600AirSuspension

Sherlock Tests for the Mercedes HPF Suspension

Analyzing Leaks in the Mercedes HPF Suspension of the W116 6.9 and W126 4-corner hydraulic suspension.

I receive many mails and calls about problems with the Mercedes Benz HPF suspension and I wanted to share and write up a few concepts in order to explain the system a little more and suggest a couple of tests, which can be performed at home in order to find the troublemaker (s) before the correct faulty unit can be overhauled.

Suspension not All Right!

With the car on the ground you scratch your head and wonder what this is? Or the car is low and won't go up? Struts leaking? Foamy oil discovered? And why is the dash warning light always on? The questions go on and on.

The answer is Yes and Yes. It is simply an old (and not maintained) Mercedes HPF hydraulic suspension and the privilege of owning a classic Mercedes Benz. The good news is: As bad as it may seem- the HPF is repairable. But in order to repair efficiently (without getting crazy) it is best to have a proper analysis of what is going on internally and which parts are leaking. This is what the Sherlock Tests are all about.

Before we start finding the problematic parts it is a good moment for a few explanations on how the system is designed and how Mother Benz meant it to be.

The Theory

The basics of the HPF must be internalized in order to understand what is going on inside the hydraulic system.

Let's start with what I call the different Groups. There is the Support Group and the two Work Groups of the HPF.

The Work groups are comprised of all units that are doing the 'Work', the action of the Gas Springs. Yes your heard correctly: Gas springs. By the way the HPF is just another interpretation of the precursor of the HPF – the air suspension. The same principles relative to the shock dampening are allied in the HPF as in the Air Suspension: The Gas Laws. The HPF and Air Suspension are based on the compression of gas.

The Work Group includes the Axle Valves (6, 24), Struts (13, 20, 30 and 31) and Gas Springs (11, 12, 13, 28 and 29) that are called spheres or pressure reservoirs. We have

one Work Group for the front axle and a second one for the rear axle, 2 Work Groups total. The Work Groups are circled in Blue in the diagram.

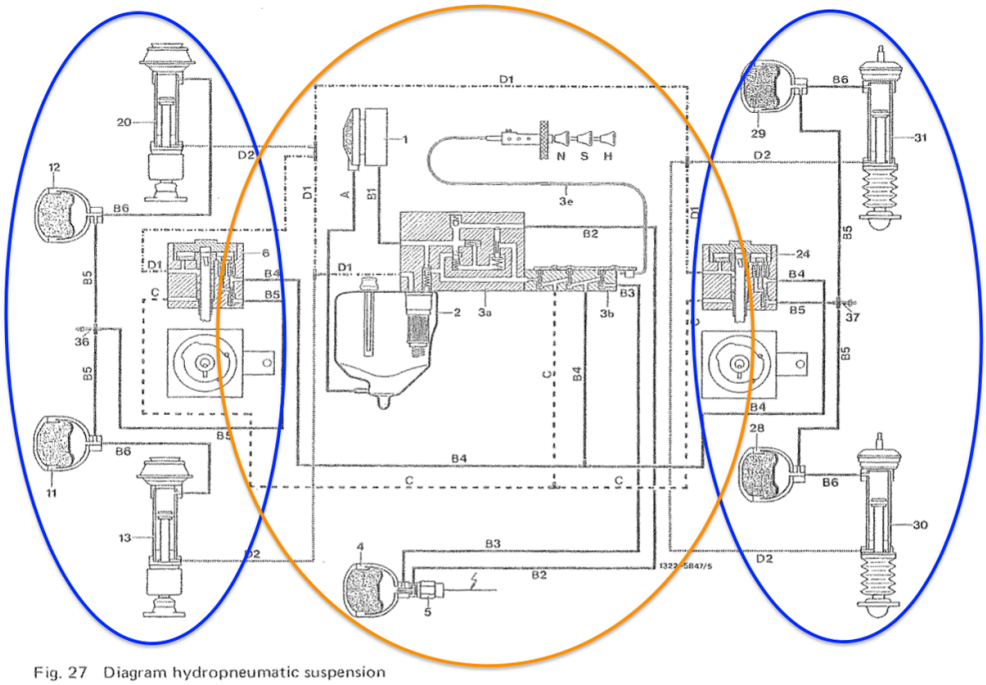

Fig. 27 Diagram hydropneumatic suspension

1 Hydraulic oil pump
2 Oil supply tank
3a Pressure regulator of valve unit
3b Adjusting switch of valve unit
3e Puller for adjusting switch of valve unit
4 Central reservoir
5 Electric pressure switch for warning lamp
6 Level controller for front axle
11 Pressure reservoir for front axle left
12 Pressure reservoir for front axle right
13 Tube shock for front axle left
20 Tube shock for front axle right
24 Level controller for rear axle
28 Pressure reservoir for rear axle left
29 Pressure reservoir for rear axle right
30 Tube shock for rear axle left
31 Tube shock for rear axle right
36 Distributor front axle
37 Distributor rear axle

A Suction line oil supply tank – hydraulic oil pump
B1 Pressure line hydraulic oil pump – pressure regulator of valve unit
B2 Pressure line pressure regulator of valve unit – central reservoir
B3 Pressure line central reservoir – adjusting switch of valve unit
B4 Pressure line adjusting switch of valve unit – level controller on front and rear axle
B5 Pressure line level controller – pressure reservoir
B6 Pressure line pressure reservoir – tube shocks
C Control pressure line for "higher level" adjusting switch – level controller
D1 Return line level controller – pressure regulator
D2 Return line for leak oil of tube shocks

Pressure line
Return line
Control pressure line for higher level
Return line for leak oil of tube shocks

HPF diagram: Work Groups (Blue) and Support Group (Green)

The Support Group is doing what the name says: Supporting [the Work groups].

The Support Group consists of the Pump (1), the Tank (2) and Regulator (3a), Switch Unit (3b), Accumulator (4) and Pressure Switch (5).

The HPF is a closed look system and works the following way. The pump draws oil from the tank and pressurizes the oil (up to 200bar) and filling the accumulator or central

reservoir (4), which is storing about 0.7Liter of oil under pressure. The pressure in the accumulator is between about 150 and 200 bar according the set point of the regulator. The regulator cuts off the pressurization from the pump side at about 180-200bar. The pump is then 'idling', meaning no pressure is produced and the pump is just recirculating oil from the tank back into the tank. When the pressure is falling below 150-165 bar the regulator cuts in and pressurization of the accumulator continues until the cut off set point is reached ….and so on.

The stored pressure in the Accumulator/ central reservoir -technically this is a hydraulic accumulator, that's why I am calling it accumulator- is distributed to the Axle Valves through the switch unit (3b) with Line B4 (pressure line providing pressurized oil from Accumulator to lift the car) and Line C (this line is providing pressure to the High port of the Axle Valves).

The two input lines B4 and C from the Support Group are able to energize the Work Group of the Suspension if needed. The Axle Valve is able then to lift, lower or 'do nothing' relative to the car height depending on the position (command) of the Axle Valve arm, which is sensing the car height through the rotation of the torsion bar.

In case of a 'Filling' command from the Axle Valve arm the Axle Valve will open the internal intake valve and fill the Gas Spring (sphere) and Strut with higher pressurized oil and thus lift the car until the Axle Valve closes the intake valve and returns to its neutral position (and do nothing- no filling and no lowering).

In case the car is too high, and the Axle Valve sensing it, the internal exhaust valve will open and (in case there is enough support pressure to release the inner check valve) the car will be lowered to the point considered normal riding height. Normal riding height will put the Axle Valve into neutral and stop the lowering movement.

There is a second command option to the Axle Valve which is 'H' or 'High'. If the Switch Unit (3b) is put all the way in with the dash knob pressurized oil will put the Axle Valve in 'High' and rotate the control inside the Axle Valve and allows the neutral position to move toward a approx. 40mm higher position. This means the car will rise without movement of the arm. In case the Switch Unit (3b) is put back to N= normal riding height the car will lower to the regular neutral zone.

During Lowering return oil will be released from the sphere and move back via Return Line D1.

Return Line D2 is collecting return oil from a leaking strut, which in general is a failure if the leakage is more than the specs allow. In that case the strut needs overhauling.

There are two more positions of the Switch Unit. One is 'S' or Sperrstellung (German for Lock Position). In this mode the support pressure from the accumulator will be cut off and no oil should leave the accumulator, so no oil will reach the Axle Valves and thus the internal check valves will be active. This will prevent any oil to leave the Work Group (meaning car cannot lower). This will lock the Axle Valve during Maintenance for instance. When the car is on a lift for example this position will prevent finding the car down on its end stops when lowered from the lift.

There is a 4th position of the Switch Unit called the M-Mode (M for Montage), which can be reached not from the dash knob but when disconnecting the cam disk cable. The cam then can be rotated all the way CCW and this will release all pressure from the accumulator into the tank. This will completely depressurize the Support Group but the Work Group will be still under pressure in case the car is in riding height.

Warning

When you intend to open up the HPF system please be very aware and very cautious. Make sure that you understand the system and release all pressures from the circuits before opening lines. If you do not understand what you are doing – Stop- right there and educate yourself. Otherwise this can be dangerous because the oil is under high pressure -up to 200 bar-, and the least what is going to happen is a big mess with oil shooting all over the place and your face.

Failures

In case of a failure the system often time is difficult to understand and to analyze without proper pressure readings for absolute pressure or differentials. For that reason I suggest that you want to install a pressure gauge at the regulator if you want to really understand what is happening inside. However often times the system can be analyzed without a pressure gauge.

The HPF is a very robust and durable system but over time a couple of things may happen causing failures.

One is the deterioration of external and internal rubber parts (rubber fossilizing/ hardening and cracking) and the other is wear/failure of Teflon rings. Most of these problems will lead to an internal leak. This means there will be no oil spills found on the floor.

Then there is mechanical wear in various parts of the system, mainly the Regulator, Switch Unit, Axle Valve and sometimes the Pump.

Sometimes there are external leaks but these are the easy ones to fix, although sometimes not easy to identify.

Symptoms of Failure

1) HPF not reaching System Pressure at 180-200bar.

This can be a failing pump. A good pump should easily reach 200 bar pressure even at idle speed. If the dash light does not come off after some time at idle speed but going off after revving the engine at 2000 or 3000 this might be a sign of a weak pump.

However there can be other failure involve in not reaching system pressure with a faulty Valve Unit (Regulator/Switch Unit). Wear in the Switch unit might cause a check valve not to close properly and thus make it impossible for the pump to build up pressure in the accumulator.

If the system is not able to be pressurized the pump is running constantly and not putting at rest because the regulator cannot reach cut off pressures. This may cause the oil to foam and cause a change in behavior of the system. This may lead to all sorts of weird things because the oil is aerated that much that basic oil properties change.

However this problem can be unseen for a long time because the dash light will only come on below 100 bar. If the pump is not able to trigger the regulator cut-off 5and be above 100 bar there is a problem that can be detected only properly by installing a gauge in order to read system pressures.

2) HPF Dash Light comes on after short time.

This problem with the warning light which comes on below 100bar in the 6.9 (set point of the Pressure Switch (5) can have various reasons. In most cases the riding height of the car is not affected (car is not sinking).

If the accumulator reaches system pressure and the accumulator is filled with 180-200bar but loses pressure relatively fast when parked then there are the following failures possibilities.

A) Pressure can be lost the same way it was built up: backward flow through the Regulator. This is not possible with a functioning Check valve. But in this case

the Check Valve inside the Regulator is leaking. The Warning Light will come on as soon as the accumulator pressure is below 100bar.

B) Switch Unit is in M- Mode (M for Montage meaning service done to the system) and all accumulator pressure is released, oil flowing back very fast into the tank. However this mode normally does not occur. It is not possible if the cam disk is connected to the wire.
C) Oil pressure is lost downstream of B4 Line inside the Axle Valve: Intake Valve leaking slightly. There will be no pressure built up inside the Axle Valve and the pressure is returned back to the tank. The accumulator is drained and the light comes on below 100bar.
D) Oil pressure is lost downstream of B4 Line inside the Axle Valve through Exhaust Valve. This means pressure in the strut/gas spring is lost and the car will sink at the affected axle. As long as there is enough pressure left in the accumulator (above 100 bar) the Axle Valves check valve will be still open and the Arm will trigger the 'Rise' of the affected axle and lift the car until reaching normal car height or until the accumulator pressure is low and triggering the warning light. When the pressure equilibrium between Strut and Accumulator is reached the check valve will stay open. As soon as the check valve closes there will be no more pressure loss. The accumulator pressure may then stay at 60 -80 bar depending on the Strut pressure. The warning light will be on but system pressure will stay constant if no other leaks occur.
E) Nitrogen pressure in the accumulator out of spec- too low. The accumulator in the 6.9 and W126 is precharged with 75 bar Nitrogen. If the Nitrogen pressure falls below 60 bar the accumulator needs to be replaced. Unfortunately these accumulators are not serviceable or rechargeable. If the Nitrogen pressure falls to 'very low', say for example 10 bar then there is simple not sufficient storage of energy possible to the point when the Regulator shuts on and off fast. This may also lead to oil foaming which changes the oil properties substantially that the system may not work as intended and accumulator pressure is lost.

There is another leak option and this will definitely affect the car height.

F) Strut leaking oil at rod seal or Cap seal. This option will drain the accumulator and for sure bring the affected axle down. Mercedes restricts the internal leakage for the Strut to 2ccm in an hour under pressure (car up).

3) HPF is not able to lift the car.

If your car struggles to lift itself up then it is getting time to renovate the system. There is simply no time left to wait.

The problems and failures described so far are not necessarily essential and you might still be able to drive the car, but only if the car is still at normal riding height. But with a low sitting car the problems cannot be ignored any further.

The system not being able to fill the spheres leaves the car sitting low, even on its end stops which makes it impossible to drive safely.

What are the problems related to this failure?

Often there are a number of possible failures or a combination of these.

A) If the Axle Valve cannot lift the car- assuming the Axle Valve Arm is connected to the torsion bar as before and assuming there is oil in the tank there might be simply not enough oil pressure build-up in the accumulator in order to lift the car. The related problems are inside the Pump or the Switch Unit, Pressure Regulator or the Axle Valves or a combination of these units. Here finally it becomes clear that units work in a team and each member of the team can bring the HPF down. If system pressure is below 100 bar the 6.9 will not lift. If the problem is low pressure the system must be tested and analyzed to find the problem. This goes back to Failures #1) and #2) as described before. The problem is just more severe and at a point when the car suspension starts failing. The problem is in the entire Support Group and all units can be affected. Plus there is the Axle Valve.
B) The Axle Valve. In case there is enough pressure build up and the Regulator is charging the accumulator to the cut off pressure at 180 -200 bar but still the car would not rise then there is another problem. It is the Axle Valve or precisely the Filling function of the Axle Valve. I can see this problem fairly often during renovation of this unit. The Axle Valve is worn out internally where a Teflon Seal is cutting into the housing after many years of use and at some point this ring cannot handle the sealing function any further. This is the main reason for lift function failure. There can be other faults in the Axle Valve that may cause this problem as well but very rarely.

4) The HPF is leaking oil externally

This problem is heard of enough but fortunately this is a relatively simple problem to detect because external leaks can be found and seen most of the time. Even if you cannot 100% identify the precise leak point but at least the area must be about where you find the oil puddle on the floor.

A) Rubber hoses in front leaking. These rubber hoses around the Pump may start getting brittle and seep oil or leak. This is simply a matter of exchanging these old lines. Most lines in the HPF however are out of metal and these are very durable unless they are worn out or heavily corroded. I have rarely seen leaking metal lines.

B) Leak at Axle Valve. Relatively often I hear complaints about a leak from the Axle Valve Shaft. At least this is what clients tell me even if the Axle Valve is rebuilt with new rubber. Most of the time these 'shaft leaks' turn out to be a leak coming from one of the 4 metal line connections at the Axle Valve. These line connectors or the M10 x1 thread at the Valve might have been compromised and start to leak. These threads in the aluminum body are very sensitive and a very low torque value is permissible (11 Nm only). If there is a leak that looks like a shaft leak you are asked to search if the leak is not coming from these lines. Of course it is possible that the shaft seal might have a leak but this would show only during High-mode or during Lowering of the car, for instance if the car lowers from High to Normal. In this case the Axle Valve has to be opened and seals replaced.
C) Leak at Pump. This happens relatively often because the pump is getting relatively hot and the pressure is pulsing all the time. That is putting a lot of strain on the seals. It is best to overhaul the pump in these cases.
D) Leak at Strut - Low and High Pressure Hoses. The old Gates Pressure Hoses are starting seeping oil as they age and if they do they should be rebuilt or exchanged. The same procedure is recommended with the Plastic Return Line
E) Leak at Bottom of Strut. The oil return area of the Strut might suffer from leakage. If the leak is not coming from the Return Line Fitting and chances are that the Teflon wiper seal inside the Strut is leaking. Rebuilding the Strut can solve this problem.

5) HPF car would not rise when Switch Unit is shifting from N into High.

Fortunately this is a relatively isolated problem within the Switch Unit assuming that the HPF is behaving to spec within N-mode. Sometimes the Check Valves inside the Switch Unit are simply sticky and do not close because of 'too little use'.

Sticking check valves can cause pressure loss in the accumulator. This problem can be corrected by rebuilding the Switch Unit.

How to find the Problem Unit in this complex HPF?

The reader might understand that the HPF can become very complex very fast if it gets down to the analysis what is happening and why. Most units are working very closely with the other units and it is difficult to isolate them unless single units are removed and tested on the bench. Performing bench testing is probably not an option for the proud owner of the 6.9 or W126.

In general given the complexity of the system and limited options for bench testing makes is hard for the DIY owner.

The only way to get some more inside information is by installing a 200 bar pressure gauge in the support in order to be able to see the pressures. The warning light is simply not enough information.

If you decide to install a pressure gauge the best location to tap into the oil circuit is

a) At the pressure regulator (the Allen Screw head on top next to the big Hex cap). This is a quicker option but only feasible for temporary install with the hood open. Hood cannot be closed here.

b) At the 5th sphere at front left wheel well replacing the pressure switch. This option allows for a more permanent installation of the switch which allows closing the hood and test driving the car (which is a great asset) but this install requires a longer flex line for connecting the gauge in the engine bay or on the wind shield.

c) Install a test port in-line at B2 metal line. This requires custom metal line modifications or new lines with a 3-way connector and a hydraulic test port. This will touch the originality of the car but would allow for a permanent option installing a gauge fast.

Having test readings available is a great asset to understand the system better. With a good pressure gauge installed it is possible to see so much more compared to the dash light. It is absolutely needed in case you want to perform the Sherlock Tests.

Warning again: For installing the pressure gauge you are tapping into a 200 bar system. Only people who know what they are doing should do this. It is a mess or even dangerous if you do not understand the system and consequences. You will need to release all pressure in the system before you tap into the circuit.

Sherlock Test #1

A very basic test is releasing all pressure from the system (Shift Switch Unit into M-mode) and shift back to N-mode. Start the engine and watch the gauge carefully. Best practice is to take a video of the sequence because you can go back in the video at any time and watch again.

What is expecting to happen when the engine is started: The gauge will jump fast to a certain pressure, say 65 bar and from there on the needle will go slow and creep up to the cut off pressure of the regulator.

You will hopefully see and witness a couple of things. Please take notes, start a logbook in order to work like a scientist. Video the first sequence until the Regulator cuts off. You need data/pressures over time and you need this data when you are repeating the test to see improvement.

1) The initial pressure the needle is jumping to is the Nitrogen pressure of the accumulator. Again this pressure should be between 60 and 75 bar. If the pressure is lower it is time to replace the accumulator sphere with a new 75bar sphere.
2) You will see the pressure creep up slowly and if it reaches the cut off pressure please note that pressure. It should be between 180 -200 bar. For a 'used' system MB is allowing for a lower pressure. Pressure could be as low as 165 bar. 165 bar would be the lowest allowable cut off pressure for an old Regulator. If the cut off pressure you monitor is lower your Regulator needs overhauling.
3) In case your system reaches cut off pressure at engine idle consider yourself a lucky man: Your pump is tested healthy.
   If this is not possible and you can reach the cut off pressure at higher speeds only, like 2000 or 2500 rpm, it is not the end of the world but this compromise works only if the rest of the system is operating very close to specs.
   In case you are not reaching the required pressure at all no matter how hard the engine is revving then the pump is bad and needs overhaul or replacement.
4) After reaching the cut-off pressure you may stop the engine and simply monitor the pressure drop over the next minutes and hours or even days. The pressure in a system to spec will not loose pressure over days or even weeks. It should be tight. If this is not the case and the pressure is dropping then you have a problem to fix. Start a logbook and note the pressure drop over time.

   In case you could not see all four steps the system should be worked on and repaired until you are able to build up the pressures for the Regulator cut off.

   If 4) shows a fast drop of pressure the reason for pressure loss has to be found.

Sherlock Test #2

Finding the pressure drop in the accumulator. If you were experiencing a relatively fast pressure drop (from 180 bar to 100 bar in less than 24 hours for instance) you should find and eliminate the leak point(s).

This Test #2 is eliminating the Axle Valve as a possible leak point. For this Test you shift the Switch Unit into S or Lock and this will remove all pressure from B4 Line to the Axle Valve. Please Repeat Test #1 procedure but with Switch unit in S (hopefully the Switch Unit is functional) and monitor the pressure drop after Regulator cut-off.

If you are noticing the exact same pressure drop as in Test #`1 the problem must be in the Regulator Check Valve. This means the Regulator needs repair or replacement.

However if you are noticing a much tighter Support Group now (less pressure drop) the problem is in one or both Axle Valves.

Sherlock Test #3

Testing the leakage of the Axle Valve. This test requires removing the steel return line from the Axle Valve and watching if oil is coming out of the open port. The port is marked with R at each Axle Valve. If the Axle Valve is working to specs there is no leak with the Axle Valve in neutral. The front Axle Valve is easier accessible than the rear. Please be cautious underneath the rear of the car when you are working at home (not on a drive on lift). You should always make sure a dropping suspension couldn't hurt you. Safety First!

In case you find the leaking Axle Valve this unit needs to be renovated.

Often times the 2 Axle Valves have the same age (and very similar problems in terms of rubber aging) and if your budget allows you should have probably both Axle Valves rebuilt as you are dealing with the repairs anyhow.

Sherlock Test #4

Test for the lift function of the Axle Valve.

With a low sitting car (both axles low here) put the Switch Unit into S and charge the accumulator until cut off pressure is reached(150-200bar). Then shut the engine off.

With the engine off shift the Switch Unit into N (disconnect the wire and shift by hand), watch pressure gauge and car height and see what happens.

If the car rises front and back all is good (pressure will drop until Spring Pressure = Accumulator Pressure).

If the pressure drops but the car is not rising there is a problem in at least one of the 2 Axle Valves.

In order to figure out if the Front or Rear Axle Valve has a problem it is best to isolate the Rear Valve.

Disconnect the rod from the Front Axle Valve and put the arm slightly into L or Lowering. Now you have isolated the Rear Valve for Filling and you can repeat Test #4.

If now the car is not rising in the rear (where it should rise) the Axle Valve is in question.

You can repeat the same Test again but this time you remove the return line at the bottom of the Regulator and watch the oil returning here (it must return). This is the proof that the Axle Valve is failing. In this example the Rear Axle Valve need Rebuilding.

In case the Rear Axle Valve is testing fine and the Rear is rising your Front Axle Valve is suspect of failure. In order to proof the failure of the Front Valve and you are isolating the Rear Valve, take it out of F=Filling (in case the rear axle is fully up the Rear Axle Valve is in neutral now and thus isolated. If the Rear is not fully up in normal riding height you can either run the engine and pressurize the accumulator and lift the rear fully or you putting the Rear Axle Valve manually into neutral or slight L- Lowering.

Now you are reconnecting the Front Axle Valve rod and repeat Test #4. If the Front is not rising and you see return oil flowing and pressure dropping the Front Axle Valve is faulty.

With these 4 Sherlock Tests you have pretty good tools at hand to analyze the HPF. It will deepen you knowledge and feel for this wonderful system and you will have fun improving the HPF until it is back to the original specs.

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