must obviously have the proper diagram for the vehicle concerned.

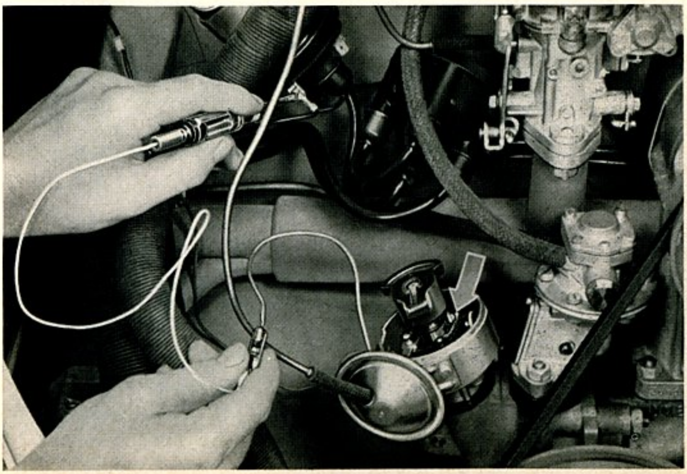
27/22 The ignition coil is grounded via terminal 1 and the breaker contacts. The defect can be here. Check by connecting a test lamp to terminals 1 and 15 on the coil and turning the engine on until the points in the distributor are closed. The lamp should light up. If it doesn't, then the points are probably dirty or burnt. If it does light up, open the points again to see if it goes out.

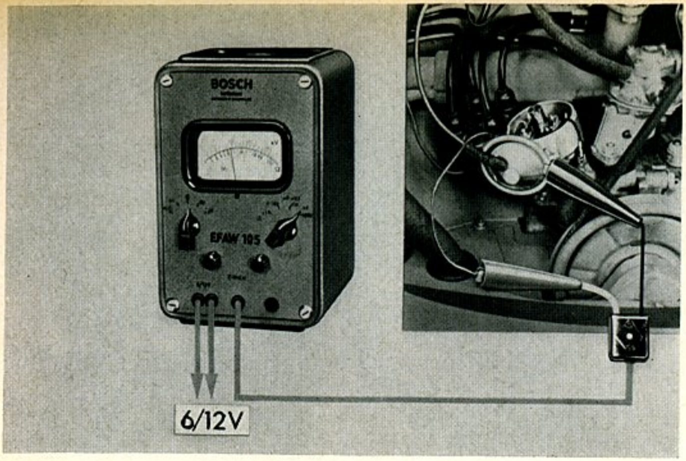




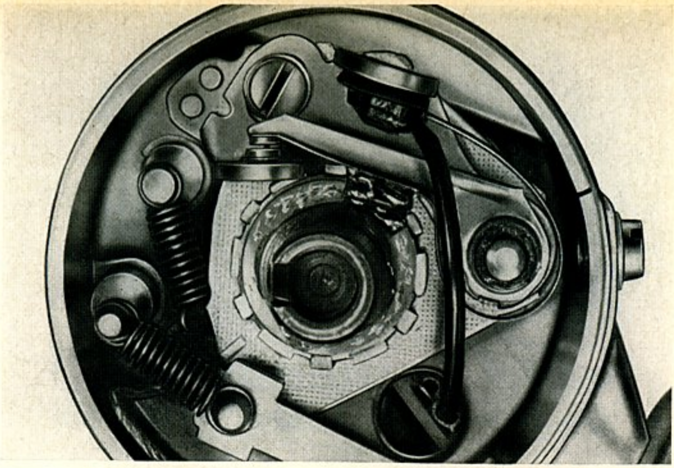
27/23 If the lamp does not go out when the points are opened, there is a short in the distributor. The following parts should be checked in the new distributors: On the left, in the Bosch distributor (1) the breaker arm bush, (2) insulation on breaker arm spring, (3) cable and (4) condenser. In the VW distributor on the right there is one additional part, namely the insulation of the connecting screw which may be incorrectly installed or defective (5).

27/24 Experience has shown that the condenser very seldom shorts. Despite this, we must know how to check a condenser. The easiest way is with a test lamp. Disconnect the cable between coil and distributor, switch the ignition on and connect lamp to terminal 15 on the coil and the green cable on the distributor. The lamp must not light up when the points are open (arrow). If it does, there is probably a short in the condenser and a new part must be fitted.

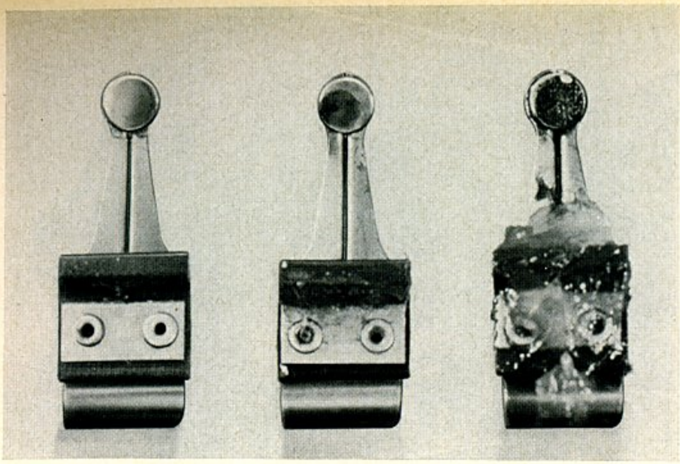




27/25 With a test lamp, the condenser can only be checked for short circuits but there are testers with which one can test for insulation resistance, capacity and series resistance. The insulation resistance should be at least 200 thousand ohms or 200 kilo-ohms otherwise the insulation between the plates of the condenser is poor and a new part must be fitted. It may also be found that, in the course of time, a resistance builds up between the condenser plates and the case or connecting cable. This is known as series resistance and it prevents the condenser from carrying out its function of absorbing the self-induction current from the coil. Poor ignition and badly burned points are caused by faulty condensers.
The condenser need not be removed for testing if you ensure that the points are kept open or the low-tension cable disconnected at the distributor.



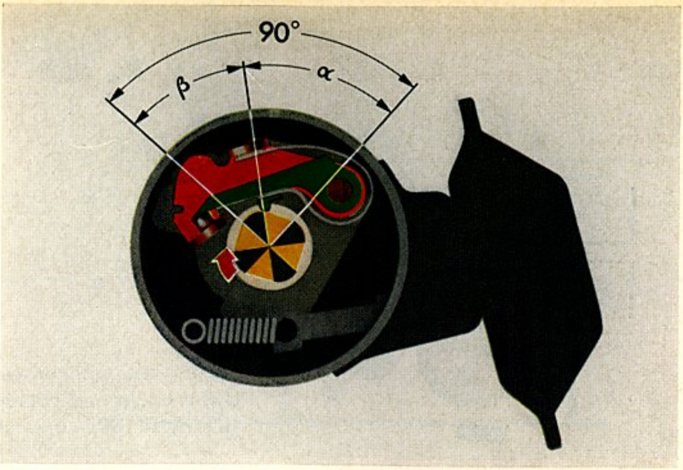
27/26 This distributor was sent to us with the comment that it was causing misfiring. We don't doubt that at all, but why? Someone had oiled and greased it generously inside. He probably meant well but he overdid it so that the contacts got greased as well. The grease then burns on the points, forms oil carbon and causes misfiring.
The only thing to be greased in the distributor is the fiber block on the breaker arm and only the smallest quantity of lithium grease should be used here. When setting the points, always ensure that the feeler blade is clean. A careful mechanic pulls a piece of clean card through the points after setting them in order to remove any possible traces of grease. Distributors like the one shown here should of course be thoroughly cleaned.



27/27 While we are on the subject of points, here are three typical contacts. Only one is not fit for use. The point on the left is almost new. The slight burn marks which appear after a few miles use can be seen clearly.

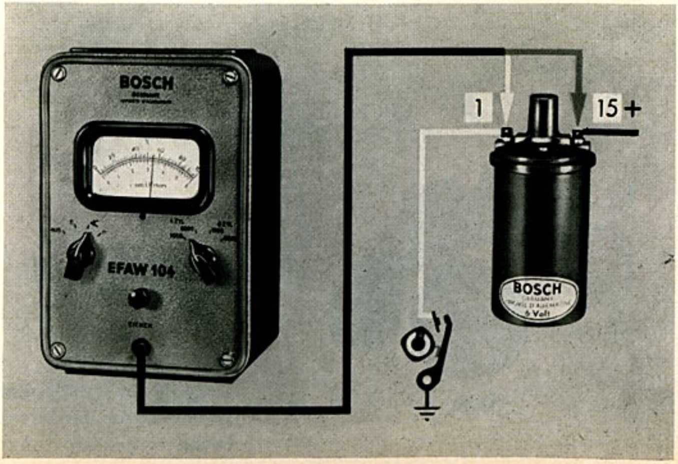
The point in the center was sent in as unfit for use. It has a larger build-up of material, it is true, but this would not normally affect its operation in the distributor. Points in this condition do not need to be replaced. If they are replaced during a maintenance check, it is no use trying to claim costs from the manufacturers of the contacts.

The point on the right is not fit to use. It was taken from the oiled-up distributor which we saw a minute ago and the black burnt appearance which is typical of oil carbon can be seen clearly. These points could be cleaned up with an oil stone but it would be better to fit new points after cleaning the distributor thoroughly.



27/28 At the beginning of this slide series we said that when the points are closed a current flows through the primary winding of the coil and builds up the magnetic field required. The current must flow for a certain period of time to do this so the points must not be opened again too quickly. The measurement of the time the points are closed is known as the dwell angle or cam angle (Alpha).
This is the angle through which the distributor cam has to turn in order to open the points again. Beta is the angle through which the points are open. Dwell angle and the angle the points are open added together make 90° in the case of a four-stroke, four-cylinder engine.

27/29 The dwell angle is influenced by the breaker point gap which is why you should set the gap to 0.4 mm (.016") at every maintenance check. This breaker gap setting is really just an indirect dwell angle setting. The angle can be set more accurately with a dwell angle tester, which, when connected properly, gives the dwell angle as a pointer movement. The dwell angle must not vary more than ± 4 % from the figure given for the distributor concerned. All these figures are listed in the workshop manuals and the test cards for the various distributors.



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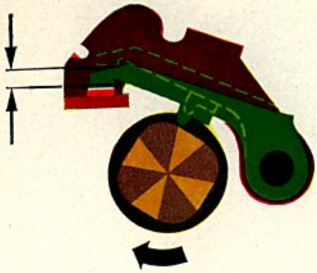
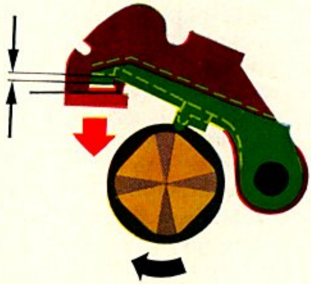


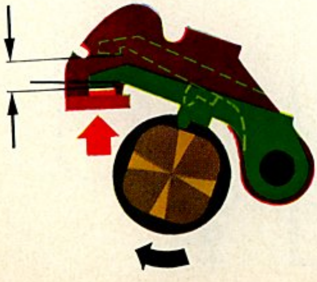
27/30 Here you can see the relationship between dwell angle and contact gap. In figure 1 the gap and dwell angle are correct.

2



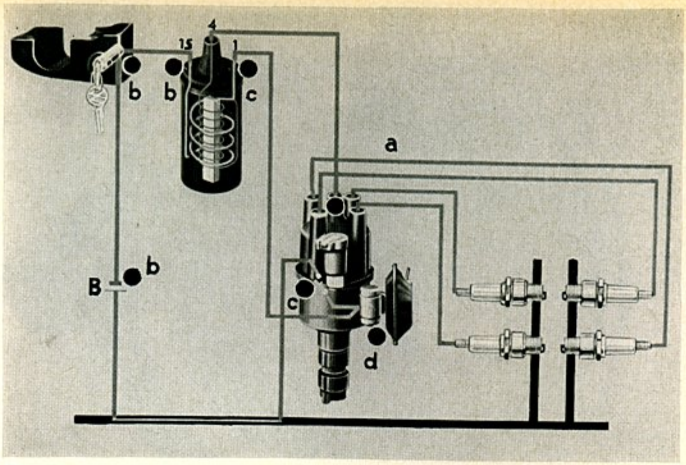
In figure 2 the gap is too small and the resultant dwell angle too large.

3



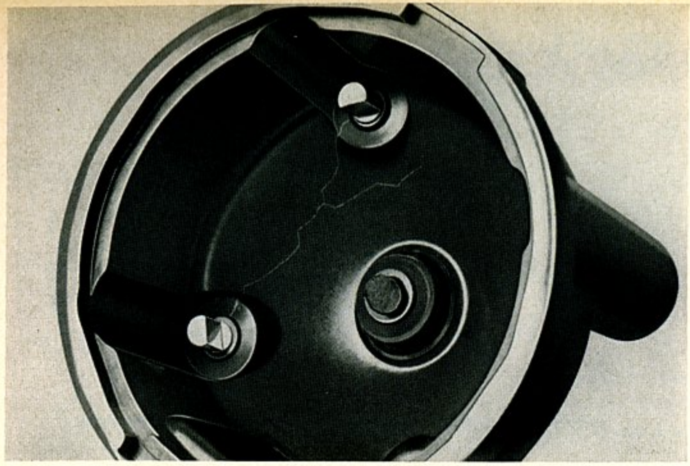
In figure 3 the gap is too large and the dwell angle too small.

The rule for rectification is:
Dwell angle too large, gap must be increased.
Dwell angle too small, gap must be reduced.

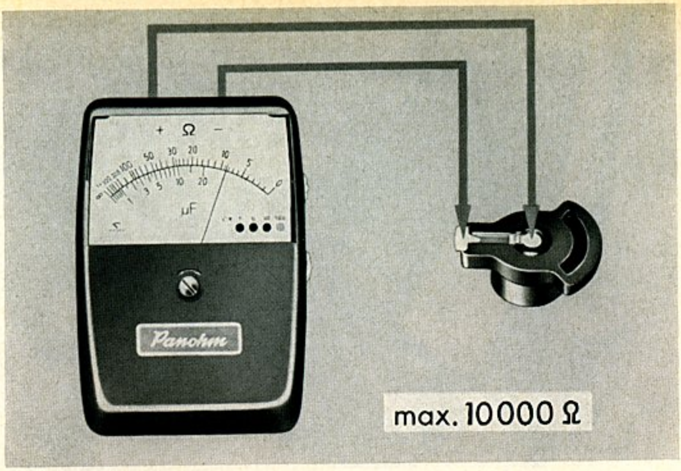


27/31 Having heard our suggestions for trouble shooting on the low-tension circuit of the ignition system, you may get the impression that it is all rather complicated. Let us just go over the main points again: The small spots show you the best way to go about checking the system.

Spot 'a' on distributor: Hold high-tension cable to ground. Does a spark jump across?
Spot 'b' on left: Is the coil getting current from battery via ignition switch. If not, why not.
Spot 'c'. Is terminal 1 being grounded properly via the breaker points in distributor.
Spot 'd'. Is the low-tension circuit in distributor in order.
These four checks which can be carried out quite quickly give accurate information on what is really defective.

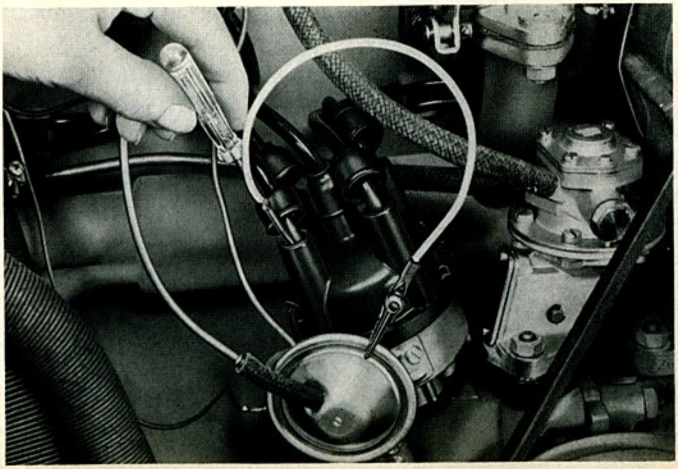


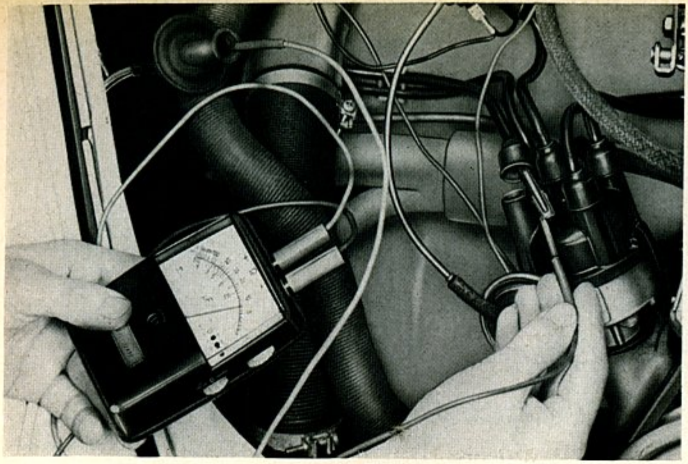
27/32 We shall now go on to deal with the high-tension side of the ignition system in the same way. Let us assume that an engine is misfiring. Everything is in order as far as the distributor cap so the defect can only be in the ignition cables, the plug connectors, the plugs, the distributor cap or rotor arm. In this picture you can see two typical defects in the distributor cap: Hairline crack and a broken carbon brush. The brush can be replaced but the crack means that a new cap must be fitted.



27/33 The VW engines with black ignition cables have a suppressed rotor arm in the distributor. The small resistance moulded into the rotor arm can be tested with an ohmmeter. The resistance can be up to 10 kilo-ohms. If it is larger or if the meter shows no reading at all, throw the rotor arm away.

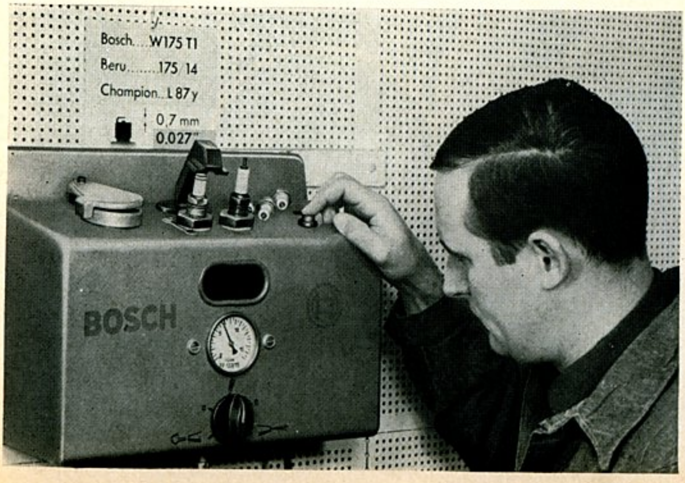
27/34 To find a faulty ignition cable we can use the old trick of shorting out the cables to the cylinders one by one. The cable which does not alter the engine speed when shorted is the faulty one. In this picture, the mechanic is using a small screwdriver to which he has soldered a piece of cable for shorting purposes. On the Volkswagen it is advisable to short out the cables at the distributor cap.





27/35 The next step is to examine the ignition cables. The ohmmeter can also be used to do this. The resistance in the plug connectors on the black cables should be 5 to 10 kilo-ohms. At the same time, check the insulation of the cables and remove all traces of moisture and dirt from cables and connectors.

27/36 And now to the spark plugs which must be removed for a proper inspection. As you all know, the appearance of the plug face can provide information on the condition of the engine. You all also know how to use a plug testing and cleaning machine. Please bear in mind that plugs which have a brown coating of lead on the insulator can be quite in order when cold but cause misfiring when hot. This brown coating only becomes a conductor of electricity when warm. Plugs like this must be cleaned thoroughly with a sand blaster but do not sand blast them too long as otherwise the nose of the insulator will be roughed up too much.
Here are a few details about plugs which you should always remember:

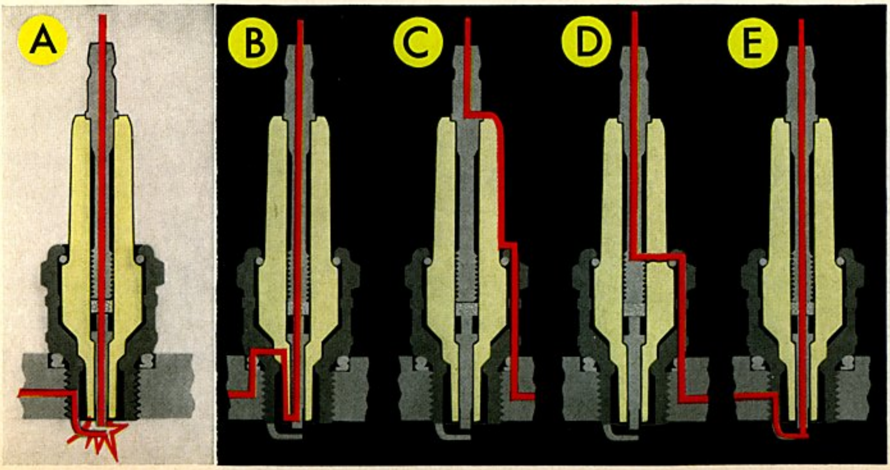


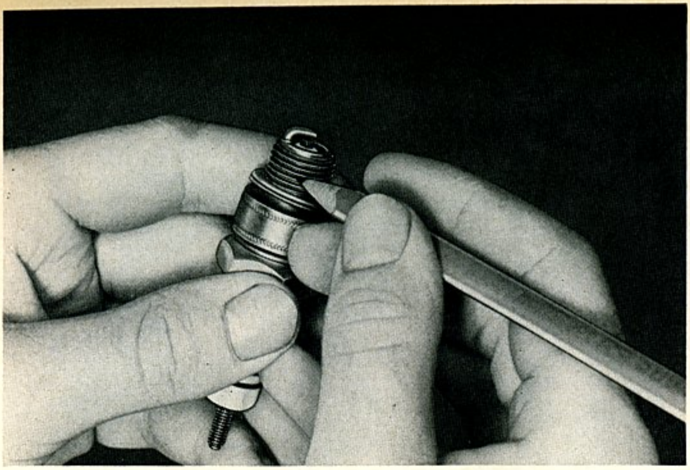
All Volkswagens, new and old models, must only be fitted with plugs with a heat value of 175. The following plug types are used at the factory:

Bosch W 175 T 1
Beru 175/14
Champion L 87 Y

Plugs with other heat values must not be installed. The electrode or plug gap is also important. It is normally 0.7 mm (.028″) but it can be decreased to 0.6 mm (.024″) when the weather is very cold in order to facilitate starting.

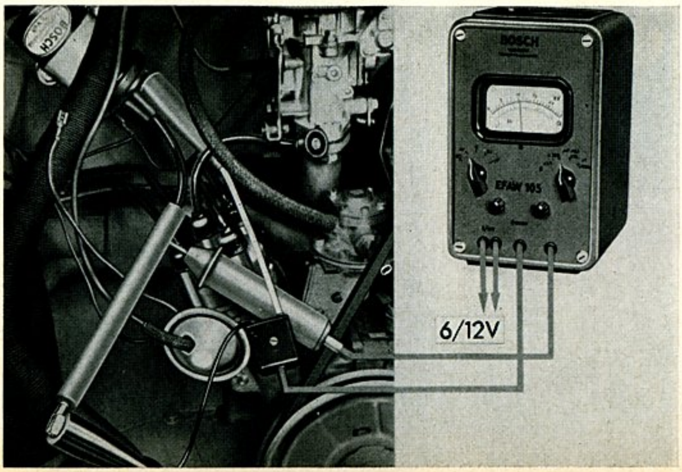
27/37 The spark should jump across the plug electrodes when the plug is tested as it should in the engine but plugs can have shorts-circuits or, in other words, the current can take an easier, shorter path to ground. The path of the current is shown in red in our picture. Figure A shows the proper path. The plug at B has a short circuit at the tip of the insulator. Remedy: Sand blasting. At C the insulator is dirty and at D it is broken. Plug D must naturally be thrown away. Plug E has a short circuit at the electrode either because it is dirty or because the ground electrode is touching the center electrode. Remedy: Cleaning or setting the gap.

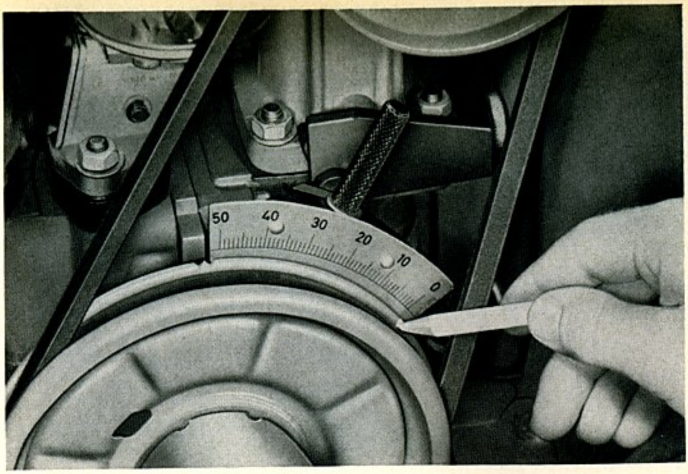




27/38 Here is a tip for use when installing plugs. Some plugs are very hard to get out of the cylinder head. You have all probably had this sort of trouble. This can be avoided by rubbing the plug thread with a soft pencil before the plug is installed. The graphite in the pencil lead prevents the plug from burning tight in the head. Keep oil and grease off the threads as plug they will increase this tendency.

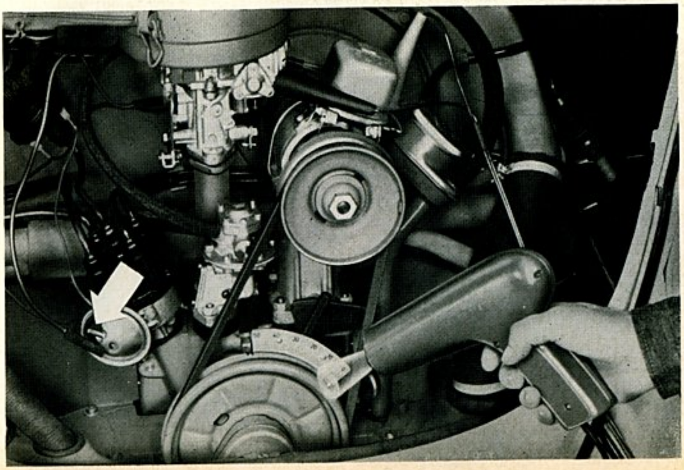
27/39 We have only spoken about the coil theoretically so far but shall now go on to see how it is tested. There is also a proper tester for this purpose. The tester shown here is the same one as was used to test the condenser. It can be used to carry out high-tension tests on the coil when it is installed. With a 6 volt system the voltage required for the high-tension side is about 8 to 12 000 volts. There are lots of testers with which it is possible to measure such a voltage. When testing coils, it is always best to follow the instructions given for the particular tester being used.

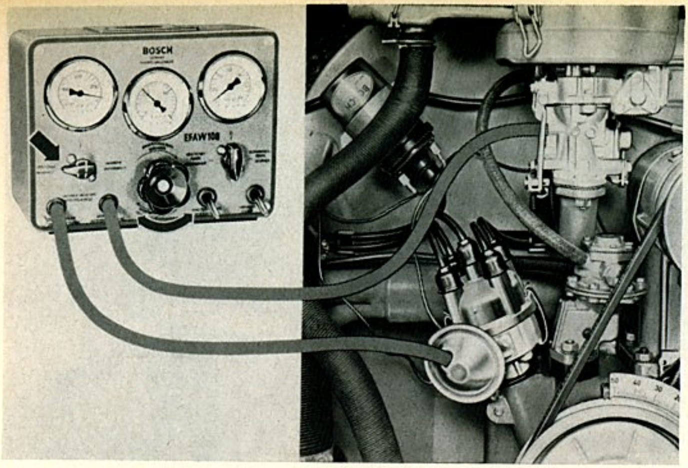




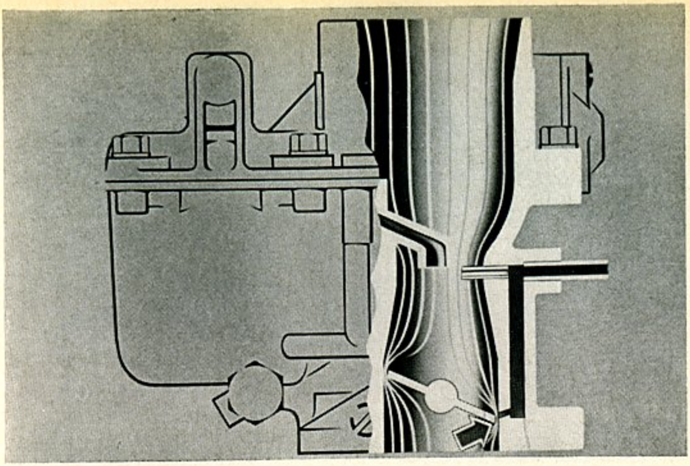
27/40 And now for the next stage which is checking the spark advance. We have already explained how the automatic spark advance mechanism works and there are various ways of checking that it is working properly. The most well known method is with a stroboscopic lamp. Let us see how this is done:
First we have a scale which is fixed on to the crankcase. Then the engine is turned until the setting mark on the crankshaft pulley is in line with the crankcase joint.
The scale has a zero mark. Take a piece of chalk or a spot of paint and make a mark on the pulley opposite this mark as shown here.

27/41 Now connect the stroboscopic lamp into the cable to No. 1 cylinder spark plug. You also require a 6 or 12 volt source. Pull the vacuum hose off at the distributor (arrow) and start the engine. In the flashes from the stroboscopic lamp, the chalk mark will appear to be standing still opposite the zero mark on the scale. It should not move even when the engine is speeded up. If the chalk mark is not exactly opposite the zero mark you can move the scale slightly.



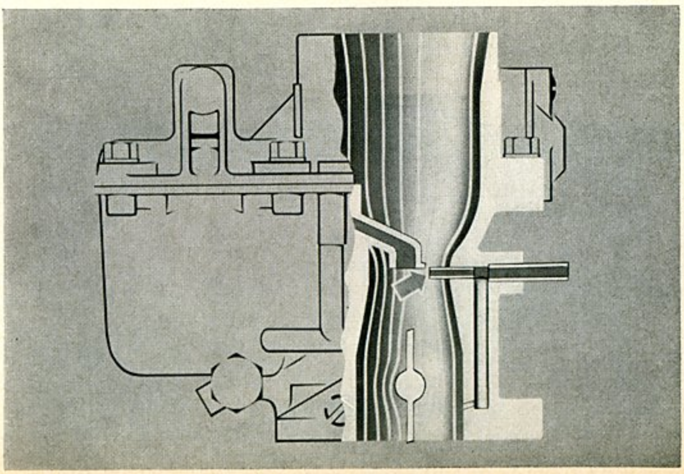


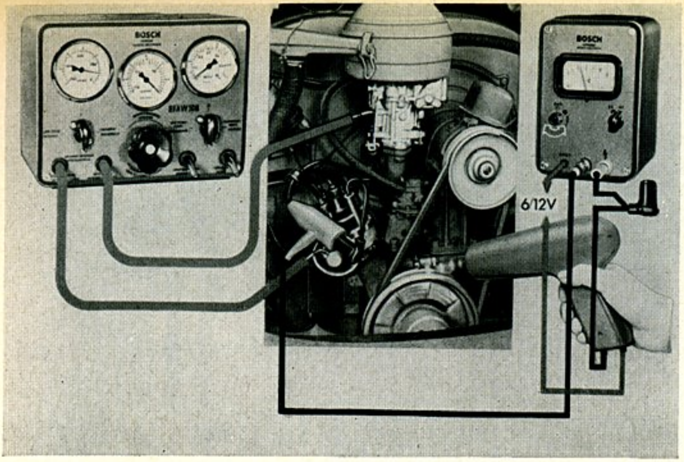
27/42 To check the vacuum spark advance we need a proper vacuum measuring instrument with a means of adjusting the degree of vacuum.
This picture shows how the instrument is connected up. The engine is then run at a fast idle speed in order to get maximum vacuum. The knob (double arrow) should be turned fully to the left. The lever on the left of the picture is in the position shown by the dotted line. At maximum vacuum, that is, more than 50 mm of mercury on Type 1 vehicles, the chalk mark on the pulley should move right over to the left when the flashes are directed on to it. Exactly how far it goes depends on the distributor concerned. The spark advance data is given in the distributor test cards.
The knob is used to set the vacuum to the value given in the tables and the spark advance is then read off on the scale in degrees.



27/43 Just a few words about the vacuum.
We are often asked why the distributor starts to advance the spark timing at idling speed. This happens because when the engine is idling, the throttle valve is almost fully closed and all the mixture drawn in by the engine has to pass through the small gap between throttle valve and choke tube wall. This creates a high vacuum at the lower drilling (arrow). When the engine is under load, the angle of the throttle valve is different and the vacuum conditions alter completely.

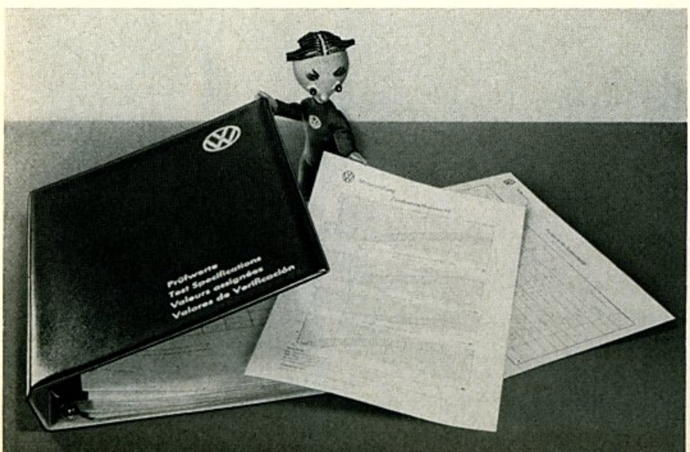
27/44 As the vehicle is accelerated and the throttle slowly opened more and more, the vacuum increases near the upper drilling in the venturi (arrow). When the throttle is fully open, the vacuum depends only on the air speed in the venturi and thus on the engine speed. But full throttle does not always mean maximum engine speed. When driving up a steep hill, for example, the driver opens the throttle wide but the engine does not turn at maximum speed because of the high loading on it. The ignition timing must also be correct under these conditions which is why the two drillings are arranged so that they work together and always give the proper amount of vacuum.

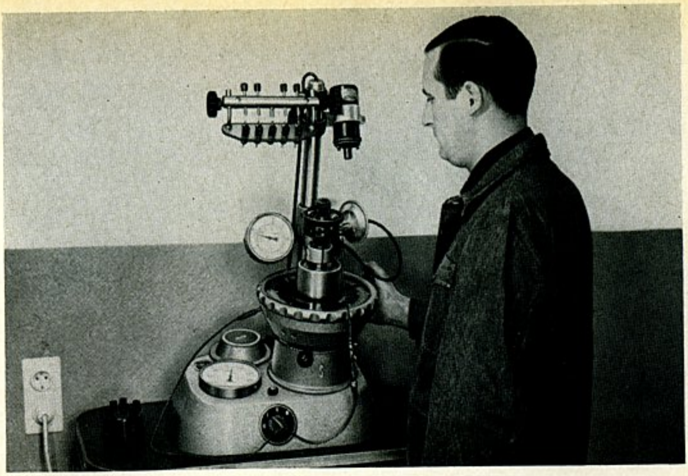




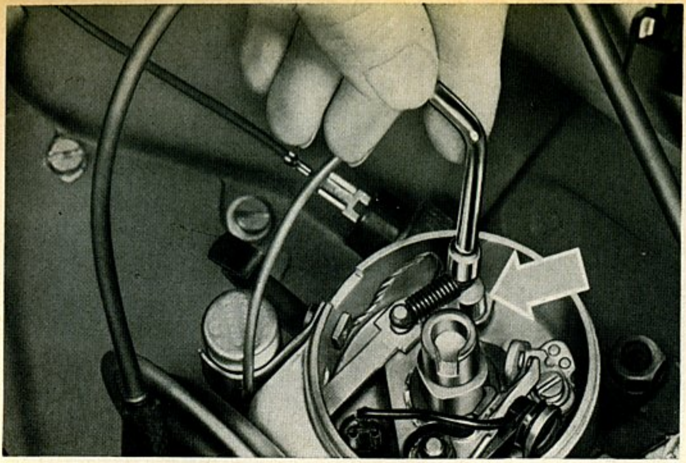
27/45 Whether or not the carburetor is producing the correct vacuum can, therefore, only be checked on a test stand with the engine under load. Our tests must be limited to testing the operation of the advance mechanism in the distributor. This can be done with the stroboscopic lamp as already explained or we can use an ignition advance measuring appliance with which the advance angle can be read off directly on a dial. The stroboscopic lamp is a part of this measuring equipment. The vacuum instrument on the left of the picture is used to check the vacuum during the test.

27/46 All the necessary test data can be found under the headling "Distributor Test Data" in a book issued by the Volkswagen factory. This book also contains the spark advance curves with which you can check the distributor accurately.



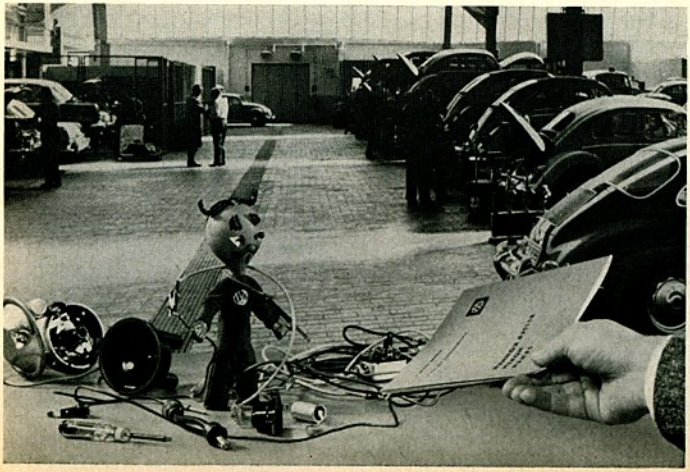


27/47 This is done on a special distributor test stand. The vacuum must be increased from zero mm mercury to just over the maximum value when testing the advance mechanism. At least four checks, evenly spaced over the complete range of advance, should be made. The test procedure is as follows: Clamp the distributor in the appliance, connect it up and run it at about 500 rpm. Then build up the vacuum slowly with the built-in pump until the distributor just starts to advance. The vacuum at this point is then compared with the curve in the diagram. The vacuum figures are then checked at 5° advance, 10° advance and end of advance in the same way and compared with the proper curve. If the values measured are within the shaded area of the distributor advance curve, the distributor is o.k.



27/48 Now for a word about pinking. One must differentiate between full load and acceleration pinking. In connection with the advance mechanism, the type which interests us is the acceleration pinking.
This can often be eliminated by tensioning the small return spring in the distributor. This is done by turning the spring retaining pin with a special wrench. The pin should only be turned far enough to just stop the pinking. The best way to check results is to road test the vehicle or put it on a roller test stand.

27/49 This poor chap doesn't seem to have got the message. Perhaps it was a bit too much all at once, but we issued this booklet especially for him and all of you who would like to study this subject more closely.



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