# Mercedes Air Suspension

A report about the legendary Mercedes Air Suspension from the 1960s

By Martin Werminghausen

You are probably familiar with the Mercedes models W109, W112 or even the W100 from the 60s and early 70s. These models were designed with a 'legendary' air suspension system, legendary in a positive way - the ride in such a car is superior compared to a steel spring system- but also legendary for the complications the owner might experience and finally legendary for its price.

In the following sections I will describe the Mercedes air suspension for cars from August 1965 until 1973, the 600 until 1981 with later style level control valves and high position option although most parts and functions are the same in earlier versions. If this article will induce you to plan doing work on your air suspension, please do so but be very cautious as an air system with over 10bar of pressure has a lot of stored power and if things are done wrong this could be even dangerous. Please use caution and common sense when working on the air suspension

A bit of History

Looking at the history of air suspension, Mercedes did not invent the system. It seems that the principle was patented at the beginning of the 20th century and the Czech company Tatra was probably the first to apply the air suspension successfully on the rear axle of a truck in the 1920s. Tetra had problems with air leaks at that time. (Sound familiar?) During the Second World War the US developed the air suspension for heavy aircraft in order to save weight with compact construction.

The reason air suspension was used in heavy trucks and aircraft was mainly the positive response to live load change. With adjustable air pressure, the axle could be at the neutral height independent of great load difference.

The second advantage of the air spring is the progressive suspension response to changing dynamics in the vehicle. This is not as important for a truck or airplane but for a car.

From their experience with air suspension in buses using air bellows, GM started to introduce air suspension in the late 1950s in one of their Cadillac models however without much success.

By the end of the 1950s air suspension appeared in Europe in the Borgward. In the early 1960s Mercedes picked up the air suspension (in parts directly from the Borgward) and introduced their air suspension with an improved system in the 300SE sedan and in 1963 in the Mercedes 600.

While the air suspension was considered to be the ne plus ultra of luxury and technology, Mercedes had not the idea that the air suspension would come cheap.

..."Mercedes Benz equipped W112 Chassis series cars, as well as 300SE sedans and Coupes/Cabriolets with air suspension since 1962. The system used a Bosch main valve (distributing the air pressure) with two axle valves on the front axle and one valve of the rear axle. These controlled an air spring on each wheel axle. This was entirely different to GM system in that the air spring used a bag mounted on a cone. As the car load increases on the bag it rolls down the cone and this in turn increases the air pressure in the bag. Because of the cone shape the suspension is infinitely variable. The axle valves do three jobs; they are fed reduced air pressure to the front and keep the bag supplied with sufficient air to keep the ride height constant. When the load is relieved they release air back to the car's air dryer. Later versions, such as the W109, included a ride height adjustment feature. The main valve has an extra setting the W112 cars did not have — the ability to raise the car up to 50 mm above the normal ride height. The rear valve is fed full air pressure from the reservoir in front, which in turn is kept filled by a single-cylinder air compressor powered by the engine. In 1964, Mercedes introduced its W100 Chassis car, the 600 Grosse or Grand Mercedes, which remained in production until 1981. The air springs on these are bigger version of those found on the W112 and W109 cars. On the 600 the air also powers the brake servo"... (Source: http://en.wikipedia.org/wiki/Air_suspension)

Advantages of an Air Spring based Suspension

There are several advantages of an air spring based suspension compared to a steel spring suspension which might have convinced Mercedes to go this route.

Advantage #1: The car can be kept on its ideal axle height independent of its variable load. This means that ideal axle geometry (castor, camber etc.) can be always maintained in the neutral height level. Driving safety is improved due to better road handling for example at night keeping the same headlight position.

Advantage #2: Driving dynamics, road handling and comfort are improved: The spring characteristic of an air spring is dynamic or progressive in nature (while a steel spring has a constant coefficient or a linear characteristic), therefore the suspension can better respond to driving: E.g. the suspension is soft and comfortable during slow driving and becomes noticeably stiffer during faster driving. The suspension responds to dynamic load as it reacts to live load.

Advantage #3: Better sound isolation of airbag and lower resonance frequency. This leads to a smoother and more comfortable ride.

Advantage #4: Higher ability to absorb energy which means better and safer handling in extreme driving conditions. The air spring has a higher ability to absorb energy or physical work compared to a steel spring and is therefore considered a safety feature.

The Air Spring in Comparison to the Steel Spring

This is an interesting comparison. Let us look at the design of two cars car with about the same properties (dynamic spring coefficient) , one with steel springs and the other with air springs. While the overall spring coefficient should be about equivalent even (although it will never be the same graph in a diagram) the W109 (air suspension) and W108 (steel suspension) are fairly comparable in terms of axle design and curb weight if both use the small V8. The rear spring of the steel suspension car has the coefficient of about 11.8 N/mm which would be a straight, sloped line as a graph. While the coefficient of the air spring is overall the same (measured at certain defined loads) the graph looks more like a rising curve indicating the dynamic character of the air spring. This property and the smoothness of dampening gives the 'air ride' its special note.

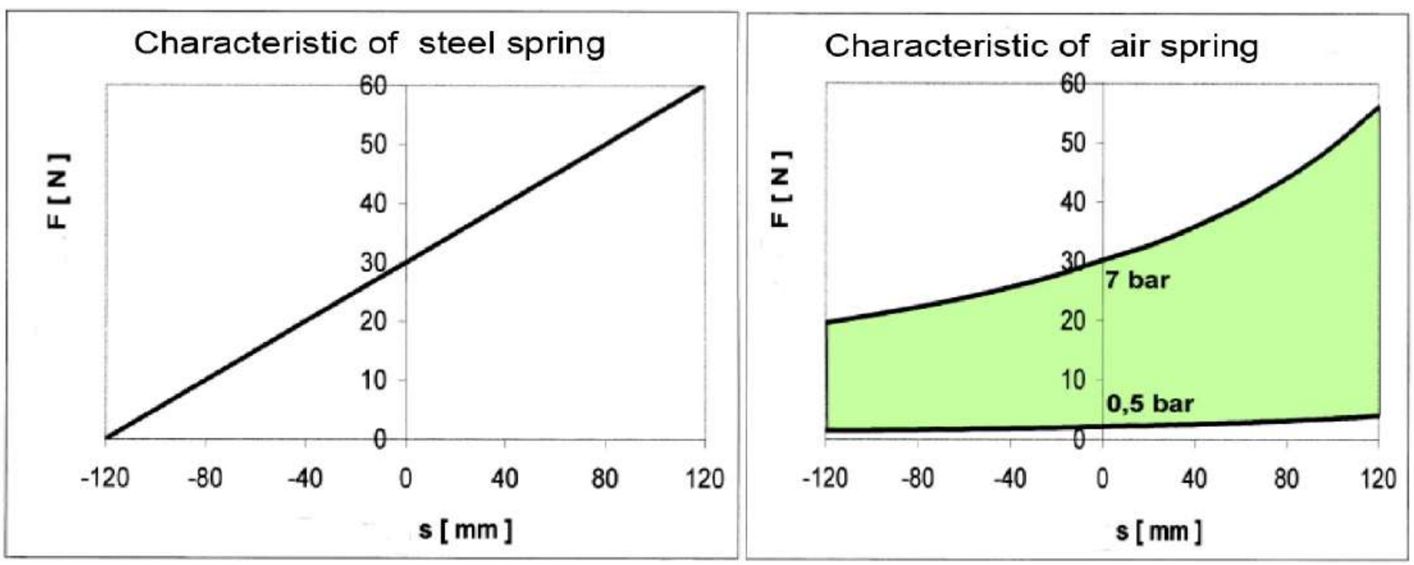


Diagram 1a: Comparison- steel spring vs. air spring

The geometry of the air suspension axle is very close to the steel spring version so that it seems actually possible to transform a W109 air suspension into a steel suspension by replacing the air springs with steel springs. Some frustrated owners (with failing air suspension) of the W109 have actually done this conversion but might regret the loss. I cannot recommend this conversion because the car will not be original any more and technically the car will lose the original ride quality.

Looking at the theoretical graphs in comparison, the steel spring has a linear function (y-axis being the load at the axle in Newton and x-axis being the spring deflection in mm) while the air spring has the curved graph indicating the progressive character. If I were to describe the air spring character, I'd say the air spring is relatively 'soft' especially during typical daily driving under no extreme load and becomes stiffer the heavier the loads get or the faster you drive. With comparable overall spring travel, the character of the air spring car during acceleration, deceleration/braking and cornering is very much improved. Also, the resonance frequency of the air spring car is lowered which means the ride is more comfortable.

The air spring also has about double the capacity to buffer energy during an extreme event before the rubber stops come into play.

How does the Air Suspension Work?

The general idea behind the air suspension is the 'spring like' characteristic of an enclosed air volume such as a ball filled with air. The air volume can be compressed in a progressive way, which is different to the linear compression rate of a steel spring. This is called the dynamic spring characteristic of the air spring.

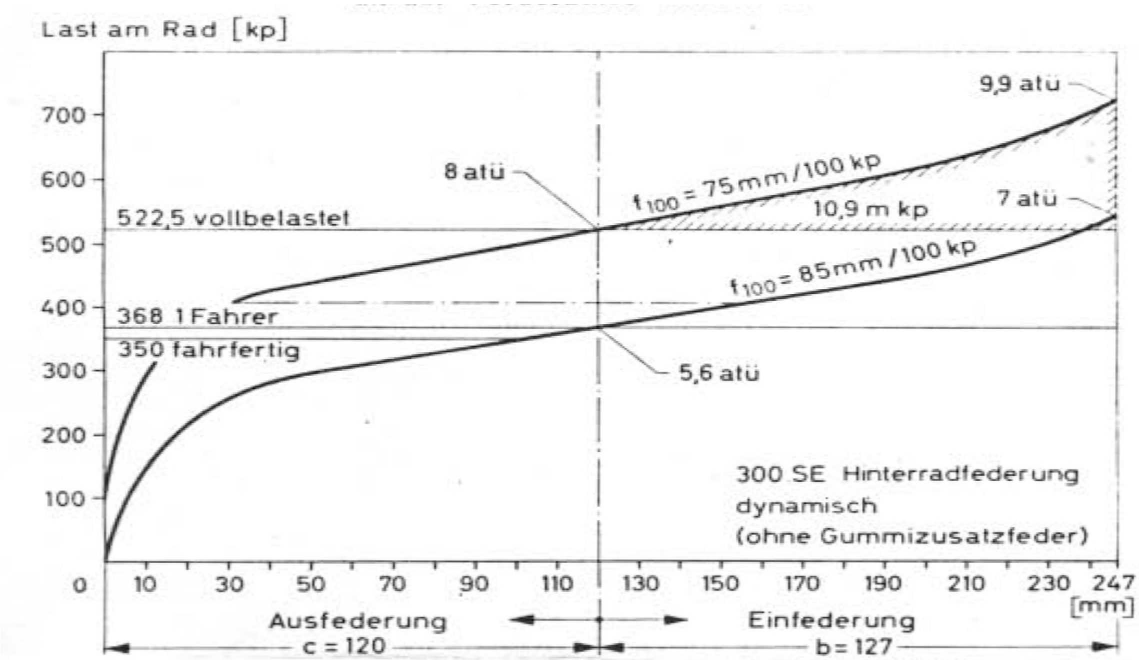


Diagram 1b: Dynamic air spring characteristic, 300 SE, rear axle (source: Article in magazine ATZ 1965 Heft 2, Februar 1963, Weller and Neuschaefer, Daimler-Benz- Luftfederung, page 38)

In a steel spring, the force (weight of car if we do not take any dynamics into account) is directly proportional to its displacement (suspension displacement or height differential). This means the more you push in the spring, the more force the spring creates in a linear fashion.

In an air spring car however the force is dynamic or progressive relative to its displacement. An air spring will get progressively stiffer as more force is applied.

Here is an interesting thought: We could remove the steel springs of a regular car and replace them with air springs, pump them up with a pump like a tire, seal off the air bags from atmospheric pressure and the result would be a very improved suspension which would be lighter and progressive in terms of the spring coefficient. However like with a tire we would loose some air over time and the car go down.

An enclosed air volume seems to be quite a simple model for a suspension and not that hard to achieve (actually the tires are pretty much that) but unfortunately we are not there yet. With changing temperatures and ambient air pressure the car would go up or down according the weather. And we could not adjust the axle height to variable live loads, one of the major points. In order to make use of all positive potentials the pressure in the air spring needs to be variable. This means air has to get in and out and it needs to be controlled. This is the tough part, which makes the air suspension complex, expensive and hard to repair.

Work Group and Support Group

In order to understand the air suspension system better, we will divide it into different groups. The most obvious ones are a) the Work Group and b) the Support Group.

The Work Group is the part that does the work, the heavy lifting. This is typically the air spring and all the parts that connect to the sealed and pressurized air volume of the air spring. Any part that holds air pressure in the air spring will belong to the work group: air springs, air lines, fittings and a few parts of the leveling valves.

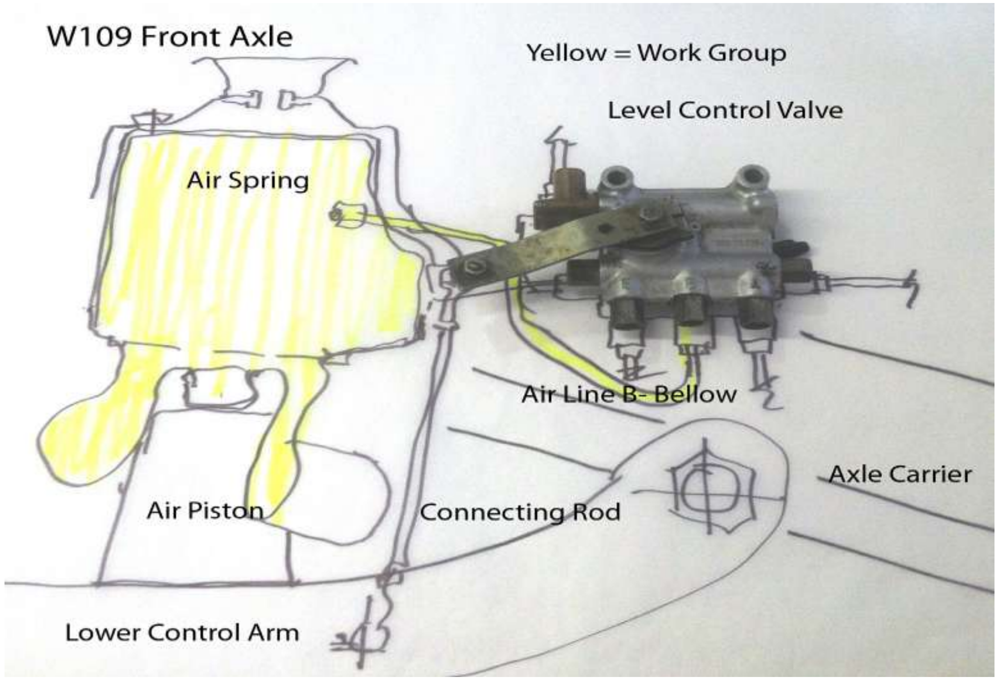


Diagram 2: Work Group  (Source: Martin Werminghausen)

The Support Group serves the work group so that it can do its job:  providing the correct air (mixture of compressed air and ethyl alcohol) adjusted air pressure, providing exhaust and recirculation air or releasing air to the atmosphere, control and adjusting riding height by providing control air suspension modes (normal driving, high position and locked position). Parts of the Support Group are: air compressor with accessories, air tank with lines and check valve, alcohol bottle for drying and recirculating air, main valve, air lines to leveling valves and the leveling valves.

Very few parts in the Mercedes air suspension belong to both groups. These parts are inside the leveling valves and are typically suspect of failure. They need replacement if the car is going down in a short time. The 3 parts we are talking about are 1) the intake valve (E-valve), 2) the exhaust valve (A-valve) and 3) the control lever (Stk) that controls the E- and A-valve.

Knowing about the Work Group, it is logical that components of this group must leak if the car is going down. Finally this group does the work. Of course the Support Group is involved if the car is going down. It will provide supply air until the tank is empty. A functioning Support Group with a malfunctioning Work Group can buy you some time but that is all. The car will finally do down.

With an air tight Work Group however the car will stay up for a long time (we are talking months, not days) independent of the Support Group. This is the system.  In other words if the car drops, there is certainly a problem in the Work Group. If you have a dropping car your Work Group is faulty with possibly some overlaying problems in the Support Group at the same time. This is not uncommon. I hope it is understood that there is a hierarchy: Work Group over Support Group.

Looking closer at Air Suspension Components

I'll explain the Support Group first which consists of a) generation and storage of air pressure and b) control of the air flow to and from the level control valves.

Diagram 3 below illustrates each of the air suspension components in a W109. The compressor (#2) with about 1 hp/ 50ccm is generating compressed air at about 11-18 bars depending on the driving situation, engine speed, ambient air pressure, etc. The fresh air to the compressor is filtered and mixed with vaporized ethyl alcohol for anti-freezing purposes. The majority of the air volume in the system however is re-circulating air. A pressure holding valve (0.2bar) in the anti-freeze device (#3) makes sure the re-circulating air has priority before any fresh air is drawn in. Only if more air is needed than available in the tank, will the compressor suck outside air into the system. The dominant situation is the tank is filled and the compressor is 'idling' which means it won't pump nor use much energy. This is a so-called semi closed system.

The compressed air from the compressor is delivered and stored in the 7 liter air tank (#13 ). Older style tanks can hold 5.5l and the 600's air tank has 7l+2l, 7l for suspension and 2l for the brake booster. This means that the common 7l tank can hold about 100 liters of air (7 liters at about 15 bar =105 liters) if released to the atmosphere. A check valve (#12) makes sure that the air won't return to the compressor. The tank has a port with a standard Schrader valve (#15) on the side for filling the tank with shop air.

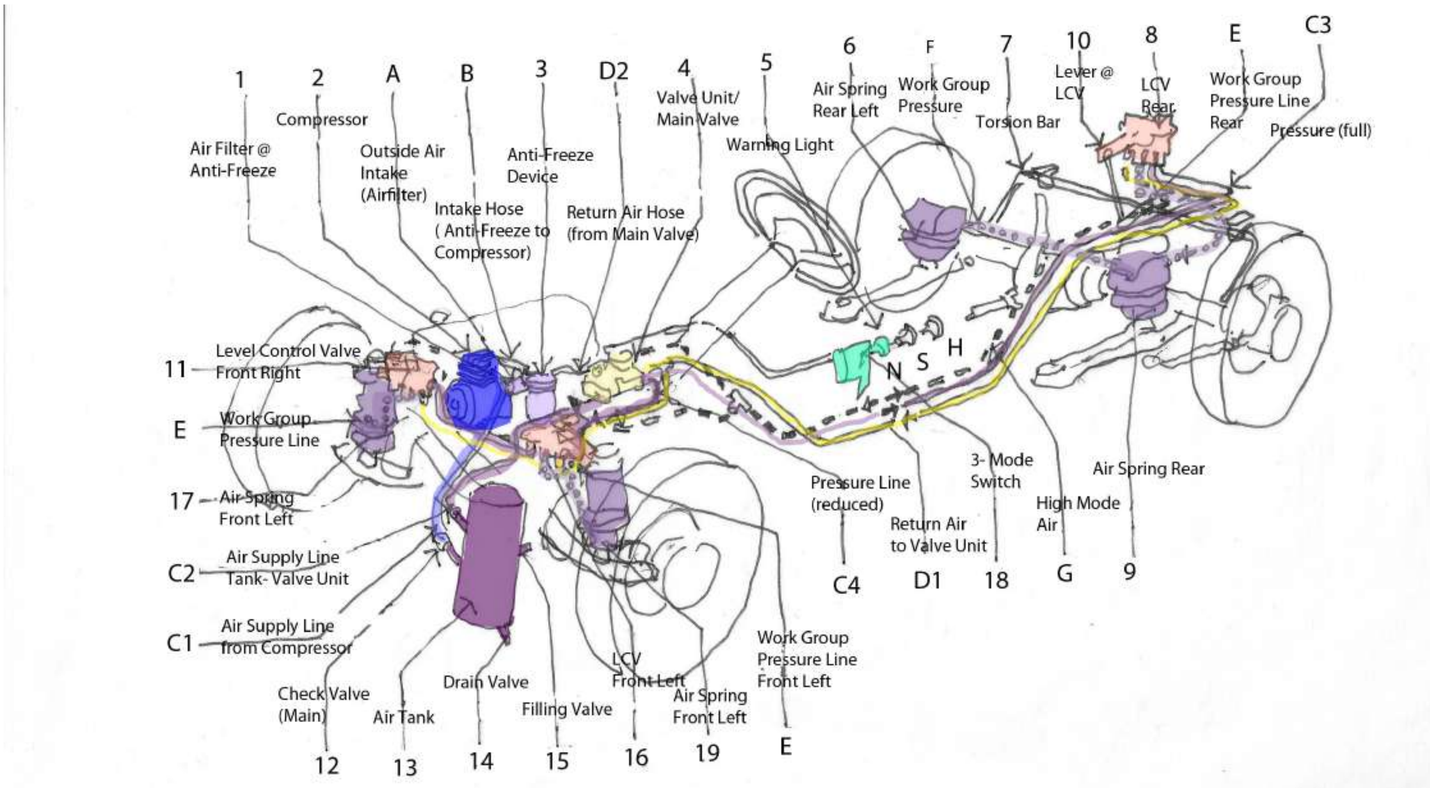


Diagram 3: Sketch Mercedes air suspension W109 overview (source: Martin Werminghausen)

In the air tank (#13) the compressed medium will lose humidity in form of condensate (like in any air compression process), which has to be released at the bottom valve (#14) during regular maintenance. From the drained condensate, a mix of water and ethanol, you can also examine if engine oil is present. Engine oil would indicate a problem with the air compressor which is internally lubricated by circulating engine oil. Releasing the condensate mixture will also drain the stored air pressure in the tank but this does not affect the level of the car if the Work Group is functional.

Air is delivered from the air tank to the valve unit (#4) which controls air pressure and distribution to and back from the 3 level control valves (# 8, 11, 16). The valve unit (after 1965) offers 3 suspension modes controlled from the driver seat for N=Normal driving, H= High level and S for Locked position (#18). There is a safety valve or over pressure valve in the main valve that limits the maximum air pressure to 23 bars. A warning light (#5) goes on if the air pressure in the tank drops below approx. 7.5 bar and goes out if pressure rises above 9 bar (The 600 switch cut-in point is 10bar, cut-out slightly higher).

Each of the 3 level control valves is connected with 4 air lines; 3 from the Support Group and one to the Work Group.

Line 1 (E-side) is the pressure air line (reduced to 10bars for front valves in W109 and W112 [#C4] and 13bars for the 600, rear valve has full air pressure of 12-15/18 bars [#C3]).

Line 2 (A-side) is the return line (return lines [#D1] for front valves are kept under 3bar or 4bar (600) by a pressure holding valve inside the main valve) and Line 3 (H-side, #G) receives full pressure for High-level function. If this line is set under pressure by the driver in ‘High’-mode the car will rise approx. 50 mm.

For any change in axle height, Line 4 (Work Group!) comes into play. Air from the Support Group (Line 1 and 2) will be controlled and channeled to or from the Work Group through the B- side of the level control valve. This air will finally regulate the air volume/ pressure in the air springs (#6, 9, 17, 19) doing the final work.

Air Lines

The lines for pressurized air and return air are made of steel tubing.  Similar to brake lines, they have double flanges for connectors with a socket union screw in the connector/fitting. This flare connection has an additional rubber seal ring in order to be airtight. This is different than brake line connections because air is thinner than brake fluid. Also all connecting fittings have O-ring seals which need to be replaced once the connection is opened. Air lines rarely leak unless they are heavily corroded. Pay attention (and use WD-40 or similar well in advance) when you open the flare as the screw connection can be corroded.

How do Level Control Valves Work?

Now we are getting closer to the details of the 3 level control valves.

They play a key role in the system. They belong to the support group, as do all the components described above. However, parts of the level control valve units also belong to the work group. This is where the overlap occurs.

Let’s explain first the reason why there are 3 level control valves. Why 3 and not 2 or 4?

All Mercedes sedans with air suspension had a swing axle in the rear. Mercedes chose a 3-point control system with 2 level control valves on the front axles and one on the rear axle. This 3- point control system is statically determined (similar to a chair with 3 legs) and has the advantage that unbalanced loads can be adjusted. A 4 -point control system had been found unpractical because the hyper static system makes control of the driving and suspension properties very difficult. One major challenge in the engineering of the air suspension was a solution for driving along a curve. There shouldn’t be any height adjustments (air going in and out) even though the front level control valves will naturally be activated in a curve (by the inclination).  We will come back to how MB/Bosch solved this issue.

The set of 3 level control valves work in the same way although they are slightly different in detail, depending on their location. The rear unit has to work less than the front units because the fronts have to respond to any curve while the rear one will stay in the neutral position.

The task is to follow and to adjust the position of the axle (height of the car) if it is out of Zero Position or Neutral Position. The lever of the level control valve (#10 in diagram 1) is mechanically connected to the axle by an adjustable rod and ball joint following the height of the axle in real time. The ball joints shouldn’t have any wear or slack.

In N-mode (normal driving mode set by the driver) here is what is happening in the air suspension with changing loads:

1) Height level too low (car too low on respective side) lever goes up= small intake valve (#29 in Diagram 4) opens and exhaust valve closes, #30). Result:  pressurized air is entering the Work Group through port B (fitting #34) to the air spring and the car rises on this side until the lever is in neutral position= riding height (both valves E-and A-valve are closed).

2) Height level too high and lever is down = exhaust valve (#30) opens (and intake valve closes). Result: air from the work group exhausts from the air spring to the main valve and the car drops on this side.

3) Height level is correct and lever in neutral position = intake and exhaust valves are closed. No air is going in or out of the Work Group. This is the situation when the car is standing and no change in load/height is occurring.

Under driving conditions, the ride height is constantly monitored by the lever and not often adjusted.  I will talk about that during cornering or braking. The major adjustments happen by live load changes or if car is parked on a non horizontal surface and therefore is permanent or statically out of balance.

The change in axle height can be minimal, a few millimeters only with the level control valve responding with height adjustment. If the car is stopped and the driver is leaving, the suspension responds with exhausting air along with a hissing noise. This is normal. It is rather suspicious if you don't hear this sound coming from the air filter /anti-freeze where the air is exhausted. It means something is not correct.

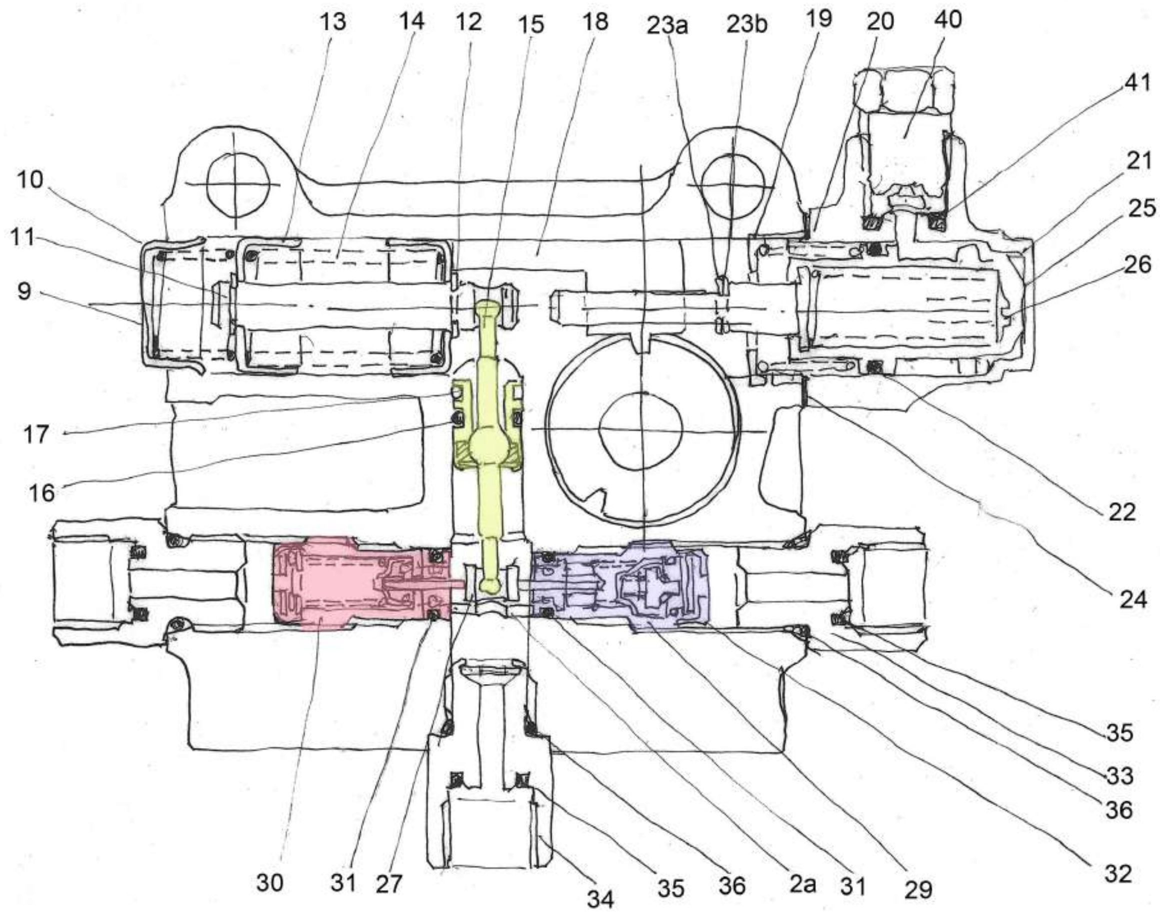


Diagram 4: Section of later style level control valve, front right side (Source: Martin Werminghausen)

Level control valve in S- mode (locked). There are the same functions as in N- mode but exhaust air is blocked even though the car might be too high. Locked mode is typically applied during service, wheel change, car on a stand or lift, etc. Another brain exercise: If your car is dropping in N-mode but does not in S-mode, which part is faulty?

Well, it must be the A-valve or is it not?

In H-mode we see the same axle functions as in N- mode but the car rides 50mm higher.

The car can be even driven (slowly!) in H-mode but the axles are not in their correct neutral position (for camber and castor etc.) and the pressures in air springs are higher meaning the spring coefficient has changed and doesn't fit a comfortable ride. In fact driving fast in High can be unsafe. H-mode can be beneficial if the car needs increased ground clearance for maintenance or road condition. When I was driving my W109 in the deserts of Oman, I was happy to have this feature once in a while, especially when I was forced to drive on dirt roads.

By the way it is very clever how the engineers achieved raising the car by approx. 50mm and keeping all the other functions of N-mode. You could put the car in H-mode and then in S-mode to lock it in H. These are the higher dimensions of the engineering and remember, this is all mechanical, no electronics involved.

Incidentally, this gives you another option for doing maintenance on your car in high position. I used this trick once in a while.

Now let's look in more detail to the movement of the parts inside. Here we see that the lever (#15 in Diagram 4) is connected to a gear that translates the axle movement- rotational movement of the lever into a horizontal movement of a piston (#27) that moves a small lever (#15) in 'Stk' (this is German 'Steuerkolben' which means control piston). There is no piston in the Stk itself but this little lever or toggle is moving/ controlling a small piston (#27) in the lower end of the unit, which controls the E- and A-valve (E-valve [#29] means 'Einlass' or intake valve, A-valve [#30] means 'Auslass' or exhaust valve). The name Stk is correct indeed. You see this also in diagram 5.

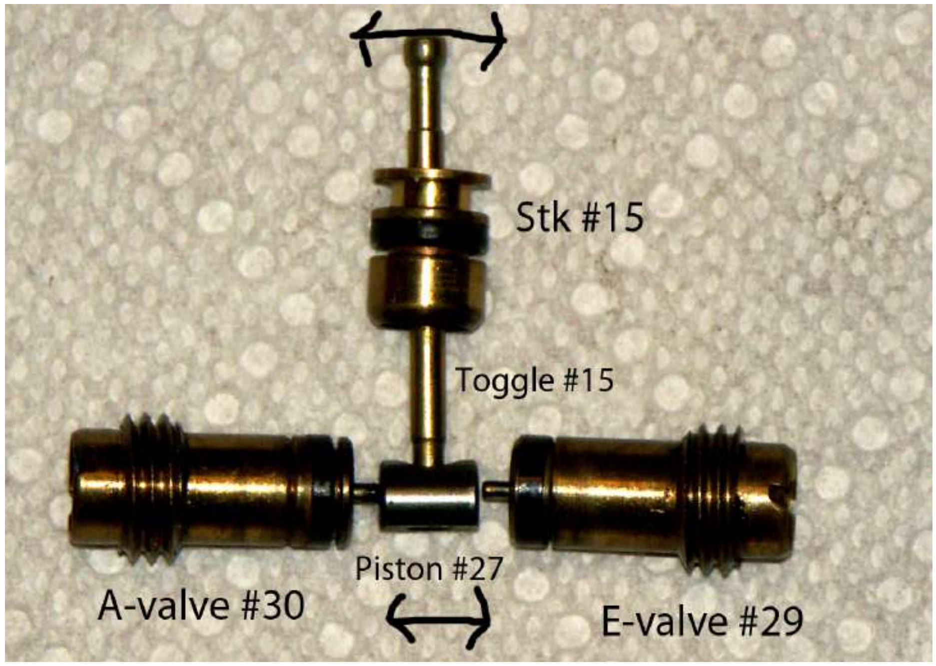


Diagram 5:  A-valve, E-valve and Stk (Source: Martin Werminghausen)

The valve unit reacts very precisely with almost zero internal slack (dead play) by design because any dead play is excluded by internal spring retraction. I have opened and examined many units and none of them have had substantial internal gear wear.

Also any mechanical slack outside the valve unit has to be avoided and worn parts should be replaced in the ball joints of the connecting rod because this will lead to a slow reacting suspension outside MB specs. This also assumes the axle movements and joints (control arms, king pin etc.) are within MB specs.

There is a major adjustment required inside the level control valve. This is the suspension play  (axle height differential) defined by the small amount of inner movement of the Stk and associated piston when neither the A- and E-valves will be activated. I also call it dead play. Positioning the E and A valves relative to the piston of the Stk does the adjustment. The tolerance has to be adjusted to or close to Mercedes specification. If this adjustment is not correct, the air suspension won't be right.

Again, the 3 inner parts of the level control valve (# 15, 29 and 30) are important as they belong to both the Support Group and the Work Group. These parts are most possibly suspect of failure and need to be exchanged if your car is dropping.

A pressurized air line activates the H-position of the car. The control air activated by the driver and main valve moves an inner piston (#21) in the attached brass bonnet. This is an interesting move indeed. It bypasses the plastic piston (#18) and by ingenious engineering the car goes up by a defined height differential (50mm) while it keeps all the other control mechanisms as discussed for N-mode. The details of this mechanism are not easily described or understood (see parts in Diagram 8).

The Air Spring Design

As said before the axle constructions are very similar and the air springs sit in the same position as the steel spring in a W109/108. The air springs with 2.8 liter / 6 – 8bar (front) and 3.6 liter/ 5.5-8 bar (rear) are composed of a sheet metal tank with a nylon and steel reinforced rubber bag, neoprene layer on the inside (company Phoenix) which is attached to the steel tank with a clamp connection. Air springs of the W100 are bigger: 4.05l at 8.5-10bar for the front axle and 4.25l at 7.0-9.5bar for the rear axle. The upper sheet metal part of the spring is fixed to the chassis while a special steel cone at the lower control arm is used as a piston that compresses the air spring in a rolling movement according to a specific progression (defined by the shape of the piston and the spring coefficient). The fitting for the air line connection bringing air in and out is attached at the sheet metal. This construction is very solid and airbags rarely leak unless the rubber has aged so much that deep cracks develop. With the air under pressure we might have about 85l of air in the springs (air expanded under atmospheric pressure). In case of a failure all this air exhausts.

How much Air is Stored in the System

There is a total of about 167liters of air (measured at ambient air pressure) in the suspension system of the W109. This is 19.8 liters under a medium pressure of about 8.4bar under light load and driving (not counting the minor volume of air lines and valves). Math: Air tank 7l (x 12bar) + front air springs 2x 2.8l (6.5 bar) + rear air springs 2 x 3.6l (6.5bar) = 19.8l x (8.4bar) = 84l in air tank + 36.4l in front springs + 46.8l rear springs = 167l total air in system. The amount of air in the system varies which affects the pressure in the air springs depending on live load, driving condition, ambient temperature and ambient air pressure.

Under more extreme load conditions (max live load) and max air pressure (depending on altitude of car and air driving conditions) there is approx. a max of 7l (18bar) + 2 x 2.8l (7.5bar) + 2 x 3.6l (8.5bar) = 229l of air in the system.

The Main Valve Unit

The main valve is a complicated component that Mercedes/Bosch invented. It allows operating the car/suspension in 3 different modes as described above: N, S and H- mode. One major critical point of an air suspension was solved by the Mercedes/Bosch system: Driving a double bend curve.

Just imagine you are driving on a curvy country road cornering the car to the right and after that cornering to the left; an S- shape route.

What happens in the front air suspension control in a right curve? The front right side will go down while the left side will go up. With an air suspension, it means basically that the front left and right control valves sense the change of axle height and respond by pumping up the right side and lowering the left side. Just imagine how bad this would be if you steer the car from the right curve into left curve? Your car will be out of balance. In the extreme this would be even dangerous.

What the engineers designed was 1) put the return air line on a pressure holding valve which keeps the return air at 3bar (4bar for W100 due to higher weight) so if the bellow has close to 3 bar (at the side coming up), no air will leave even if the exhaust valve is open and 2) reduce the air pressure for the front level control valves to 10bar (13bar for W100 due to higher weight) which will be close enough to the increased pressure of the compressed air spring (at the side going down). With this design the engineers could keep the axle levels largely neutral so that almost no air moves in and out of the air spring during cornering. If air is moving for a short time, the pressure differential is too low for the air passage which is especially designed for reduced flow. The air passage is a throttle which is finely tuned and is different for the front and rear, approx. 0.3 and 0.6 sqmm inside the valves in order to prevent substantial air flowing during cornering and in order to optimize ‘air usage’ in the system.

During hard braking we see a similar but less complicated situation. The impact is short with no air flowing because both front air springs are compressed (intake valve opens) with little to no pressure differential in the bellow and intake.

With the main valve design, Mercedes/Bosch managed to overcome a major negative and get the best performance out of the air suspension system.

How well Designed and Built is the Air Suspension System?

The design of the system as described is thorough and even ingenious from my point of view. It was a great pleasure to discover the design with the help of people and friends. While I was renovating my own W109 air suspension, I could use my contacts back home in Germany. A friend of mine (working for Bosch) helped me machine the first bullets according my technical drawing that required a special lathe and tools…so small were the parts.

The air suspension system technologically was potentially the best suspension system on the market at the time. It was for sure the best-engineered system of its time. The parts are mostly built of metal which lasts 'forever' however a second material is used: rubber. Achieving reliable air tightness was possible with the help of rubber seals but rubber tends to harden over the years. Even today with better quality materials there is an expiration date for the rubber. In my experience the custom O-rings are the main leak points while standard rings seem to be more durable. Failing rubber seal rings bring the system down after the rubber has lost its elasticity and hardened. Other problems may add to this but not in an essential way. Contamination inside the system rarely causes problems. Dirt in the air can accumulate inside (check your air filter!) or if the compressor is throwing oil it will end up in the air system and contribute to decay. Corrosion of steel lines is also rarely seen. Sometimes lubrication inside the unit is challenged by hardened grease, but this also is not a big issue compared to failing seals.

From what I have seen, the rubber seal rings are the main problem as everything else is very robust and amazingly durable. You might get even more frustrated if you knew that some little rubber rings cause the trouble. During the repair not only will all the rubber parts be new but also contamination and long term lubrication will be taken are of.

No doubt, the air suspension requires a high degree of maintenance. And most possibly your system will work perfectly fine after components have been brought back to spec. This means the failing components have to be repaired/ rebuilt and the system maintained according the rules.

The bad news is: The repair can be frustrating, appearing complicated because the theory is not well understood.

Rebuilding the valves units by a qualified specialist does not come cheap simply because it is demanding and complex. Engaged and experienced DIY people can repair some of the simpler hardware but the renovation of the core air suspension components should be in the hands of the specialist. Too much knowledge, experience, specialized tools, precise instruments and parts are needed for rebuilding the core parts such as the level control valves, the main valve and the pressure regulator (600 only) as well as probably restoring the anti-freeze unit.

What can go Wrong with the Air Suspension and how can it be Repaired?

These old cars want to be driven and they work better. This is to say that an air suspension in use will work better and not leak as much as those that spend their years in garages. This at least is the experience of people driving these cars.

But if the car starts to drop in shorter periods of time it is time to repair. The assumption is that the leak is not getting any better.

Some want to know what the problems are.

In order to figure out what the problems of the air suspension are and how to solve them, you can do an analysis. A detailed analysis is not an easy task as the system is relatively complex and must be fully understood in order to come to the correct conclusions.

Some people say that it is okay if the car goes down within a week or two. Even Mercedes mentioned in their service book that a pressure drop of 1 bar per day is within the limit. A 1 bar pressure loss would mean that your car drops within 10 days with a 10bar load in the air tank. But this cannot be seen as a good standard. A 1 bar of pressure drop per day I'd call the extreme side of the tolerance. The design calls for an airtight system and that means even with no support air from the tank, the car will stay up for months if things are right.

If the system has leaks and the car is down sitting on its stop buffers, the axle construction is under stress and the compressor has to work very hard every time the car needs to rise. The compressor will have constant stress because it was not designed for this additional load and the axle stops will suffer. If a dropping car is not repaired it might cause even more expensive repairs. Don't wait too long with the repair.

My car was sitting low every morning after I bought it.  I had to start the engine and let it idle for at least 10 minutes until the car came up.  You can imagine how embarrassing and frustrating that was for me (and for my neighbor).

Potential problems of the system might be a worn out compressor due to wear of piston rings sometimes caused by restriction in the oil line to the compressor, crusted and leaking reed valves (check valves) in the cylinder head or other hardware, corroded or damaged air lines or single failing elements like the rubber bellow or a failing main valve, level control valve, a leaking check valve or a leak in the air tank bottom valve.  The compressor must be healthy which is checked by how fast it is able to pump air (pressure increase from 12-14bar within 90 seconds at 2000rpm for the W109). The 600's compressor must be even healthier as compressed air for the brakes is needed in addition to the suspension.

Here it comes again: The core issue of a dropping car is typically failing rubber seals. Oh yes, there are plenty of rubber seal rings in the system. Many of the air line connections are sealed with rubber rings and these may leak but in fact they rarely do.  And yes, they all need to be exchanged once the line is opened.

If the car goes down the primary problem lies inside the 3 level control valves, sometimes in combination with the main valve and other components with main valve and others being only a secondary, additional reason. Again the primary culprit is a leaking A-valve, E- valve or Stk or a combination of the 3. The problem clearly comes with aging rubber causing an otherwise entirely perfect inner valve to fail with the car is going down.

The other 2 units that can fail and possibly need professional attention and rebuilding are the main valve and possibly the anti-freeze unit as they also contain inner valves (and the pressure regulator for the 600).

Analysis and Rebuilding of the Level Control Valves

With a tight work group the car will not go down even if the support group is failing. Remember also that the 3 inner parts of the level control valve belong to the work group: E-Valve, A- valve and Stk. If the car drops there is a high potential that these 3 parts are involved.

If the car goes down you can analyze which side is failing. The first thing to do is put the car on a horizontal surface such as a level garage floor. The car can drop at 1, 2 or all 3 level control valves. Which front side is failing is sometimes hard to identify. If one front side goes down the strong sway bar will pull the other side down as well and it might seems that both sides failed while in fact they didn't. The level control valve in the rear sits in the middle so you will clearly see the drop on both rear sides. Remember the rear axle goes down on both side in parallel.

With some experience you can identify which level control valves have failed. However the question is do you renovate the ones you identified or all 3 units at once.

Yes it makes sense to renovate all 3 as they are probably the same age but this is a matter of money. Sometimes the rear unit is more robust because it has less action that the front units which have to handle a bigger part of the dynamic axle movements from acceleration, deceleration and steering.

Let's look at the different kinds of leaks: outer leaks and inner leaks.  You might already know where this is going. Outer leaks are relatively easy to identify. The air leaks directly to the outside where there is hole.

Inner leaks are different and more difficult as they leak not to the outside but instead to another inside volume of the system which is not easy to access or analyze.  These inner leaks or internal leaks are the ones we are talking about when it gets down to the analysis. This is a bit like the chess master who needs to imagine several moves ahead.  The inner leak will exhaust air into another inner volume and then probably to another until the air finally escapes to the atmosphere, appearing as an outer leak. As an analyst you must know the logic of the system and exclude one part after the other. All the leaks inside the level control valves are considered inner leaks and are therefore harder to analyze.

Let us zoom into the level control valve. The A-valve inside the level control valve rarely leaks. However if it does, it could be identified as a single element. As I mentioned it before, if the A- valve leaks internally exhaust air will leak out of the exhaust line to the main valve and drain the air spring. The car will go down, the lever will go up and pressurized air will enter the air spring (keeping the axle up) until the air tank is exhausted with the car finally dropping to the stops. This particular problem (A-valve) can be verified with a pressure test on the specific port of the main valve (disconnect the return hose from main valve to the anti-freeze unit and watch for exhausting air). Or you put the car in S-mode (locked) and if a miracle happens; with the exhaust line locked and the car does not drop, the culprit must be the A- valve. You can identify A-valves this way but you won't know which of the 3-A valves is or are failing. For identifying which A-valve, you need to isolate each exhaust line A (German Auslass= exhaust) and test each port separately for leaking air.

It will be the side that is dropping but the bad news is: This doesn't mean that other sides do not drop for a number of different reasons.

As you see, a detailed analysis is not easy. The inner leak of a failing Stk is often hard to identify because the air will find its way out in places you cannot easily access with the unit in situ. The primary leak will exhaust the air into the inner volume of the upper valve body and then escape at the spot with the least resistance to the outside atmosphere. It can be the locking pin of the Stk or the valve axle.

You can use a leak test spray of soapy water and watch out for air bubbles. You will possibly find the leak if you are persistent however often you don't find it easily.

In an old manual, MB recommended filling refrigerant in the air tank and then searching for leaks with a leak tester. This is not an option today as it is illegal to exhaust refrigerant into the atmosphere.

Diagram 6: Old Stk cut open (Source: Martin Werminghausen)

An inner leak of an E-valve (it will most possibly be the check valve) is fairly complicated to identify. A leaking check valve is not even noticeable if the support pressure is active (air tank under pressure and low pressure light not on). Only if the support pressure is finally exhausted will the check valve leak 'upstream' with the exhaust air from the work group also upstream through the intake line back to the main valve. This means that if the air is escaping through this check valve, there must be another problem existing in the support group (it could be the check valve in air tank or main valve leak or an air line leak). Or in other words, if the support group is working properly the non- functional check valve in the E-valve is dormant.

Diagram 7: Old E-Valve cut open (Source: Martin Werminghausen)

External leaks of the main valve are relatively easy to identify with a leak spray test. Inner leaks are more difficult

You can now understand that a detailed analysis what exact parts are failing is difficult. A safe analysis and testing of the A, E and Stk can only be properly done with the unit on the bench before rebuilding. But in this case the units are already removed and an analysis doesn't make much sense anyway because rebuilding is under way.

A straightforward analysis for a car owner is often more helpful and 'good enough' to find which axle drops and to and remove/replace the level control valve with a newly rebuilt unit. If only one front level control valve is leaking is it highly recommended to renovate both front units which come as a pair.

It is even recommended to consider rebuilding the full set of 3 because the rubber in the not yet failing rear unit has probably aged too. Since it is just a matter of time until this unit will fail so why not do the set if you are going over the air suspension anyway.

Detail of Re-building the Unit

I have to mention this here: Rebuilding of these complicated units is a job for a specialized and experienced professional. With all respect this is not a DIY job. It involves a clean 'lab' or workshop, a lot of knowledge, experience, custom tools and testing and adjustment equipment, new CNC parts and new rubber rings. The job requires a high level of understanding, cleanliness, precision and accuracy. Rebuilding is done according to a protocol. There is a system. I cannot explain all the steps but this might give you a rough idea of the sequence:

The outside of the unit gets a thorough cleaning. After this the unit is taken apart with special tools.

The diagram 9 shows how the parts look like after removal.

In sequence all single parts will be cleaned. All steel parts will be plated after rust is removed. Bolts, washers and paper seals will be replaced. The rubber wiper seal of the lever/gear gets inspected and replaced if needed. The aluminum valve body gets another cleaning in an ultrasonic bath.

All the inner parts except for the 3 'bullets' will be cleaned, lubricated and resealed with new O-rings. Not only the size but also the hardness of the elastic material is of importance as there are rings of different hardness used in the level control valves.

Newly machined CNC parts will replace the 3 old 'bullets' called A-valve, E-valve and Stk. Some rebuilders won't change the A-valve necessarily if it tests okay. All the inner and outer seal rings will be replaced by fresh and new seal rings. In order to harvest the inner parts of the old bullet (little valves, springs and valve seats) the flanging has to be opened which makes the old brass bullet useless (see diagram 6 and 7).

New A-valve, E- Valve and Stk brass bodies are precisely machined parts. The inner small interior parts of the old bullets (springs, valve seats, toggle etc.) will be cleaned and reused. These interior parts are not available from Mercedes and need to be reused.

After the new bullet is assembled it will be permanently closed by flanging- just as the original.  Flanging is deforming the thin edge of the new bullet with a special flanging tool. Finally the bullet will go through specific testing procedures before it receives 'approval status' and is ready to go in.

Pressure testing begins meaning the parts need to hold defined test pressures for a specified time. Typically there is a short primary test with high pressure and low air volume. This gives a quick idea if the bullet is good for the longer test of over 12-24 hours; the E-valve goes through an additional testing procedure in order to make sure that the second valve (check valve) will work with minimal pressure differential.

In the rebuilt valve unit not only do the single parts need to open and close (and be airtight) properly but all three bullets (E-Valve, A- Valve and Stk) need to work together according specification. It is team work.

The position of the A- and E-valve in the unit relative to each other will define the 'dead clearance' and 'zero point' of the unit. Both adjustments will be done to Mercedes specification by the professional. The required clearance is a very fine one and precision tools are needed in order to achieve the correct result. A third adjustment is the proper suspension displacement of high position (50mm higher).

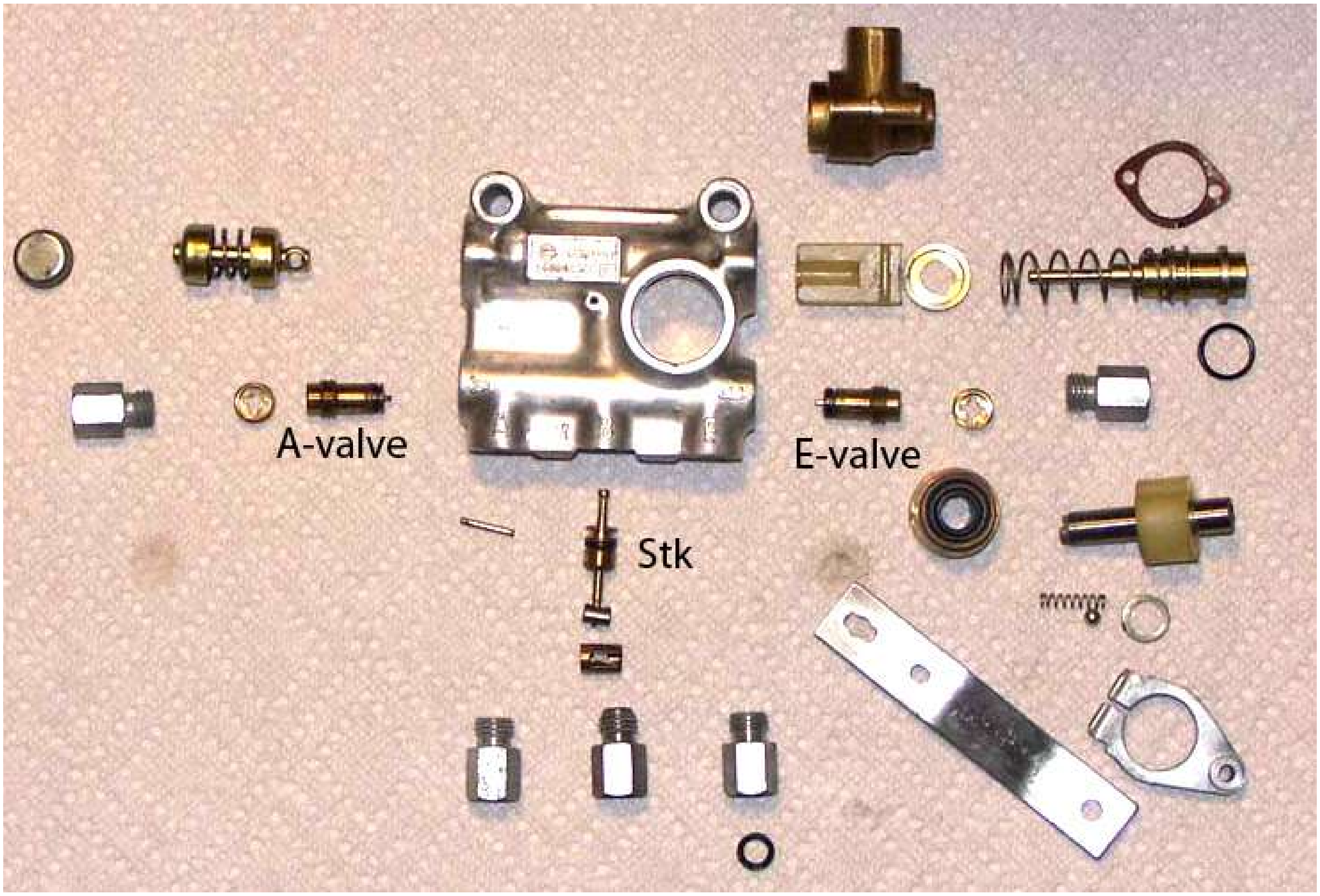


Diagram 8: Level Control Valve taken apart  (Source: Martin Werminghausen)

Rebuilding Main Valve and Anti-Freeze Unit

The procedures and logic behind rebuilding the main valve unit are similar in principle to the level control valves. The parts and protocol however are different. Some tools and testing equipment are shared with the level control valves and some are not. Some of the replacement parts for these units might be still available from Mercedes but chances are that they are not or will be NLA (no longer available) in future. The most important issues of the main valve are the function and air tightness of the 3 small bullet valves, the pressure reduction valve and the pressure holding valve.  The over pressure valve and pressure switch need to pass the test. These functions will be checked and tested during renovation. Rebuilding and testing is demanding and needs to be executed according to a protocol.

The function of the anti-freeze unit (some call it the drier) is often underestimated. It dries the air because ethyl alcohol (min 96% denaturated ethanol) absorbs moisture from the air. The unit requires attention because it contains 2 inner valves directing the flow of air and it features a nozzle, similar to the one in an old school carburetor. This Solex nozzle need to be clean and functional because it provides the correct amount of alcohol for the incoming air which is necessary for keeping the system free of ice in winter (it works down to minus 40 C). The recommendation is to use ethyl alcohol during all seasons. If the nozzle is closed or partially closed this function is diminished and the health of the air in the system in question.

There are 2 valves inside which direct the air stream in order to 1) recirculate the air from support return line back to the compressor (0.2 bar pressure holding valve, if return pressure is higher return air will exhaust out) or 2) provide fresh outside air to the compressor through the air filter. The second valve opens as soon as the compressor produces a certain amount of vacuum/suction. This happens after the compressor is moving compressed air to the tank where it cannot flow back (check valve). Sometimes these inner valves are stuck and the rubber seals in the alcohol bottle and filler screw have hardened and need to be changed. The paper air filter also needs attention. If damaged, unfiltered air can enter the system which should not happen. A filter change makes sense but it is not easy to do as it requires opening up the flanged aluminum filter housing which damages the housing. It doesn't look good. Mercedes still provides new air filter units but they are expensive. Long term a repair solution for the air filter housing makes sense because the air entering the system has to be clean.

600 Pressure Regulator

For the Mercedes 600 there is another device that needs attention: the air pressure regulator. This is a device screwed directly to the air tank controlling and directing air into two different areas: air brakes and air suspension. For this reason the 600 air tank has 2 inner chambers. The brakes in these cars work on air pressure instead of a vacuum brake booster. Of course the brakes have priority in case of air shortage. A problem with leaking air or compressor failure would be a critical problem for the 600 braking system. In case of an air emergency, the brakes borrow air from the air suspension. The regulator gives the brakes the right of way. The device works in some ways similar to the main valve, and in other ways it is different as it controls the pressures and passages from the compressor to the various groups, brakes and air suspension. It also includes a check valve for the air supply line.

Availability of Spare Parts

Over time fewer parts are available from MB. This information might not be 100% accurate but I want to give you some idea of what it takes to obtain parts. You can still buy (2013) the rectangular o-ring for the air fittings for about $7 per piece. Air fittings M12 x 1.5 (#33 in Diagram 4) and M14 x 1.5 can still be ordered but they typically do not fail. Air lines are not available and would need to be manufactured. The level control valves are no longer available new to my knowledge and the only way is to order rebuilt units. No inner spare parts for these units are available. The main valve can be ordered new, at least for the 600, for around $1450. No inner parts for the main valves are provided to my knowledge. The anti-freeze device is NLA (last price was $850) with the exception of the air filter that is available for around $350. The 600 pressure regulator can be ordered new for about $2900 but no inner parts. The check valve, drain valve for the tank and parts for the compressor might be available.

Buying Remanufactured Units or NOS Units

Remanufactured units off the shelf or NOS units (new old stock) might bear the problem that shelf life is limited and as a buyer you want to make sure that the unit was rebuilt not too long ago. If this is not the case or you just don't know the 'expiry date' the seemingly 'new' unit might be at least questionable. Shelf life of rubber seal rings is about 15 years according to some sources.

Afterword

From my personal experience I can tell that you will enjoy every bit of a ride with a proper working Classic Mercedes air suspension. I hope this article sheds some light on the complexity and the ingenious engineering of the Mercedes air suspension. It is a bit like a Swiss watch. If it works it is heaven but if it's not…it is hell. I hope this article gives you the courage to understand the background and fix this extraordinary system.

It is clear to me why the air suspension did not become mainstream. The system is too exclusive, too complex and too expensive for an ordinary car. The good new is: A Classic Mercedes-Benz is not an ordinary car.

The air suspension is a distinguished piece of German engineering. You can be proud if you ride in one of these extraordinary 'time capsules'.

Martin Werminghausen

Boston, February 11 , 2014