Mercedes 600 Comfort Hydraulics

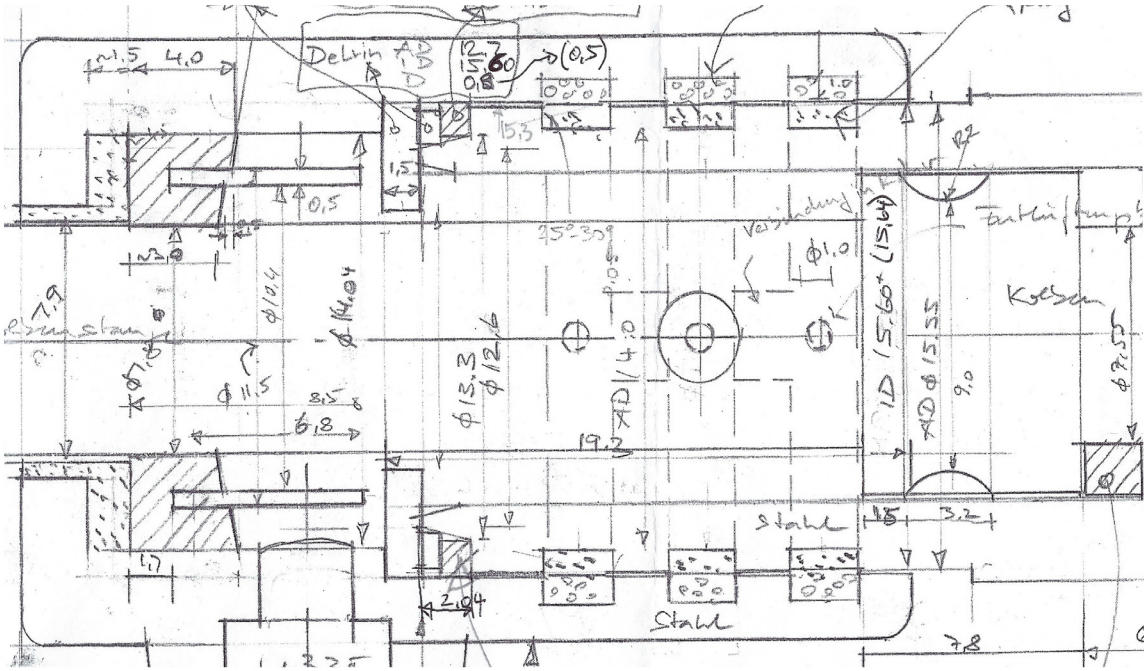
A report about the Mercedes 600 Comfort Hydraulic System

By Martin Werminghausen

I still remember the Mercedes 600 self-closing doors when I saw the car in the 70s. This minor detail was very fascinating to me.

Introduction and Research

Since I am involved in repairs of the system I was doing research excamining single components and I am impressed by the quality and finesse of the parts. The quality is showing after 40 or 50 years.
With the 600 Mercedes /Bosch was applying the first sophisticated hydraulic 'comfort system' in a car - beating the competitors at the time of its design in the early 1960s. Back then hydraulic pistons operating at 200 bar were well known but used in the air craft industry.
Hydraulics was not used for luxury or comfort in cars before in operating accessories such as windows, seats, ventilation, A/C or doors.
In the 1950 sand 60s the US was working on space flight. Hydraulic systems were essential to operate a spacecraft because of its reliability and power under severe conditions. Similar systems were used before in aircrafts since the early 1900s.
Smaller dimensioned hydraulic cylinders were used rarely in other industries, for example in medical operation tables.
Hydraulic piston and pressure seal technology was not yet developed fully to the extent they are today. During these early days O-Rings and hydraulic piston seals for instance were still in their infancy. The first Teflon guide rings were applied and explored more by experience than by material science. O-rings were fairly new and not standardized compared to today's standards. New materials were invented like rubber and plastics, for instance Teflon, Delrin and made hydraulics possible.



Partial Section, Sketch of a KH Double Acting Piston, source Martin Werminghausen

Years ago I disassembled some units out of interest. I wanted to know how these seals look and how they work: pressure seals, piston seals, the pump seals and switch seals including valve seats and valve bodies. People normally would not do this for the joy of analysing an old system –would you? Even if you are able to perfectly rebuild a unit it doesn't mean that you understand how exactly the parts perform under high pressure. My way is different. I need to know how it works and why. The intuitive 'feeling' of the inner working is not a guaranteed experience but for me it is. I want to dive into the minds of the former designers and feel what the engineers might have experienced. Therefore I built my own testing devices with the most precise measuring instruments I could get.

Back in the 60s when Mercedes/Bosch developed the KH hydraulics were not new but there was no common industrial norm for seals but company solutions. The 200 bar operating pressure in hydraulics was well established for decades and considered a good standard in terms of power density and sealing technology for air crafts. However this system was never applied to a car in the complexity of the Mercedes 600. And to my knowledge this has not been repeated ever since for one simple reason: Money.

Hydraulic Pistons (also called cylinders or rams) were commonly used in aircrafts for its robustness, reliability and strength.
In the early times of hydraulics there were as many seal designs as there were pistons.
Seals were unique to the application using a mix of custom Teflon rings and custom rubber seals. The use of custom rubber profiles for cup seals or custom forms was not unusual. As a result a failing piston leads to grief because there is no original replacement part available.
However there are solutions. I do recommend using a high quality modern seal. This solution will often come with some custom machining. Another option is a custom machined Teflon seal with a back-up ring. Either option should provide the same quality as the original seal.
The M-100 was obviously not a mass production car and repairs of the hydraulic units require custom work and repairs are not cheap.

The 600 hydraulic system is a unique and exclusive feature in an automobile because of its silent, soft and still powerful movements of seats, windows, sunroof, air flaps, door and trunk latches etc.
The KH (KH stands for Komfort Hydraulik in German) is a wonderful system but it is not essential for the operation of a passenger car and therefore it is 'unnecessary' but also the most exclusive luxuries of the Mercedes 600. And although this superb system comes with a price it is well worth the effort to maintain.

ATE Piston Accumulator Seals

In a repair situation the old piston seals, rod seals, cap seals and guide/wiper seals will be replaced by modern seals. Often times additional adjustments of the piston require machining.
A modern piston seal and rod seal is a complex composition of different parts, mostly NBR or Viton combined with ETFE (Teflon).

The piston of the original ATE (Teves) accumulator was designed with 2 aluminium parts, connected with a vulcanized rubber piston ring and 2 Teflon back up rings. This seal has to hold 100 bars of nitrogen pressure in the 80mm diameter cylinder. Most of these old accumulator piston seals are leaking and need replacement. The new piston seal comes with a new piston or a new piston head.

Original ATE Piston from Accumulator, source Martin Werminghausen

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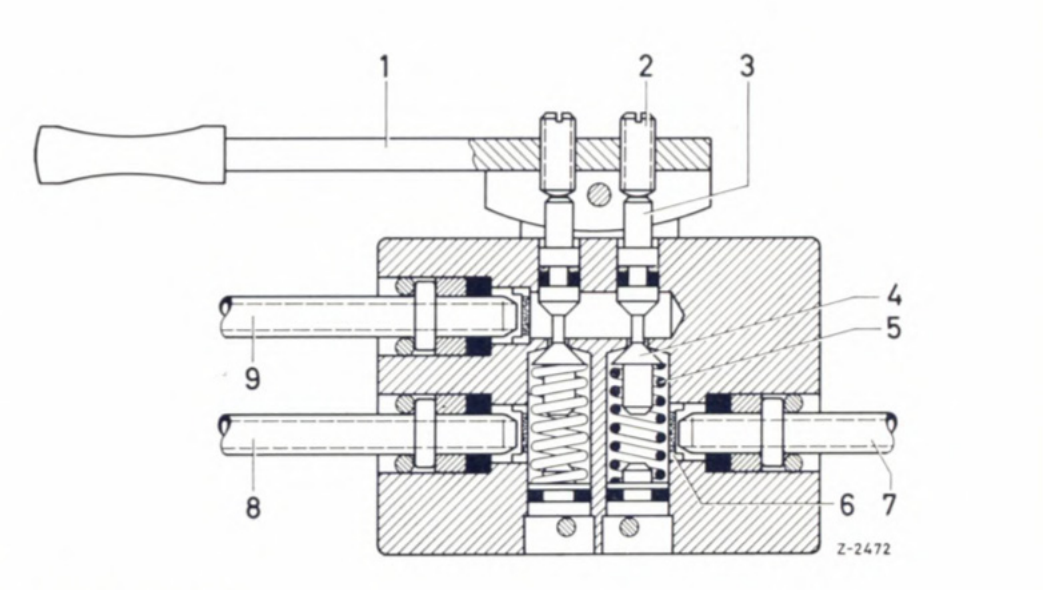
External leaks in the KH system at driver door window switch area, source Martin Werminghausen

Leaking pressure ports are external leaks and very common. They occur in switches, pistons and connectors. External leaks are easy to identify because of the great mess they cause (oil puddles). Also pistons can develop external leaks. That could be the pressure port or the cap seal leaking (double acting piston) or the piston seal leaking (single acting piston).
These painful oil leaks need to be properly repaired.

The many 600 KH pressure connections are designed with a precise boring with brass sleeve, a custom rubber seal and a filter. This is a mayor leak point in the entire system.
If there is an external leak at a switch it might appear sufficient to change the leaking seal locally. However due to the fact that the other seal rings are the same age it is recommended to rebuild the entire switch.
It is not worth trying to safe money doing a partial repair in my experience. Most 600 owners understand that fact.

Internal leaks are more mysterious than external leaks. They do not leave a puddle of oil on the garage floor or inside the car.
Inner leaks can occur in switches and piston seals. By nature they are more difficult to analyse. If a piston is moving in an uncontrolled manner (piston moves without command or control) it is a clear sign for an inner leak. The question is: Is it inside a switch block or in the double acting piston. Remember, a leaking single acting piston seal will cause an exterior leak while a leaking double acting piston inside will cause an uncontrolled movement, but leave no external oil trace (the double acting piston can also develop exterior leaks). With some logic the owner can analyze the inner leak (switch or piston) but it is not that easy. In general if the hydraulic seat is moving forward (piston moving outboard) or a window is closing by itself (piston moving outboard) -without activating a switch- the problem could be a leaking switch (in the pressure zone) or a leaking piston seal.



Hydraulic Switch, Schematic Section , source Mercedes 600 Manual
3- Actuator Pin
4- Intake Valve
7 - Pressure Line
8 - Return Line
9 - Control Line

In case the seat is moving backward or window opening (pistons moving inboard) or a single acting piston contracting by itself, without external leaks, then the problem is most possibly inside a switch (control zone). On top one piston is often controlled by more than one switch. The owner must find the faulty switch by separating the switches. Sometimes the inner leak is hiding well with the system under pressure and shows itself when the system pressure drops (which means another leak somewhere).
The sign is a piston contracting after pressure loss mostly when the car is parked.
Mercedes has provided a wood wedge to use in an emergency situation if a window is falling down. Also there are pins at the front seats to mechanically lock the backrest in case the hydraulic piston fails.

Window Wedge, source Mercedes 600Manual

The leaking hydraulic parts can annoy the proud 600 owner very much but the car might be still drivable. However if there is a severe failure of the hydraulic system the car should not be driven any further. The parts that can bring the system down entirely are the pressure pump/regulator and the oil pressure storage (accumulator). If the pump fails the problems are obvious. Also if the accumulator that lost a lot of nitrogen cannot store energy anymore and bring the system down because the pump cannot build up pressure. With a failing accumulator the pump/ oil has no time to rest and settle as it normally does. High-pressure peaks then trigger the regulator frequently. Issues might be wearing on the otherwise robust pump and 'foaming' of the oil. If the oil cannot settle it can cause odd behaviour especially if combined with cavitation because the properties of oil start to shift from liquid to gas.

Therefore be advised to check the oil supply side, pump, regulator and accumulator, in case of suspicious behaviour. It is good practice to perform frequent hydraulic oil and filter changes also to avoid moisture content in the oil that can cause cavitation in extreme situations.

Life of Seals

In general the original hydraulic units of the Mercedes 600 were lasting for a very long time and many piston seals last to this day because the aging is reduced compared to the air suspension system. The longer life comes from the oil-enclosed environment, sealed from aggressive elements like air and ozone. However even these 'Methuselah' seals have an expiry date and this is the reason for a leaking 600. The process of fossilizing rubber seals often starts with pressure port seals, which cause external oil leaks. In general a fully enclosed seal in a piston is preserved the best and will last the longest while a pressure port to the outside environment and will age faster.

Rebuilding the System

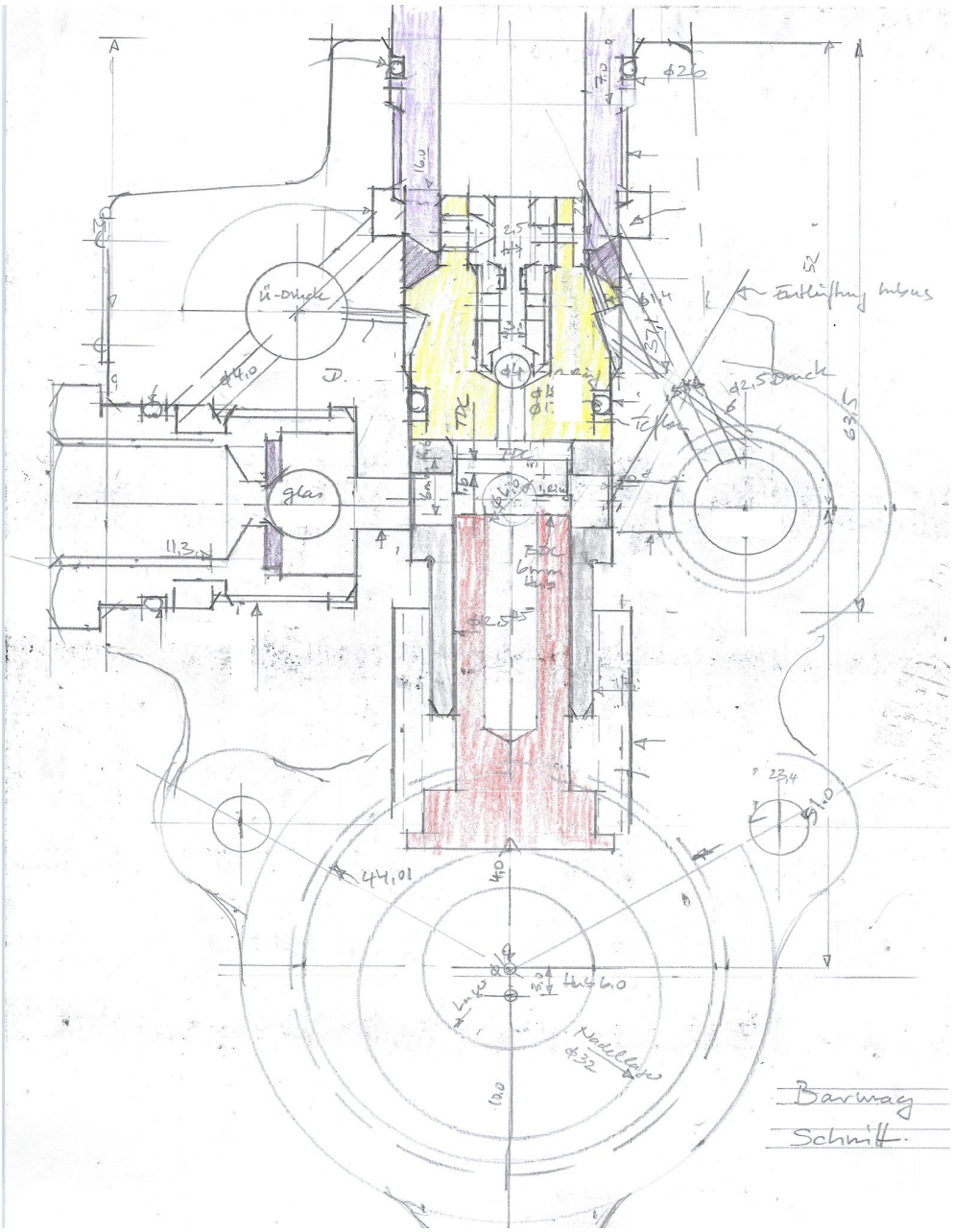
Is the renovation of the system recommended even if one single component fails, you might ask?
The answer is Yes. Hydraulic failures are annoying, for instance you have oil leaks or a window is dropping but there are instances that affect the safety of the car. If safety is compromised, if you are experiencing a seat moving or a hydraulic door latch open on the highway then it is about getting time to stop and rebuild the system.

One leak seldom comes alone. Often other leaks are following due to a 'disturbed' system. If a line is moved or

removed in a borderline system other leaks might follow. The disturbance is too much for the fossilized pressure seal to stay flexible and the leak is starting.

Good news is: Each of the units can be repaired (most possibly). However rebuilding requires knowledge, experience, patience, special tooling, new parts and a proper testing facility. Without a proper testing protocol the repair is not guaranteed. Short cuts are not possible.

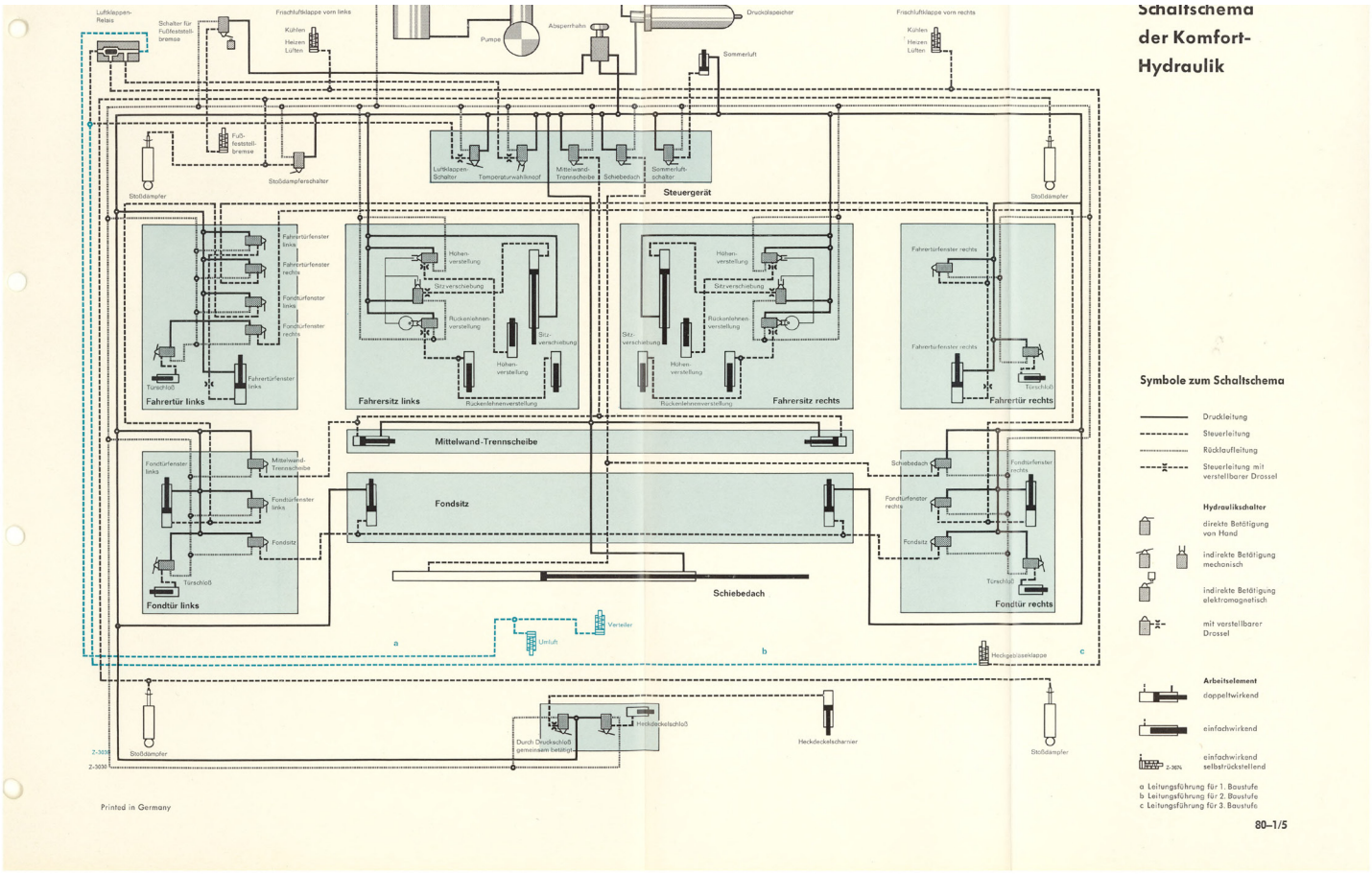
We can offer repair for each unit of the 600 comfort hydraulic system. I did enough research to fully understand the parts because the engineer in me loves that kind of work, exploring the design and experiencing (laws of physics) the system.
If you are the owner of a 600 and complain about the hydraulics please be reminded that your car has elegance, precision, durability and components that still can be repaired after 50 years and no modern car can compare. For me the Mercedes 600 is a timeless piece of art for its coherence of form and function. The success in repairing the 600 is well worth the effort.



Research on KH Pumps: Barmag Pump Section, source Martin Werminghausen

Understanding Support Group and Work Groups

Before repairing the system there must be a basic understanding of the parts and functions. A complete understanding is not necessary for the owner/customer but for sure it helps to find the problems. For professionally rebuilding the 600 hydraulics this knowledge is mandatory.
KH Diagram, source German Mercedes 600 Manual. Top 3 Units are the Support Group (Tank, Pump and Accumulator), all the units below are Work Groups (simplest Work Group: Switch and Piston).



The Mercedes diagram shows the circuits of the system. There is not much surprise for an engineer and the principles are clear. Like any hydraulic system there is a Support Group and several Work Groups. The two groups are separated in the 600 by a shut off valve (all later cars have this valve).
The Support Group is supporting the system. The support is providing the proper pressure and storage that balances pressures on demand and allows the Work Groups to do their job- moving the pistons when commanded.
The Support Group consists of the oil tank, the pressure pump with pressure regulator (providing constant system pressure) and the accumulator with check valve for energy storage.

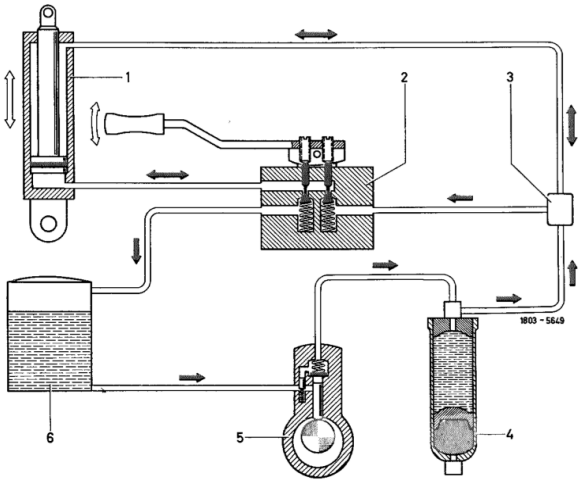


Fig. 80–1/3
Diagram of finger-tip hydraulic control system (system with piston container)

1 Double-acting hydraulic element
2 Hydraulic switch
3 Distributor
4 Oil-pressure container (piston container)
5 Finger-tip control hydraulic pump
6 Oil-supply reservoir

KH Support Group and Work Group, source Mercedes 600 Manual
Support Group consisting of Oil Tank (6), Pump (5) and Accumulator(4)
Work Group: Distributor /Connector (3), Hydraulic Switch (2) and Hydraulic Piston (1)

The 600 hydraulics are a closed loop system: The oil sent out for work (moving pistons) will return to the tank after work.
There are multiple Work Groups capable of operating in parallel (see hydraulic diagram), fed by the Support Group. Pressing a switch opens the control valve and pressurized oil (between 175 and 200 bars) is operating the Work group. Windows, seats, air flaps, air conditioning, sun roof, door latches; suspension struts etc. are operated this way.
The constant pressure is doing the work through the pistons by pushing the rods outboard and inboard. The return of the push rod also returns the oil back to the hydraulic tank. In a system that works to specification all oil is returning to the tank.
A Work Group consists of one or more switches (activating the lever gives the command for doing work), one or more pistons (doing the actual work) and the associated lines (pressure lines for conveying the energy to and from the piston).
Pressure tightness is the baseline of any hydraulic system and in return this means that every part of the system must be absolutely pressure tight over 200bar externally and internally. 200 bar pressure tightness is also the baseline for the repairs.

Analysing a faulty system in order to find the component can be simple or it can be complicated. Simple external leaks are easy to find (follow the oil) but then there are complex problems. If the faulty part is found the unit needs to be removed and sent in for service.
We are offering rebuilding/testing for all hydraulic units and assemblies. I do recommend to rebuild the original unit and not to replace it with a substitute if the old part is repairable. I have seen accumulators being replaced by 6.9 spheres or alternative accumulator but it is better to professionally rebuild the original part. There are cases when the old cores are damaged and need replacement.

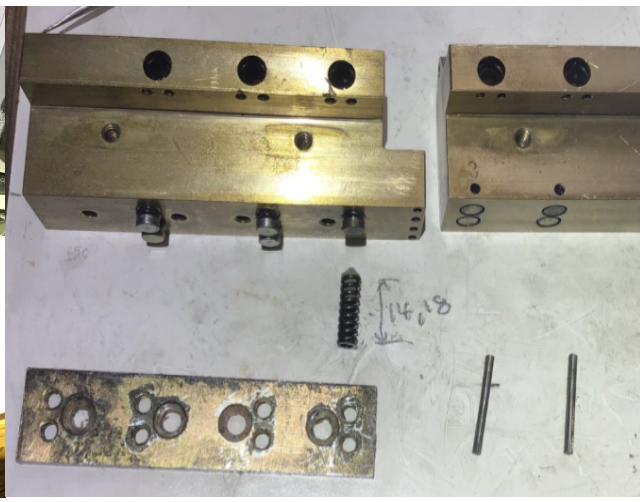
Oil change and New Oil Filter

With every hydraulic oil change it is recommended to change the oil filter: The original Filter is no longer available unfortunately.
600Airsuspension offers a practical solution for a new oil filter (early and later tank design) using a standard modern oil filter (see 600airsuspensionshop.com).

Material Weaknesses and System Tightness

The critical parts regarding tightness are the seals and valves, the main failures come from aging rubber. The other parts of the system probably outlast the car. Rubber (NBR and Viton) has a life span of 10- 20 years and in a hydraulic system rubber can possibly have a longer life compared to an air system but still there is a limit. At the end of its life rubber starts fossilizing with its elasticity declining. Fossilizing can show itself with a temporary leak problem at lower temperatures and over time the leak may occur constantly.
If you see leaks at low ambient temperatures it is time to rebuild the unit. Don't have false hopes that a miracle will happen. After a leak occurred there is no return. Don't wait for too long.

Valves inside the switches seem to be durable but once in a while I find a leaking valve during pressure testing. This is especially true for the aluminium blocks. In this case the plastic cone valve has to be exchanged and the valve seat machined. Another issue with the aluminium switch block is the smaller actuator pin bore (3.2mm versus 4mm in brass switch blocks). The bore can wear out. If this happens the pin has too much play and it is lacking guidance. There will be no external leak necessarily but the operation and function of the switch will be compromised to the extent that the switch is not operational.
Again the switches are relatively solid and durable with the exception of the many rubber rings and small cone valves.



Window Switches in Brass during Rebuilding (source Martin Werminghausen)

Rebuilding Switches

The typical rebuilding process includes dismantling, reaming of all bores or threads, cleaning of core inside and outside, assembly with new seals, filters and sleeves, valves and other parts specific to the switch and at last various pressure tests to make sure the switch will hold 200 bar.
If the aluminium core switch fails there may be two problems involved: A leaking valve seat and a worn out actuator pin bore. The valve seat can be machined with custom tools and a new cone valve installed. The worn out bore is a bigger problem. The solution is to enlarge the bore and install a bigger actuator .This problem happens very rarely.

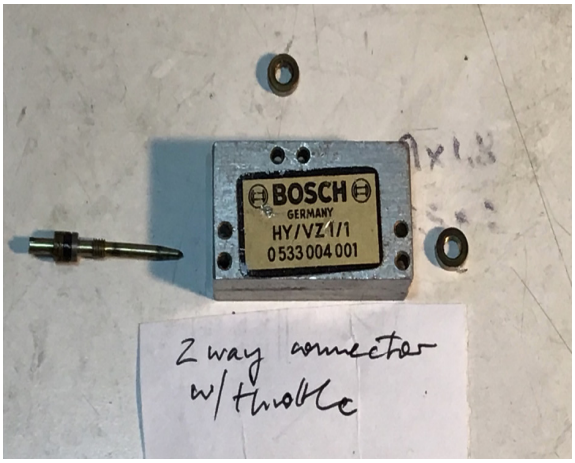
Smaller and Larger Actuator Pin , source Martin Werminghausen

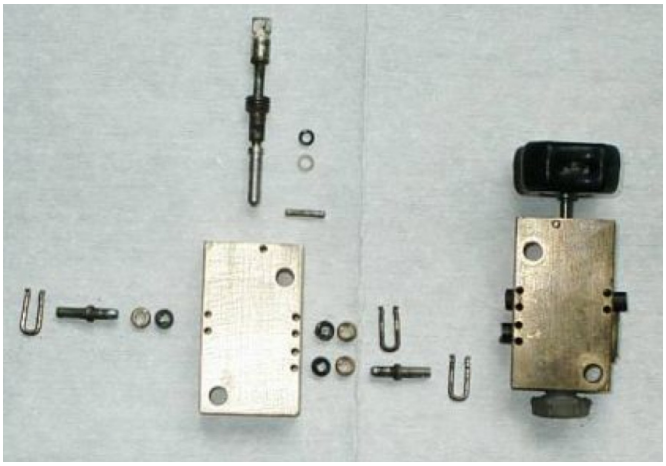
One common failure is the later style aluminium lever with a worn out bore for the 2.5mm pin. I see these levers often damaged to a point when operation of the switch is impossible. The best solution is a replacement lever in steel.
There are special levers that are hard to find replacement for, for instance the center dash temperature wheel lever (triangular shape) or the stalk switch lever located at the steering column. 600airsuspension is offering a good solution for repairing these levers.

Worn out Window Switch Lever (Aluminum) , source Martin Werminghausen

Connector Blocks and Lines

Thin steel lines and flexible hose lines connect the single components of the Support Group and Work Groups. Both types of oil pressure lines are very durable and rarely fail and is little to repair here. A variety of junction connector blocks is used for connecting lines and distributing the oil throughout the system. A special connector is the Shut-Off Valve that separates/connects Support and Work groups.
The various connectors use the common pressure port stick design with rubber seal and guide ring. There are few blocks with screw connections or throttle valve.
Special care is required for repairs of the aluminium blocks because of the soft material. Pressure port bores require reaming and proper installation of guide rings to avoid any bore damage.





Connector with throttle valve and Shut Off Valve/ Connector, source Martin Werminghausen

Piston Repair

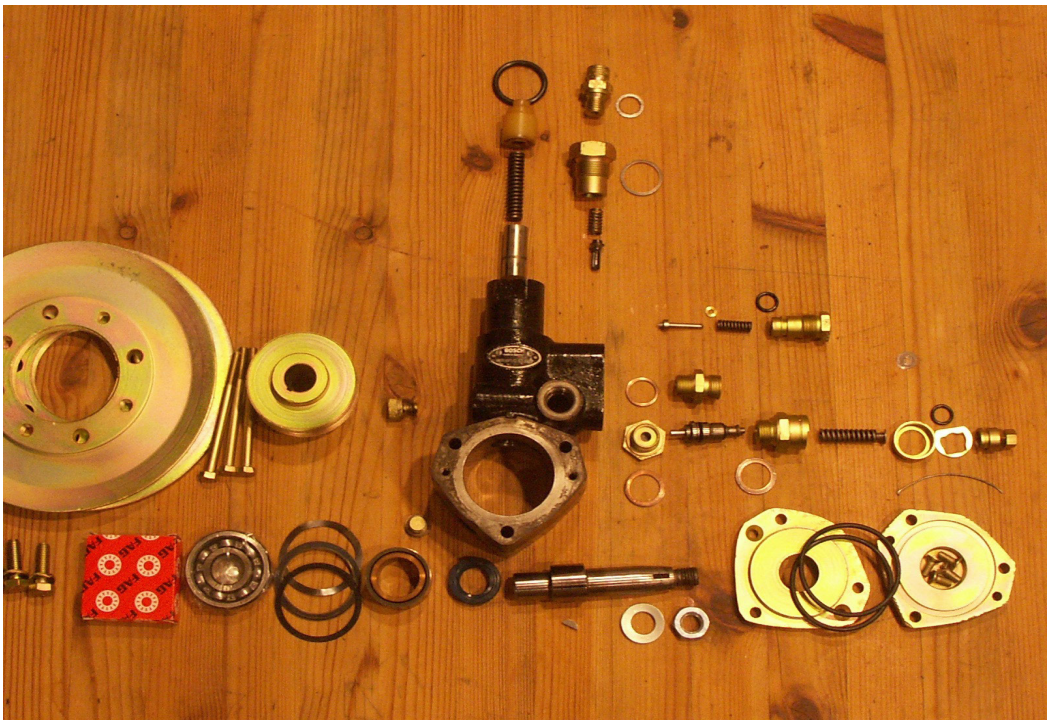
Pistons normally need very little repair. There are 2 types of pistons, Single Acting Pistons (SA) and Double Acting Pistons (DA). For each type there are various sizes (piston diameter and rod length) used in the system. The stick pressure port seal (pressure line connecting to piston) leaks quite frequently and they require proper rebuilding.
The inner piston seals, rod seals, wiper seals and cap seals are very durable and I see them fail only occasionally. If a piston seal failure is suspected (DA piston is expanding without pressing a switch) the piston seal failure (inner leak) can be detected during bench testing.
In a single acting piston (SA) a piston seal failure will lead to an exterior leak- oil puddle next to the piston rod.

Window Piston during Rebuilding, source Martin Werminghausen

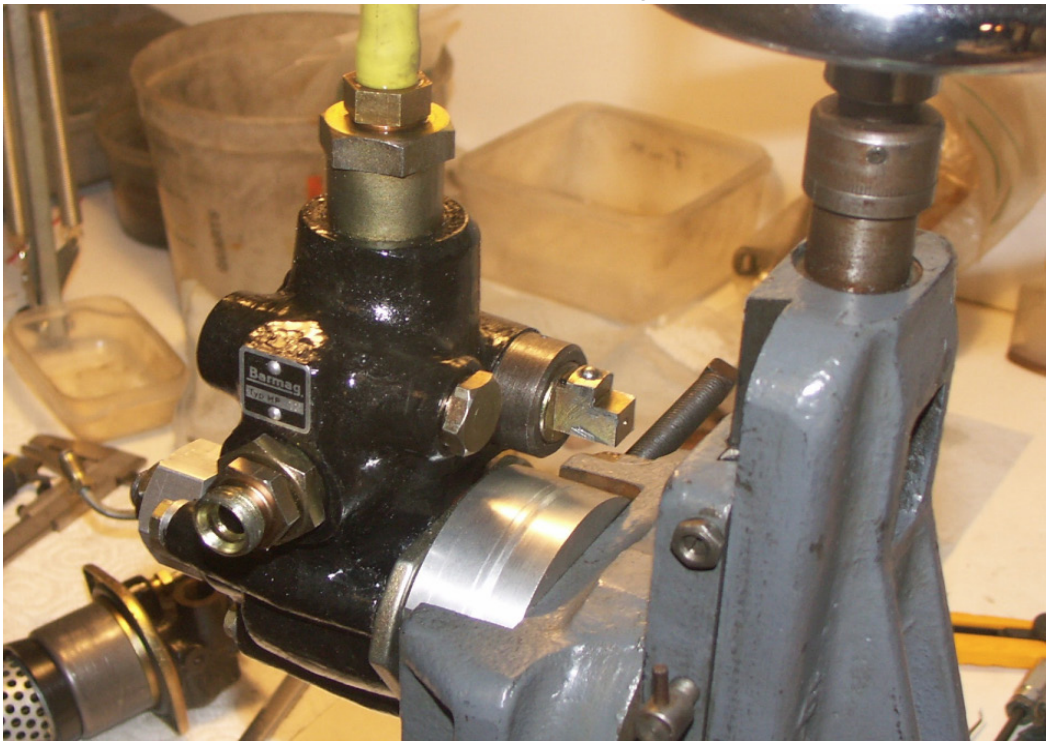
Hydraulic Pump Repair - Bosch and Barmag

Both Bosch and Barmag pressure pumps are very robust and last a long time. However if the pump leaks externally and/or internally (and specified pressures cannot be achieved) the pump needs rebuilding. The Barmag pump often has an issue with the intake check valve and the upper 'bridge seal', also the pressure check valve

needs attention. Bearings and bushings sometimes have a problem and need to be changed. Pump cylinder and piston are mostly in good order unless the pump ran dry. Rebuilding the pump addresses all issues and after the process it will work just like new.
For the rebuilding special tools and precise pressure tests are required. This is true for any repair of the system but especially for the pumps.
Static tests confirm functions like general pressure tightness, intake and check valve and safety valve function. Even though these units are called pumps they have an integrated pressure regulator with adjusted cut-off pressure at set pressure (175 /200bar). Pressure settings and regulator function require dynamic testing.



Bosch Pump dismanteled, source Martin Werminghausen

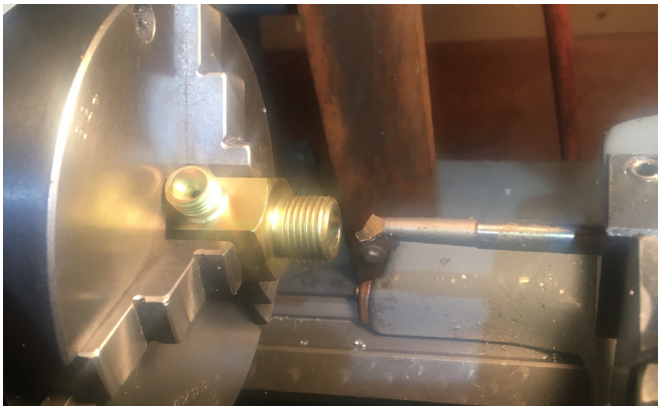


Barmag Pump on Test Stand during rebuilding, source Martin Werminghause

Accumulator and Check Valve Repair

The Teves accumulator often fails and looses its Nitrogen filling. Problem is a failing piston seal. The accumulator is the power storage of the system and can only work if the nitrogen charge is at 50bar min. The initial charge is at about100bar. The Teves (ATE) accumulator is rechargeable but this might not be entirely possible if you have the early design with a simple valve: copper ring and screw. Later versions use a high pressure Schrader valve. Filling a leaking container will not be successful long term because the gas will escape again, sooner or later.
The Accumulator can be rebuilt most of the time. I am using the best piston seals available in the market. Piston machining is needed to accommodate the modern seal.
A separate check valve is used to make sure that the oil is not returning to the pump and from there back into the tank. In total there are two check valves used in the Support Group (pump and accumulator).
I am installing a modern high pressure Schrader Valve rated for the required pressures.

ATE Accuulator during Rebuilding, machining new Piston for modern piston seal, source Martin Werminghausen

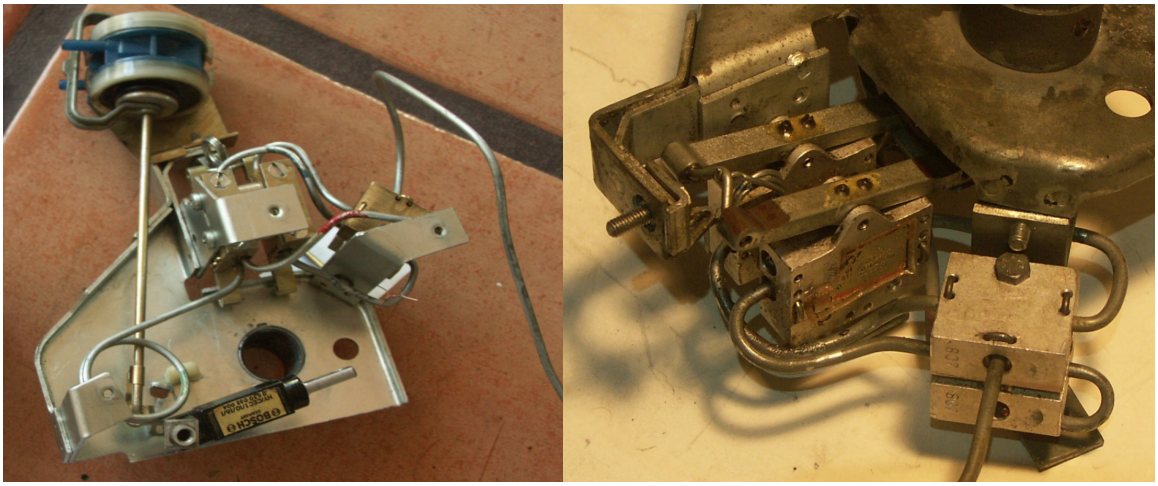


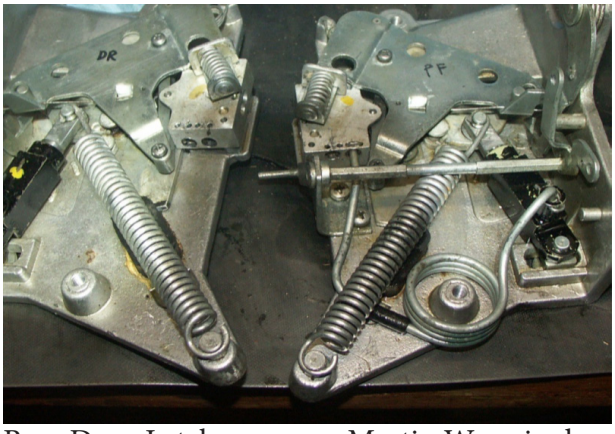
Machining during Repair of Accumulator Check Valve, source Martin Werminghausen

Complex Assemblies

Often I get entire assemblies sent in for repair, for instance the Door and Trunk Latches or Seat Units or the Center Dash Unit that controls the HVAC of the car and sunroof.
These are complex units and require attention during disassembly and reassembly after rebuilding (sequencing is difficult) and finally testing the entire unit (single parts were tested before reassembly) confirming the functions.

Door and Trunk Latches
The 600 doors operate like the doors of an airplane. After closing mechanically and triggering the hydraulic switch the door is pulled into place and closing tight by the hydraulic piston. The trunk latch works the same and has the additional feature operating the lid by a separate single acting piston. Central locking is integrated and controlled by the vacuum system quite similar to other Mercedes cars of these years.
Not every 600 car has the hydraulic latches and it must be mentioned that it is not safe to drive the car if the hydraulic system is not working as specified.

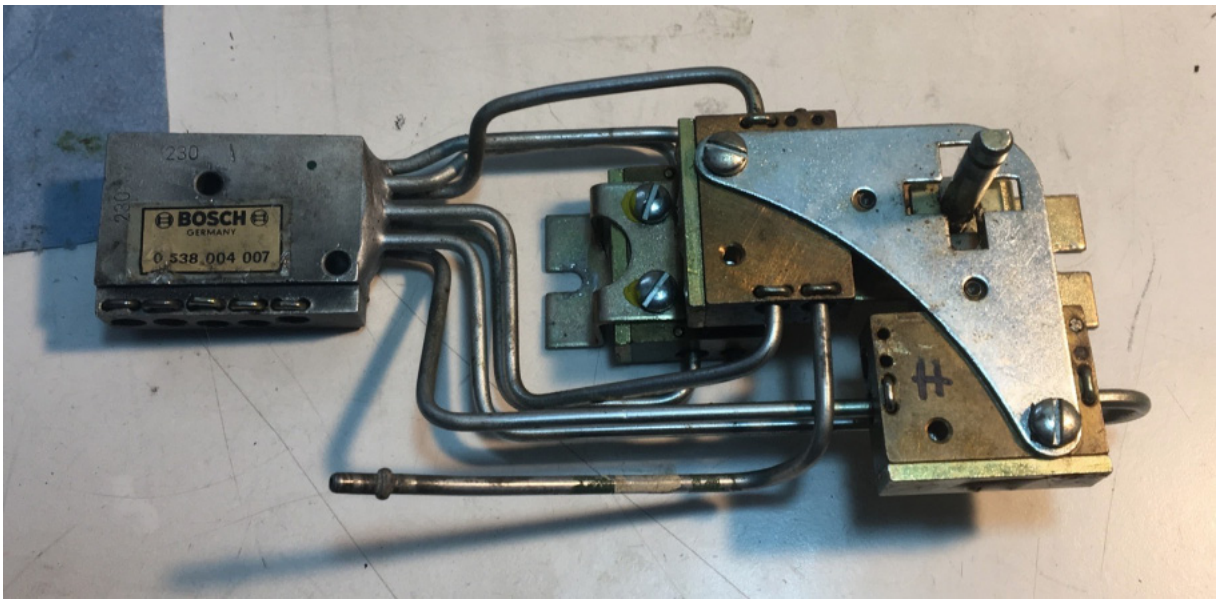

Trunk Unit during Rebuilding, source Martin Werminghausen



Rear Door Latches, source Martin Werminghausen

Seat Units

The hydraulic seat unit for the font seat is a great feature. 3 hydraulic switches are grouped together. The joy stick at the side of the front seat controls the 3 seat movements (horizontal, vertical and back rest).



Center Dash Unit
The center dash unit is operating mainly the ventilation and air-conditioning but also the outside air vent, sun-roof and if equipped the glass partition behind the front seats (Pullman).

Center Dash Unit on the work bench, source Martin Werminghausen

I hope this report gives you a deeper insight of the unique Mercedes Benz 600 comfort hydraulics and its repairs but also the good news that the system is repairable and worth the effort to maintaining these wonderful cars.

Martin Werminghausen
Lincoln, 2019