

# Six-plunger pump - structure and function

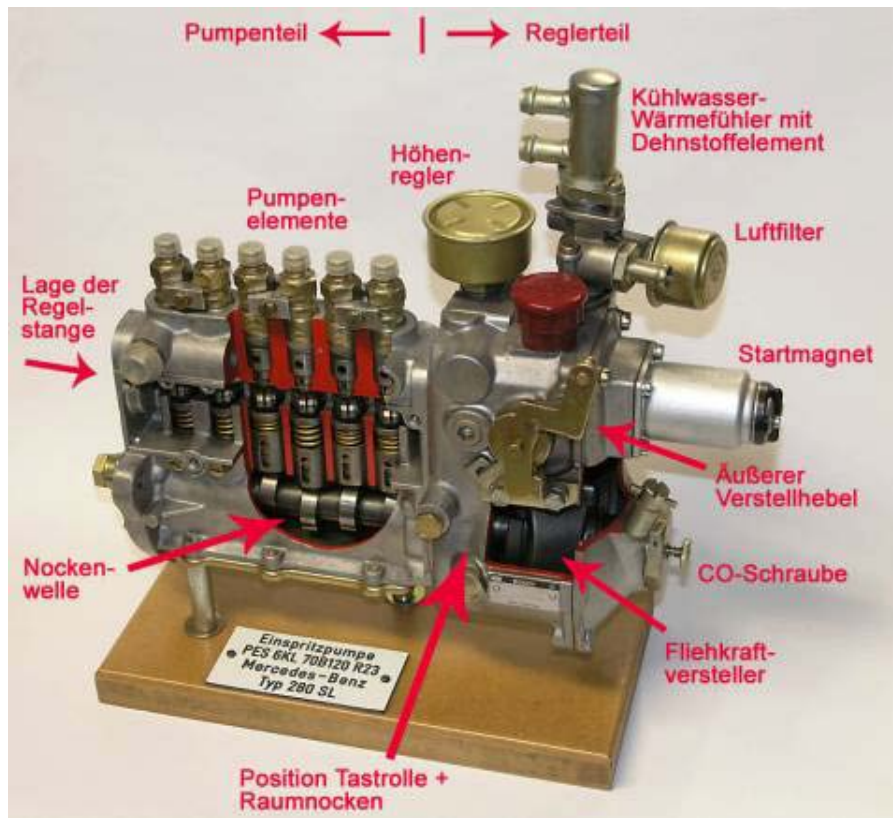
Somehow it is strange: If an engine with mechanical injection has problems and chokes when idling or in the warm-up phase, then most owners tend to look for the cause in the first step of the diagnosis on the injection pump. The CO screw, which is only responsible for idling up to the maximum lower partial load and does not adjust without external influence, seems to have a magical appeal here. And that despite the fact that sufficient knowledge about how the pump works is seldom to be found among the owners, because on the one hand the description of the function in the newly available workshop manuals was a bit short of breath and on the other hand Bosch did not yet have a suitable "yellow booklet" to clarify the issue during production "(so-called technical information). These were only offered in later years and only for successor systems.

Adequate knowledge of the structure and function is necessary for fault diagnosis. At this point, however, the goal is not to copy the work instructions from the workshop manuals available to everyone at DaimlerChrysler.

The W108 / 109 primarily used six-plunger pumps, and this is exactly what will serve as an example in the following description.

## Functional description overview

Each unit is divided into a pump and a controller part. The controller with all sub-components has the task of determining the correct amount of fuel for the operating state of the engine. The operating state is determined via a number of parameters (speed, cooling water temperature, etc.), after which the controller adjusts the so-called control rod. The control rod is the interface between the control and pump unit.



Overall view of a sectional model: the six-plunger pump with controller type R23. The control rod cannot be seen directly in this view; it lies behind the six pump elements.

The pump elements with their respective pump pistons and cylinders have a certain internal structure, through which the amount of fuel to be injected can be changed when the pump pistons are rotated. The pistons of the six pump elements are connected to the control rod and are always rotated together in the same way. The cams of the pump camshaft driven by the engine actuate the pump elements in accordance with the firing sequence, as a result of which the fuel is conveyed to the respective injection valves in the cylinder head.

For the six-plunger pumps of the 250 and 280 series and the eight-plunger pump of the 6.3, the CO values at idle and full load are given by 4% by volume, with lower and upper part loads by 0.5% by volume. From this it can be deduced that there is a richer operation at idle and full load (Lambda 0.9), but a leaner operation in the partial load ranges (Lambda 1.1).

In general, carburetors and injections must be able to map a range of the mixture quantity over all operating states of approximately 1:30. The speed range is determined by the two basic values 600 rpm and 6000 rpm (1:10), the quantity control at a constant speed of approx. 1: 3. The limits are therefore determined on the one hand by the very low load at low engine speeds (not idling because greasing takes place here) and on the other hand full load at maximum engine speed. The mechanical injection pumps have a control map from which it can be seen that flow rates from 0 mm<sup>3</sup> to 60 mm<sup>3</sup> are possible (maximum value varies depending on the engine). If one ignores the extreme values here and limits the range to essential values such as 15 and 50, the above statement agrees quite well. The 60 mm<sup>3</sup> can only be found in a very limited area of the

map, and the smaller quantities than 15 mm<sup>3</sup> indicate that the fuel injection pump can become leaner in push mode and practically “pull” to zero fuel delivery.

## Anatomy of the regulator

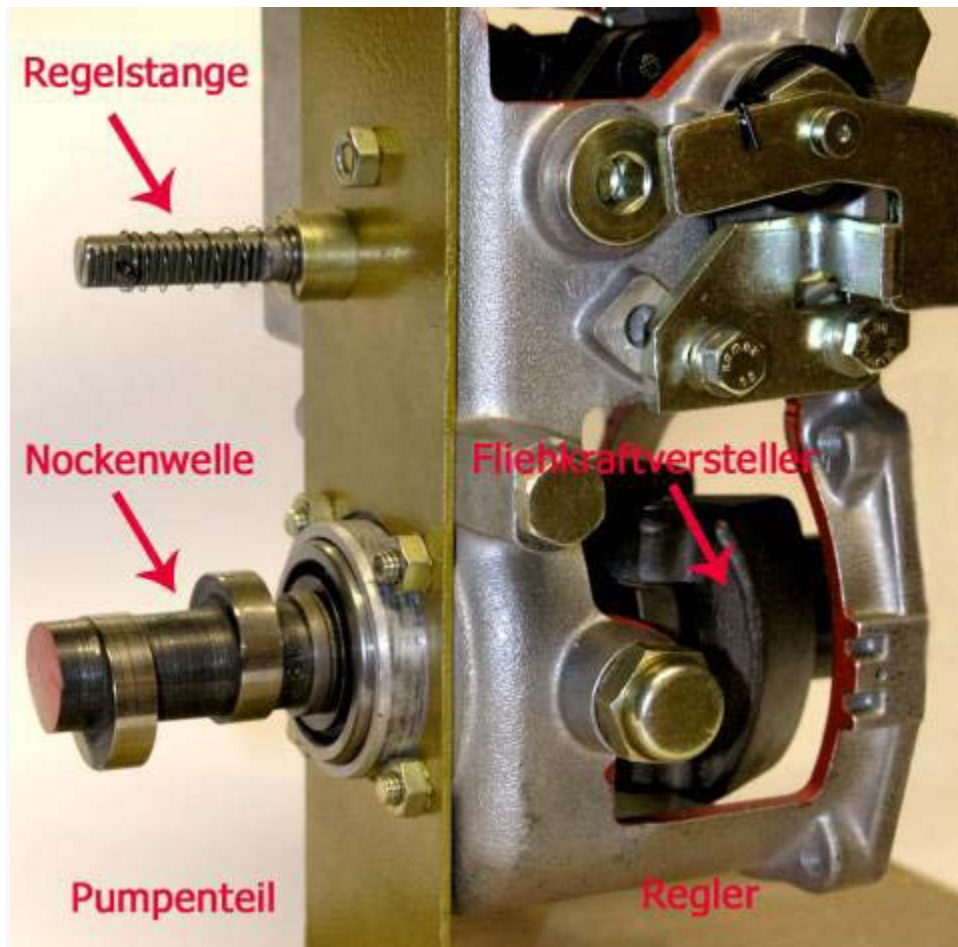
In contrast to the earlier injection pump types, the six and eight plunger pumps on the W108 / 109 are no longer underpressure-controlled but force-controlled. In the vacuum control, only the pressure conditions in the intake manifold are used to determine the amount of fuel; there is also no centrifugal adjuster yet.



*Sectional model with a clear view of the vacuum control (top right), below the regulation for air temperature*

Forced control, on the other hand, includes two factors: the speed and the accelerator pedal position, the latter as parameters for the load. The mechanical injection pump is driven by the engine, and the governor's centrifugal adjuster records its speed. The accelerator pedal is connected directly to the throttle valve in the valve neck and to the outer adjustment lever of the injection pump. If the driver accelerates, they are moved at the same time. The intake manifold pressure is therefore no longer the parameter for the load as in vacuum control. One advantage of forced control is that the injection system reacts to changes in principle immediately. With vacuum control, on the other hand, the new pressure ratio in the intake manifold sets in with a slight delay. If the throttle valve is opened, a total amount of air flows, which is composed of the

amount of air for the combustion chambers, supplemented by that required to raise the intake manifold pressure to the new value (Footnote \*1). Only then can the controller precisely determine the amount of fuel. (Footnote \*2) The vacuum control also has the disadvantage that it is influenced by engine wear (= lower compression) and is then no longer completely in the correct operating point.



*Demo model without pump unit for a better insight into the hidden: All individual elements of the controller (height correction, centrifugal force controller, etc.) affect the position of the (cut here) control rod.*

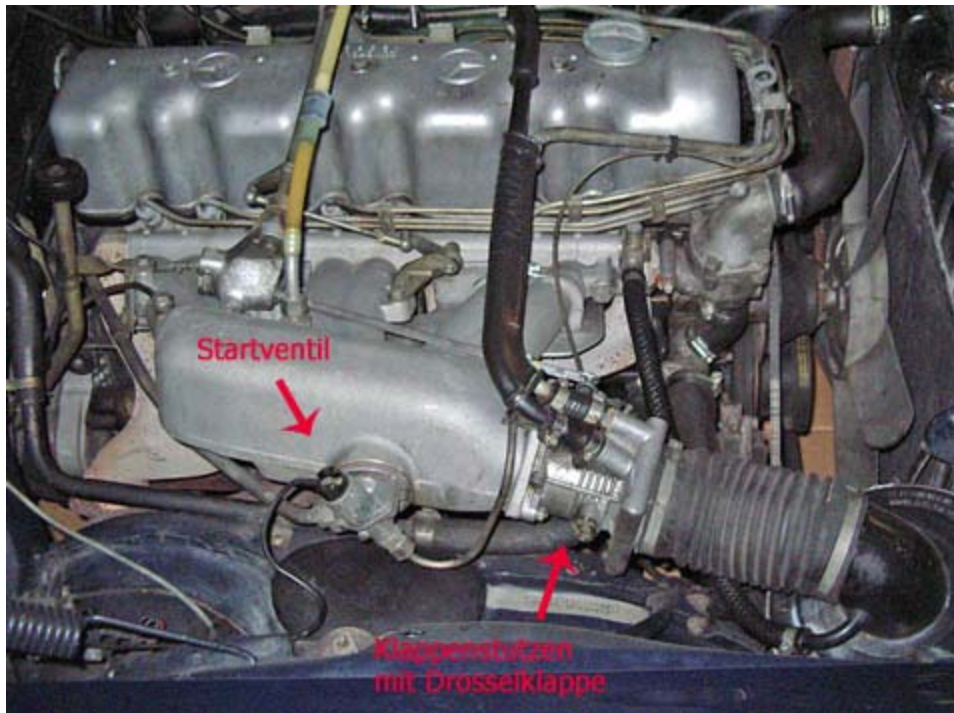
To avoid misunderstandings at this point: The outer adjustment lever of the injection pump does not directly actuate the control rod! The position of the outer adjustment lever flows into the controller part of the pump via the lever mechanism, as do the positions of the heat sensor (cooling water temperature) and that of the height controller. The latter leans the mixture at lower air pressure. The cooling water temperature is recorded by the heat sensor, which contains a so-called expansion element. When heated, its wax filling drives a mandrel out of the housing, which in turn acts on a lever inside the controller. This gradually reduces the mixture enrichment in the warm-up phase. Shutdown should be between 65 and 70 degrees, for USA vehicles at 50 to 55 degrees. It can be changed using special washers between the mandrel of the expansion element and the lever of the warm-up regulator.



*In the foreground the expansion element for the six-ram pumps, cost point about 50 euros. Behind it is the sensor for the air temperature in the ZEA two-plunger pumps of the 220 models (up to exclusive controller type R11). If this component is defective 600 euros due.*

In the warm-up phase, air is also fed to the engine via a slide directly on the heat sensor of the injection pump; a special cleaning filter sits at its opening. The superficial control with regard to the functionality of the heat sensor is quite easy, because in the warm-up phase there is a hissing sound, which disappears after a few minutes when the additional air slide closes. If this is not the case, a new expansion element is most likely due; one has to reckon with a failure after long years of operation. Things become unfortunate when an attempt is made in the workshop to compensate for the faulty function of the expansion element via the CO screw due to a lack of knowledge of how the heat sensor works. Incidentally, the mandrel of the expansion element must not be pulled "just like that". If air penetrates the hole, the element is immediately defective; an air cushion then forms in the guide, the air no longer escaping when the mandrel is inserted. The correct position of the mandrel or the previously perfect function would now be a thing of the past. The expansion element is therefore also supplied with a special wire bracket when ordering spare parts, which prevents accidental removal or falling out.





*Position of start valve and flap neck on engine M130*

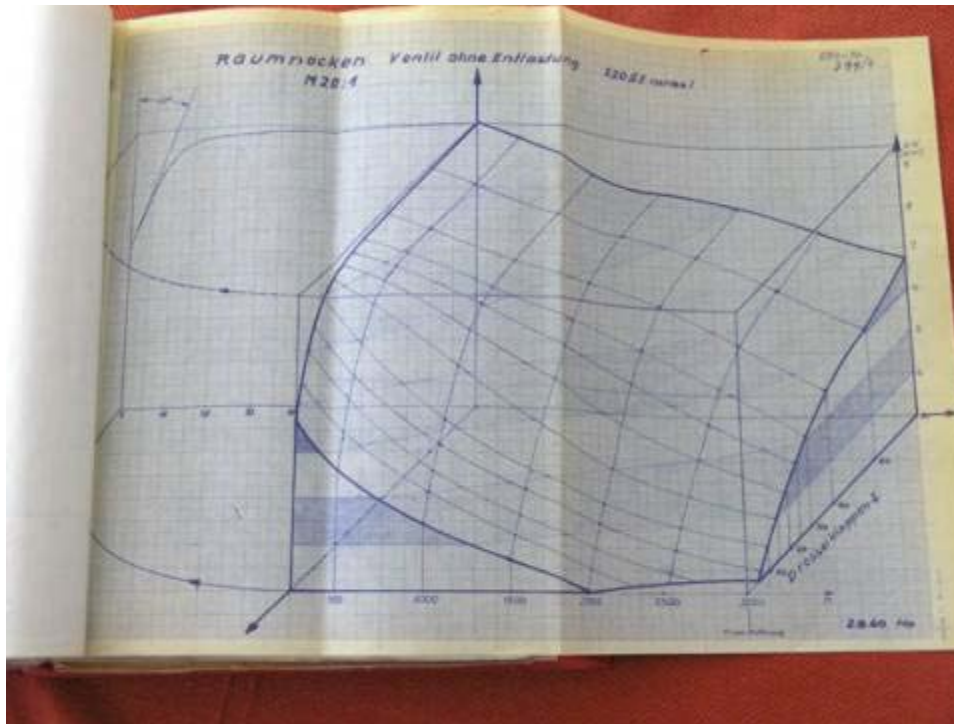
In contrast to the six-cylinder models, vehicles with engine type M100 (300 SEL 6.3) have a two-stage starting magnet. Its first stage is connected in parallel to the starting process and is ended when the ignition key is turned from the starting position to the normal driving position. The second stage of the start magnet and the start valve on the intake manifold are controlled via a thermal timer, which allows a mixture enrichment of up to 12 seconds depending on the outside temperature.

The most important element within the controller is the space cam. This contains, so to speak, the map for the amount of fuel to be injected as a function of the accelerator pedal position (= outer adjustment lever) and the speed (= centrifugal force adjuster).



*The whole world of fuel injection driving was once a disk - in the picture: the space cam. The map for the amount of fuel is on its surface.*

The space cam does not rotate continuously, as one might assume, but is only shifted, depending on the load in the range of 0 to 90 degrees, and back and forth depending on the speed by the centrifugal force adjuster. In the sector that can be traversed by the tracer roller, there are approximately 3,600 individual pieces of information. This hilly landscape, which can be found on a quarter of the surface of the space cam, was determined in advance in test bench runs. The remaining 270 degrees of circumference contain no information and are therefore "smooth."

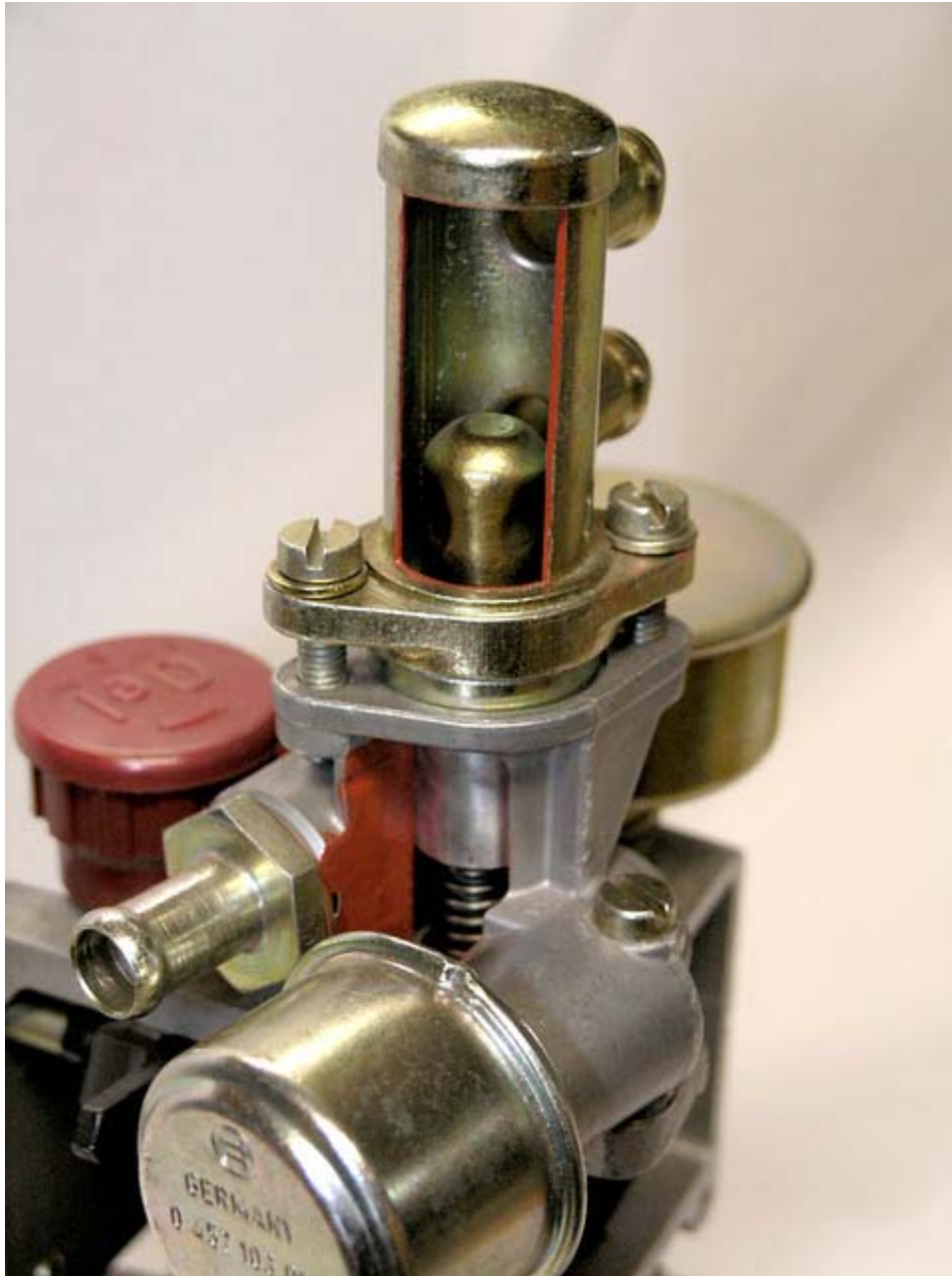


*Original documents from the development period at Bosch (1960) - part of the surface of the space cam for a 220 motor, but ultimately this control is not was used.*

As a curiosity on the side, the Koller & Schwemmer employees can report a case in which a customer believed that the surface embossing of the space cam showed wear. Ergo he expanded this and removed the embossing by machining on a lathe. The result was that the injection pump, revised in this way on its own, now delivered the maximum possible amount of fuel in every operating state.

The map on the room cam is now to be connected to the lever mechanism of the controller part. This is done via a feeler roller, which is always in the same place and under which the space cam moves, thereby raising and lowering it, depending on the surface properties. The position at which the feeler roller is at a certain combination of accelerator pedal position and engine speed corresponds to the specification for the fuel quantity. The control rod is then pushed into the correct position together with the values from the heat sensor and the height controller.





*Average heat sensor: The cavity is filled with cooling water, the expansion element is in the lower area of the sensor. When heated, the mandrel extends and actuates a lever in the regulator of the injection pump. At the bottom, not completely shown: The filter for the additional air during warm-up.*

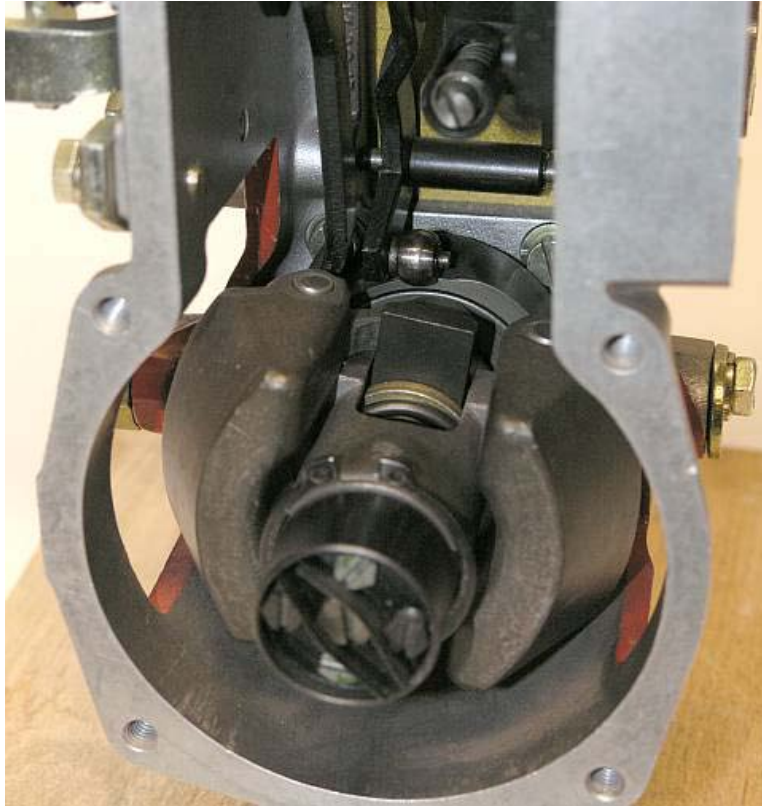
To support the pure starting process of the engine, various devices are available, which also depend on the model year. Engines up to around early 1969 have a so-called start magnet on their injection pump, which pulls the control rod in the pump to a certain position for additional fuel as long as the starter is running. At the same time, the start valve on the intake manifold also delivers fuel. It is operated electrically and is time-controlled, but runs only very briefly (at -20 degrees max. 12 seconds). You should always keep this in mind when troubleshooting. In later

models (pump types R22, R22Y and partly R23), the starting magnet on the injection pump is no longer used, but the flow rate of the starting valve on the intake manifold has been increased.



*View into the innards: The feeler roller (above) takes the information from the space cam.*

At this point, the centrifugal force adjuster should now be examined in more detail. Why is it needed at all? Can't you just add the right amount of fuel to the throttle position? Unfortunately, this is not sufficient, as the degree of filling depends on the speed at a certain, fixed throttle valve position. An additional, speed-dependent control element must then be designed for this - here it is the centrifugal force adjuster. This also distinguishes between static and dynamic processes, because: What actually happens when the speed changes? An infinitely fast-acting centrifugal adjuster is conceivable in a theoretical model, but in practice this prevents inertia. It takes time until the centrifugal adjuster has reached the higher speed. You have to know that the part of the centrifugal force adjuster in the fuel rating is large at low engine speeds, small at higher engine speeds or is close to zero. This leads to a brief mixture enrichment during acceleration due to inertia, which improves the transition (e.g. partial load to full load) - similar to the accelerator pump for carburetors. The centrifugal adjuster lags behind for a short time and thus leads to the delivery of a larger amount of mixture than necessary. This enrichment is not absolutely necessary for the positively controlled injection pump, it is more of a "welcome side effect." Conversely, i.e. from higher speed to lower, the centrifugal force adjuster acts like a simple overrun cut-off; the mixture is emaciated until the lower speed is reached.



*Space cams and feeler roller at the back, the weights of the centrifugal force adjuster in the middle, the adjusting screws at the front. The CO screw is centrally located in the holder. At the top, above the feeler roller, the adjusting screw for the control rod (full load).*

Taking off the throttle too quickly can result in a lurching jerk, and for this reason some models also have a closing damper on the regulating linkage in the area of the intake manifold, which causes a slight delay in the movement of the regulating linkage.



*In the middle: A damper on a 280SL with an M130 engine, which is only available on one Version with manual transmission can be found. The speed drops in automatic models slow down when accelerating, which is why the damper can be dispensed with there.*

Every owner of a vehicle with mechanical injection from Bosch knows the externally accessible, resilient CO adjusting screw for idling, at the latest after the first visit to the workshop. The workshop manual also reveals that the lower and the upper partial load can also be influenced. To do this, first remove the cover, called the closure flange - only then do these screws appear. The two screws for lower and upper part load are arranged around the idle screw. The full load setting, which acts directly on the position of the control rod, is hidden behind another cover above the flange mentioned.



*The adjusting screws: In the middle the idle screw, which is also accessible from the outside. The light ones for the upper, the dark ones for the lower partial load.*

As can be seen from the figure, the settings for the CO value at idle, lower and upper part load are communicated to the control system via spring pressure. The springs only act on the centrifugal force adjuster - more or less independently of one another. There are no really sharp limits when setting idle and partial load areas. All screws can be locked in place, which of course has to be done in the same way and in the same direction. Otherwise there would be an unbalance in the centrifugal force adjuster and, in the event of large deviations between the settings of the two screws, an unevenly "sawing" fuel metering. If you turn much further than necessary (max. +/- 3 notches), the holder for the adjusting screws and other components in this area of the controller will be mechanically damaged, since the corresponding screw will protrude very far from the actual position.

What do-it-yourselfers cannot know is the fact that the settings for the upper part load change the full load setting, a peculiarity of the controller. If you do not have access to a dynamometer, so you cannot measure anything and actually only have a tendency to turn the adjusting screws a little as you please, you should really refrain from these "adjustments."

The holder with the adjusting screws sits in front of the centrifugal force adjuster and rotates just like it during operation. For this reason, the idle CO cannot be set while the engine is still running.



The installed controller type can be seen from the pump designation on the type plate, which can have the following identifier, for example:

### PES 6 KL 70 B 120 R25

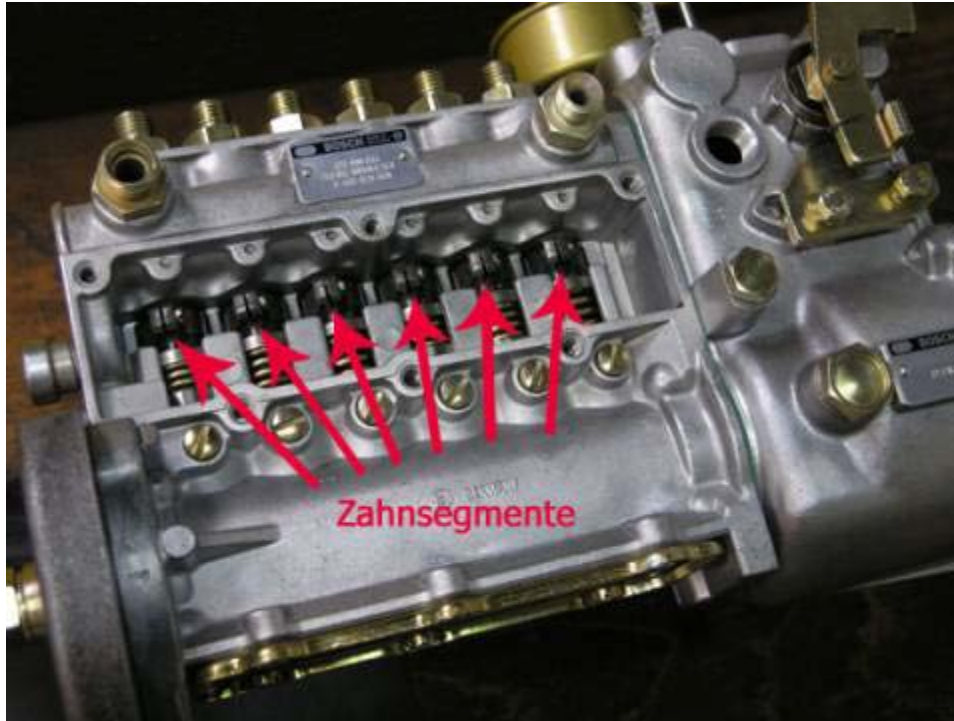
The numbers here mean a pump with its own drive (camshaft) and end flange mounting for 6-cylinder engines. In addition to information on the piston size and number of assemblies, you also get the controller type, here the 25 for clockwise rotation (at 6.3: L for counterclockwise rotation). An even finer distinction in the variants of the controller types can then be made by additional labeling with letters, e.g. the R24W controller type replaced the R24.

Which type of pumps and controllers was installed ex works can be found in the technical data tables in the section on the W108 / 109 models and of course in the official workshop manuals from Mercedes-Benz.

Pumps with older controller types can be replaced with newer ones, such as an R21 with an R25. With some combinations, however, further conversion work can be expected, such as changes in the fuel supply line or the change to a start valve with a larger flow. Information on this is contained in the WHBs.

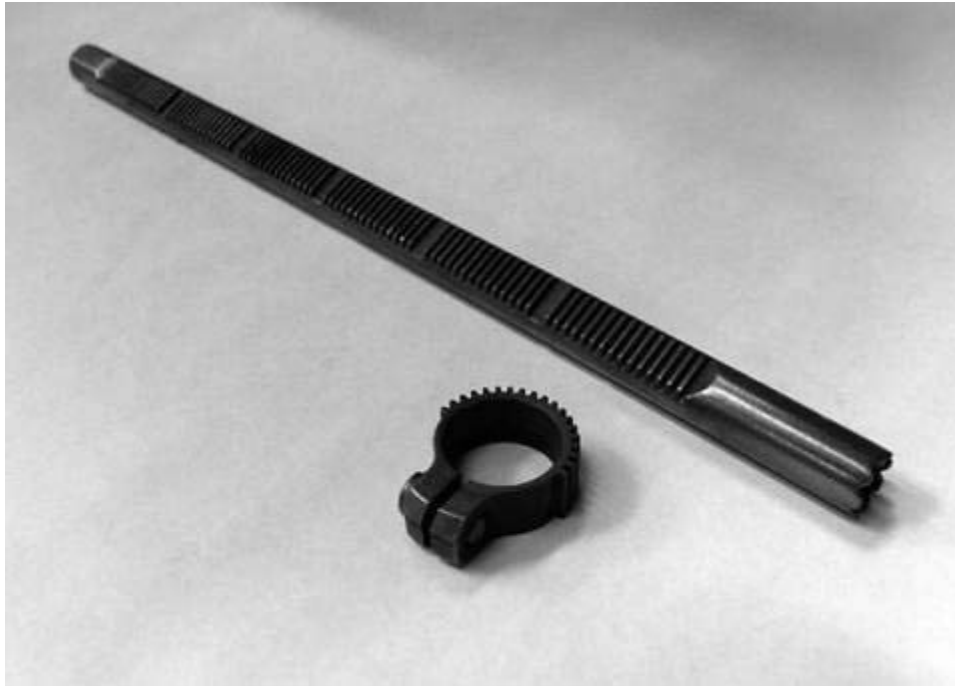
## Anatomy of the pump

The pump part consists of the individual pump elements and the drive, which is essentially the camshaft driven by the engine. A four-stroke engine has two crankshaft revolutions per cycle. The injection pump camshaft runs at half the speed and therefore has fuel delivered to the injection valve once per revolution. There is one cam per element, which opens the valve of the pump element against spring pressure.



*Pump part of the injection pump. Behind the tooth segments, on the opposite side, is the control rod. (Zahnsegmente = tooth segments)*

As already described, the position of the control rod specifies the amount of fuel to be injected. The pump pistons engage the control rod via so-called toothed segments in which they are clamped. If the control unit of the injection pump now moves the control rod, all pistons of the pump elements are rotated at the same time.



*Detailed picture: The all-determining control rod and one of the tooth segments, in where the pump piston is clamped.*

It still has to be clarified how a certain amount of fuel is actually metered by turning the pump cylinder. The piston makes a stroke movement in the cylinder of the pump element for each injection process and can also be rotated in the process. The fuel reaches the pump element through the inflow bore, the cross section of the opening being different in size depending on the position of the control edge.



*Pump cylinders and pump pistons are the central components of a pump element*

The total stroke, i.e. the up and down movement of the piston, is always the same, but the "useful stroke" (the amount of fuel delivered) can be different, depending on the position of the pump piston and thus the released cross-section of the inflow hole.

At this point, we would like to briefly examine two terms that keep coming up in connection with mechanical injection pumps. In the case of diesel, the start of delivery is so important that it is fine-tuned for these injection pumps. Even small deviations at the start of injection no longer allow optimal combustion, which results in nailing, soot and loss of performance. With the petrol engine, on the other hand, there is no need for an exact determination of the start of production. Every carburettor works continuously (as does the K-Jetronic injection), the start and end of delivery are determined by opening and closing the inlet valve of a cylinder, so to speak. Exception: the gasoline direct injection. Here it has to be determined exactly when it has to end. From "well-informed circles" comes the information that in the development period of mechanical petrol injection pumps very long thoughts about the concrete implementation. They changed from a fixed start of delivery and a variable end of delivery for diesel engines to a variable start with a fixed end of delivery for gasoline direct injection. The mechanical pumps for intake manifold gasoline injection on the W108 / W109 models are derived from the latter and have the same configuration in terms of delivery. The end of delivery is 20 degrees (250/280) or 60 degrees (300SEb / SEL) after top dead center (TDC) and thus within the opening time of the inlet valve (with 250cc 11 degrees before TDC up to 53 degrees after UT). The two-plunger pump systems and the subsequent injection processes (K-, L-Jetronic), on the other hand, no longer take the position of the intake valve into account; the systems have been simplified in this regard.

The equal conveyance of the individual elements can only be set on test benches. The pump power is measured and controlled at different speeds or operating states. If there are deviations, the positions of the pump pistons in their respective tooth segments are changed accordingly.



*A six-ram pump with vacuum control on the pump test bench.*

## Today

Mechanical injection pumps from Bosch have proven to be very robust components that can live much more than "an engine". But you have to keep in mind that the last S-Class models with this type of gasoline injection came off the assembly line in 1972 (600 to 1981), and thus the youngest models have been in operation for well over 30 years. In the past, the rule was that the injection pump should at least have seen a test bench when the engine was worn out and had to be overhauled or when a replacement unit was installed.

At Koller & Schwemmer, a certain workflow has proven to be useful for determining the cause when searching for faults:

1. Check compression
2. Spark plugs, cables, plugs
3. Ignition coil
4. Distributor

This stems from the fact that, according to the Nuremberg, more than 90% of the defects are not due to faults in the mechanical injection pump. The very first look under the hood then also applies to the seals of some screws, such as those for fastening the metal plate for the idle and full load stop on the outer adjustment lever. If the seals are missing at this point, the pump must even be put to the test. Every time you troubleshoot, you should be aware that a) many ignition or fuel supply problems have similar symptoms, and b) overlay effects can always occur, i.e. that there may be several causes.

If the ignition coil can be exposed as a culprit, it is not uncommon for the owner to convert it to so-called high-performance ignition coils and other series resistors; always with the best intentions, but without really sufficient knowledge.

The distributor is responsible for almost a legendary mistake in complaints about idling, which has already run through the classic car press, but which cannot be referred to often enough, because it can only be located after a very long search. The low-voltage path from the ignition contact to the capacitor leads through some cases, mostly older versions of the distributor, through the housing and should be sufficiently insulated. If this is not the case and there is a short to ground, the capacitor is bridged and becomes ineffective. The idling is characterized by a large number of misfires so that the engine sometimes dies when starting - which is particularly pleasing to automatic drivers.





This passage (arrow) must be very well insulated. But there are many different ones distributor designs.

One should also always take into account that the vacuum and centrifugal force adjustment of the distributors work mechanically on the oldies and that the cause of restless idling can be found here. Anyone who checks "his" idling ignition timing with a stroboscopic lamp can get to know the qualities of his own mobile. In the same breath you should also check to what extent the bearings in the flap neck are knocked out and the throttle valve actually still holds in the intended place.

The regulating linkage, which connects the accelerator pedal to the outer adjustment lever of the injection pump and the throttle valve, is of course also subject to wear, more precisely: it is the ball heads of the linkage. An exchange for new ones can be done quite easily on your own, of course with a parallel look in the Mercedes-Benz workshop manual. Ball heads are available

with right-hand and left-hand threads and cost only a few euros. Under no circumstances should you come up with the idea of adjusting the idle and full load stop on the pump and the idle stop of the throttle valve! A basic rule should be that when accelerating, the outer adjustment lever and the throttle valve move at the same time with practically no play. If the latter were to open first without the fuel injection pump giving additional fuel, the mixture would become lean. Deposits and dirt can build up on the spool valve on the spool valve over the years despite the filter. The slide, which is moved by the expansion element against strong spring pressure, should not jam.

The space cam, on the other hand, shows no significant signs of wear - a bit surprising, since its surface is continuously scanned at every moment of operation. If something wears out in this area, then at most the bearing of the feeler roller, but this rarely happens.

The pump body camshaft is also not considered to be excessively susceptible to wear. With injection pumps that are connected to the oil circuit of the engine (the L17 of 6.3 has a separate circuit like previous two-plunger pumps), however, there is a danger if there is a major engine damage with metal abrasion. These pumps must be checked and cleaned in any case.

The mechanical injection pumps survive dry storage quite well, but the cleanliness of all parts and connections that belong to the fuel area of the pump is extremely important. Even the smallest dirt can cause malfunctions, for example if cars have not been moved for a long time and rust has formed in the tank. Anyone who has ever had the opportunity to "experience" the extremely small tolerances in the interaction of the pump element with the pump piston need no longer doubt this statement. If the storage is unfavorable, the pump elements themselves can become rusty, which of course puts them out of action.

The control rod can also hang or be stiff. If multiple movements of the control rod do not improve the supply and return connections of the suction chamber filled with clean petrol, this is also a case for a more in-depth inspection.

When setting the idle CO values, it is recommended here and there to drive a few kilometers after changes and only then to check the new value. Certainly, however, you should briefly pull off the crankcase ventilation line (on the flap connection) when making settings so that oil vapors cannot influence the measured value in older engines.

As already described, the centrifugal force adjuster acts as a fuel cut-off when the accelerator pedal is withdrawn. The innovations to the Mercedes-Benz type range from 1970 also reveal that there was such an additional device for the USA vehicles. For this purpose, the injection pump had a stop magnet, which could pull the control rod to zero delivery and was connected to a temperature switch on the cylinder head ( $> 17$  degrees), an oil pressure switch (automatic transmission) and an empty gas switch on the flap nozzle. In the case of mechanical switching, there was a clutch and gear switch instead of the oil pressure switch; the fuel cut-off is only in 3rd or 4th gear. On the part of Koller & Schwemmer, there is no experience with regard to effectiveness or advantages in fuel consumption.



*A completely disassembled six-piston pump*

## Costs

For comparison, prices for carburetors (per pair) - new and completely overhauled - are also listed.

	8-Stempelpumpe	6-Stempelpumpe	Zenith-Vergaser
<b>DaimlerChrysler (neu bzw. ehemalige Neupreise)</b>	18.800€	5.700€ (160PS) 5.900€ (170PS)	3.150€ / Paar 3.800€ / Paar (abh. von Fahrgst.-Nr)
<b>Koller&amp;Schwemmer (im Austausch)</b>	4.750€	2.800€	
<b>Drittanbieter (Überholung)</b>			900€ / Paar

The mechanical injection pumps of the models from the W108 / 109 series are certainly not among the inexpensive spare parts. Experience shows, however, that with good care, years of (better: decades of) trouble-free operation can be expected. Used injection pumps are offered more often, but there are clear risks here, because no one can know which life cycle the pump that “survived” its vehicle once again actually took, contrary to the promises of the suppliers. As

already described, poor storage and contamination in the fuel area of the pump are the greatest dangers.

This owner of a 300 SEL 6.3 can count himself lucky - everything here is like new.

Footnotes:

\*1 This effect is used as acceleration enrichment in the K-Jetronic, which also works completely differently from the vacuum-controlled D-Jetronic and measures the air volume via a baffle plate.

\*2 In the vacuum-controlled, electronic D-Jetronic, the pressure sensor in the intake manifold is exposed to vibrations; the pressure pulsates. This behavior should of course not be corrected by the injection. For this purpose, a throttle hole is made in the connecting piece of the sensor, which, however, greatly increases the response time of the pressure sensor (to 0.3 seconds from idle position to full throttle valve opening). To compensate for this, the throttle point is bridged by a valve, which results in a rise time of approx. 0.1 seconds. Nevertheless, the D-Jetronic also has an acceleration enrichment.

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