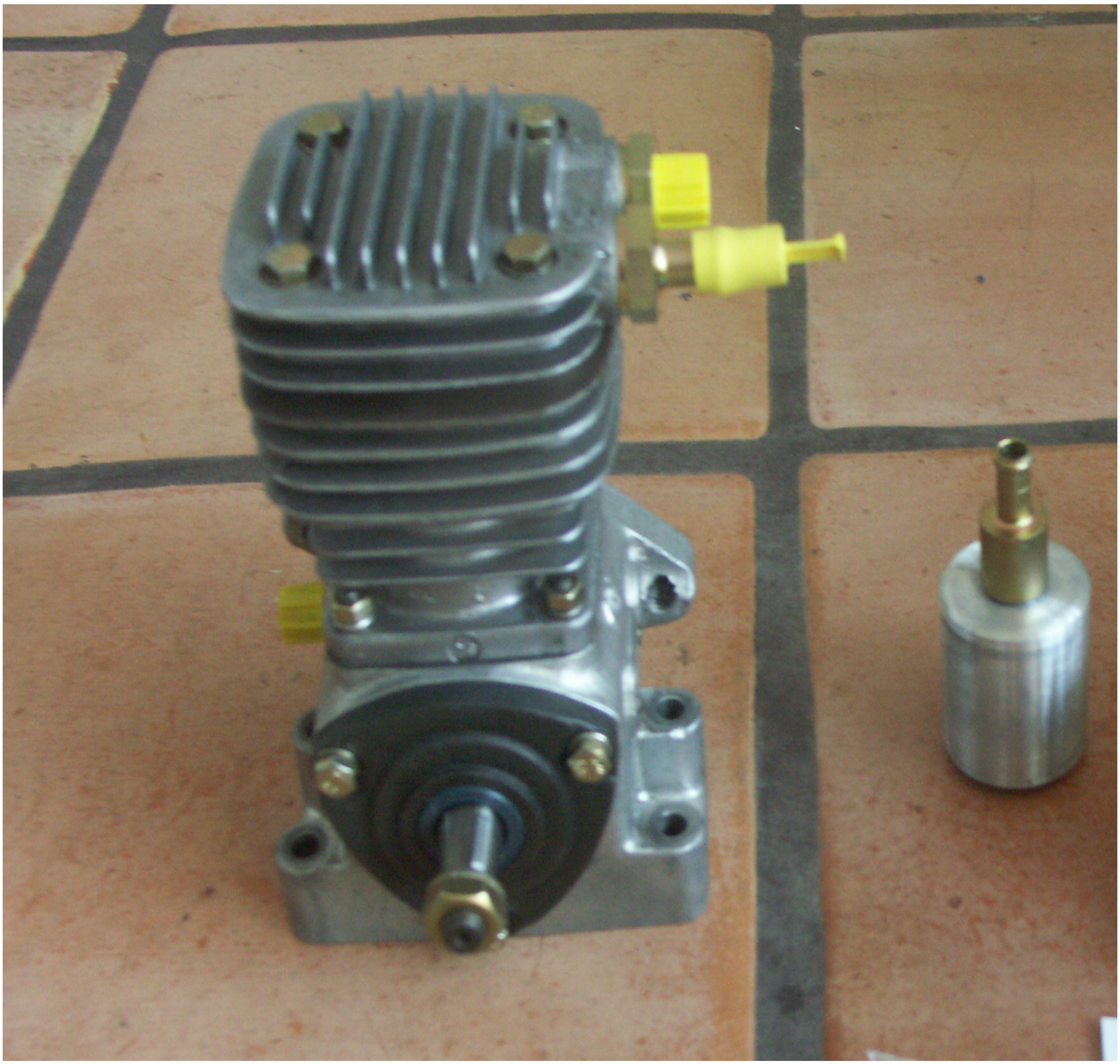
Mercedes Air Suspension

A report about the Mercedes Air Compressor for W112/ W109 and W100

By Martin Werminghausen



Foreword

It is time to publish some information about the Knorr air compressors used in Mercedes air suspension cars from the 60s and 70s (W100 up to 1983). This paper was developed in collaboration between Thomas Jaekel from Germany, a good friend and colleague We work together in developing and rebuilding air suspension units and Thomas is starting to offer air suspension services in Germany.

People reading this are probably Mercedes enthusiasts, having trouble with the compressor in their vintage Mercedes or both.

If you have basic trouble with air supply and the compressor cannot lift the car easily....here is a test:

According the Mercedes manual the compressor has to increase the air pressure in the tank from 12bar to 14 bar within 90 seconds at engine speed of 2000rpm. If this test turns out negative, your compressor needs rebuilding. We'll come back to the rebuilding of the compressor later. Basics first.

Basics

The air compressor or 'Luftpresser' as Mercedes calls it is the power source for the air suspension generating the air pressure for the air bags in this seemingly delicate system. When this power source doesn't operate within specs trouble is to be expected. With specs I mean a) a minimum air pressure output of roughly 15 -19 bar and b) delivery of clean, uncontaminated and dehumidified air.

Power source- wait a minute, does that mean that this suspension requires energy to suspend the car?

That is a good question because the steel spring car for instance does not need any power supply. The answer is not simple: Yes and no.

The answer is yes, it needs energy because the car needs to be raised against gravity for instance if the car has to carry a heavier load or if the car is down caused by an air leakage. Also there is always some friction in moving parts of the compressor even if the compressor 'idles'.

The answer is no, it needs no energy because the air suspension once up in normal height does not require additional energy similar to a steel spring system. If no air is going in or out, like in a tire, then there is no additional energy needed.

The real answer is yes, we need some energy because the dynamics of driving does activate the axle valves meaning the car goes up and down…typically not much as only very little air is needed if the system is working according to specs. Exhausted air doesn't give the system credit like a steel spring system does. So there is a portion that involves the 'use' of air and there is simply friction in the moving parts. This is a constant amount of energy, very little if the compressor is idling and not pumping.

However if the car needs to be lifted from the ground up to higher riding level with an old and badly leaking system then a relatively high amount of energy is required.

$E= m*g*h$

Compressor as Part of the Support Group

Before we dive into compressor details let's back up for a moment and look at the compressor as part of a bigger picture in terms of the Mercedes air suspension system of the 60s, 70s and early 80s.

The compressor is the driver or heart of that system and it is part of what I call the Support Group. I have spoken of the Support Group before. The air suspension comprises of two groups, a) The Support Group and b) The Work Group. The Work Group consists of the air springs and the adjustment devices (axle valves) of the air springs. In short the Work Group does the suspension work. The Support Group is a series of devices that work closely together and support the

Work Group by proving the correct storage, pressure and condition of air. Detailed is the compressor with the air filter and alcohol device (antifreeze), the main check valve, the air tank and the main valve (valve unit) and even parts of the axle valves (axle valves are part of both, Support and Work Group depending on the situation). Within this Support Group the air compressor cannot 'live' without the other devices of that group. Like the organs of a body they depend on each other, the compressor is the heart that pumps the life blood of the air suspension system (air in this case).

Resilience

This compressor is a fairly sturdy and resilient 'engine' in general. There is hardly a report about a catastrophic mechanical failure. And if the compressor starts operating slightly below the threshold of expected specs it still might deliver sufficient air for the system, say 12 bar minimum and sufficient volume. If the compressor for instance has a badly worn cylinder and piston/rings or worse leaking check valves, this might possibly result in low-pressure output but could contaminate the sensitive semi closed air stream with engine oil or particles/fumes of engine oil (on top of the low output). Air contamination is a real problem. Unfiltered, not dehumidified air with engine oil particles will call for a short life span of the air suspension system. Think of it this way: The cleaner and conditioned the air inside the system the better and longer the life span of the air suspension. The main reason for low output is leaking check valves. We will go through the items step by step.

Principles of the Knorr air compressor

Mercedes decided to use the 'Knorr Bremse' which is a compressor designed by the Knorr company for air brake systems like the one used in trucks…and the Mercedes 600. The 600 does use the compressor for both, the power brake and the air suspension. In the W109 and W112 cars the compressor is for air suspension only. All compressors have the same output capacity (with the 600 compressor having greater cooling power/rips). This means the compressor for the W109 and W102 has more than enough power and plenty for the 600 if the system operates within specs (no greater air leaks in support and work groups).

The single cylinder Knorr compressor looks in parts similar to a small air-cooled engine. With 50ccm of displacement, the compressor works almost like a small 2 stroke engine. Of course the compressor has no fuel delivery or ignition for internal combustion. It is not made for power production but instead wants to be powered (by a single or double V-belt) for delivery of compressed air. It is the reverse of an engine.

There are 2 reed valves in the cylinder head, basic and robust but not very precise check valves for air intake and air exhaust.

The compressor is comprised of a forged steel crankshaft, aluminum piston, aluminum cylinder and cylinder head with the two valves described. For lubrication purposes the compressor has an engine oil supply line from the engine -pressurized oil from the pump. The oil line attaches to the side of the compressor crankcase and feeds directly into the brass bearing/bushing of the crankshaft. The oil is lubricates the bearings, rod and piston. On its way back the oil is collected and drained at the bottom of the crankcase and flows back to the engine.

How is the compressor working internally?

During the compression stroke the air is enclosed and compressed by the cylinder, cylinder head and piston. The upward moving piston reduces the volume and therefore increases the pressure in the upper chamber. The weak and potentially leaking points, if any, would be the cylinder wall/ piston rings and check valves. If the air tightness were compromised here the compressor would not have the specified pressure output. (Test for the pump is described later in more detail)

The lubrication film on the cylinder wall needs to be maintained at all times. A proper hone pattern on the cylinder wall as well as the correct mechanical play between cylinder and piston and good piston rings will provide good lubrication and compression without contaminating the compressed air with oil.

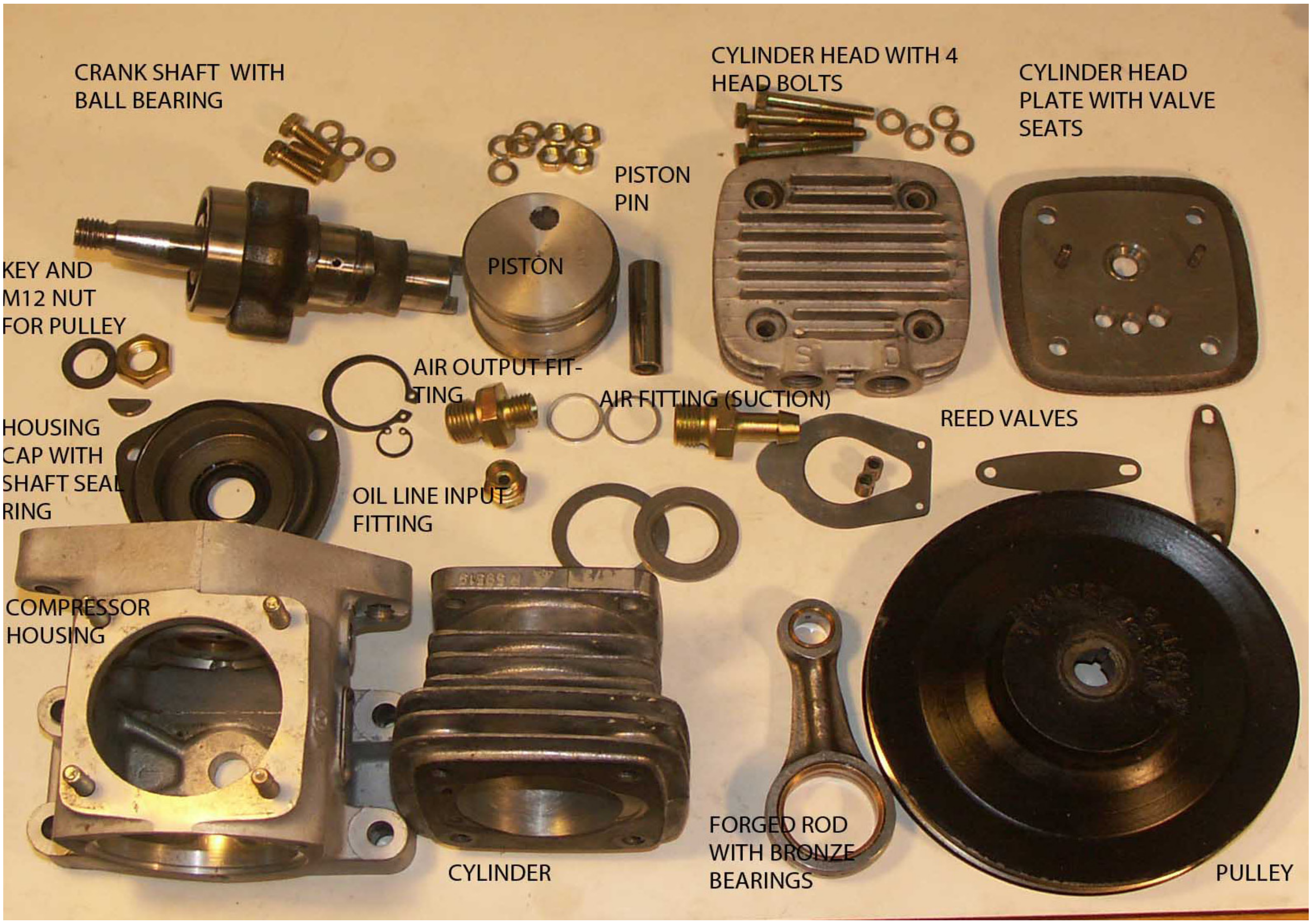
Compressor Piston after removing Cylinder Head

It is fairly easy to find and identify symptoms of engine oil in the condensate-alcohol soup after draining the fluid as part of a regular maintenance schedule. The fluid should be whitish, grayish or even clear. What can mix into the condensate is possibly rust from the steel air tank (tank was originally not coated inside) and engine oil from the compressor. Engine oil is swimming in the soup of condensate and can identified. It will have the typical color of (darker) engine oil and will separate itself after some time and swimming on top of the soup.

The compressor is driven by one or two V-belts from the crankshaft pulley of the engine. The power requirement will be about 1 HP for max output.

If the compressor's output has reached its max air pressure under the actual conditions, no air can be delivered and the compressor would do what is called 'idle'. Idling is the dominant state of the compressor in a good working system. This is when the support pressure is reached which is the equilibrium between the compressors output relative to the height above sea level.

Parts of the Air Compressor



At idle state a pump will just compress and decompress air like a rubber ball that bounces seemingly endless. At idle no further air is delivered to the tank and the compressor is using only minimal power during idle to overcome friction. In a healthy air suspension system we find the ‘compressor idle’ as the predominant state.

If the compressor is not idling most of the time something is off meaning leaking. The system is not designed for delivery of compressed air all the time. It is designed to top off some minor pressure loss unavoidable during driving but not to pump up an empty system at each engine start as we see it in a leaking air suspension system.

If a car sits on the oil pan after a couple of days or even hours the compressor needs to work very hard to lift the car off the ground. This is not normal and will wear down the compressor. Under normal driving conditions in a healthy system I’d guess that the compressor might be idling 90% of the time or more depending on road condition, loading and driving style.

Compressed Air Delivery to the Air Suspension Support Group:

In compression mode the Knorr compressor will deliver compressed air at every stroke and pressurize the air tank. Energy will be stored in the air tank through air pressure to be used at a later time in case the air suspension demands air for raising the level of the car. The compressor has reed valves (check valves) so compressed air will not leak back to the suction side and air can be sucked in from the suction port. Again leaks or partial failure of the check valves will lead to poor output. These valves have metal seats and won't be 100% airtight especially if they are renewed in an old cylinder head valve seat plate. They don't need to be absolutely airtight like for instance the axle valves for instance but they should be relatively airtight. There is one detail at the pressure side check valve seat in the plate. A tiny little groove in the seat ring makes sure the valve is leaking a bit in order to have the main check valve at the air tank work properly. The pressure loss in the pressure line to the tank makes sure the main check valve is engaging properly. The 600 compressor does not use this groove because the pressure regulator takes care of this issue.

I have tested many reed valves and the degree of leakage can change very much especially with new installed valves at the valve seat plate because the steel valve plate seats and the reed blades were worn. These valves are designed to slow down the equalizing the airflow between the high and low pressure side. The frequency of the pump is high enough that the compression and suction strokes with slight leakage are still acceptable.

Wait a minute. What does slight leakage mean? Give us some data.

I am defining leakage with pressure loss per second. I am testing valves using vacuum. Vacuum should reach 25 in Hg and the max pressure loss should be around 2 in Hg per second measured with a manually operated vacuum pump. If higher leakage leads to low output it is time to inspect these valves in terms of mechanical condition and contamination and correct the valve seat plate and install new reed valves.

Main Check Valve

The task to seal the air tank from back flow is done by the main check valve between compressor and air tank. This main check valve needs to be in good working order and this part is essential for a well-maintained system that doesn't leak. Through aging the rubber cone inside the check valve is hardened and cannot seal as good as a fresh, soft rubber. I see this all the time. Even if there is only a minimal loss of air this is not acceptable. Basically all old check valves are questionable and should be rebuilt.

Gas Physics

If we are looking at the properties of the air that reach the tank we should look also into basic physics of gas.

The Ideal Gas Law $P*V= nRT$

Maybe that is getting a bit complicated and theoretical. What I want to say there is no guessing when the engineers designed the system. It is just physics. So lets back up and talk about a few examples of this law applied to the air suspension.

Air is a mix of different gases mostly CO_2 and O_2, also humidity that is water in form of vapor (… not an ideal gas all together). Air can hold only a certain amount of humidity until water changes from fine triplets into liquid or called condensate. The amount of water the air can hold in steam depends on pressure and temperature of the air.

If condensate/water were to enter the air suspension lines we would call this a problem. By the way water will be a problematic issue in any compressor system but especially in the air suspension because water will cause corrosion. This will have undesired effects as it is tough to get the water back out of the semi-closed loop. Therefore the interiors of the air suspension need to be kept free of water and humidity as much as possible. If outside air, and not recycled air from the air spring exhaust, is sucked into the compressor (through the air filter) the outside air will be ideally mixed with a small amount of ethanol (in case you have the antifreeze device working per specification and ethanol in the antifreeze bottle which is recommended at all times). You see we have a complicated gas situation.

Here are 3 examples of the behavior of gas in this pneumatic system.

Example One

The first example is complex- air is a mixture of gases and water vapor. What happens with humidity in the air?

After the compression stroke, the compressed air (this mix of gases and humidity) is substantially warmed up to 200 degrees F or more. This raise in temperature is the work delivered to the pulley of the compressor driving the pump's crankshaft and passed on to the air in form or pressure increase. Condensation doesn't happen during compression because the high temperature of the compressed air can hold the same amount of moisture as ambient air does. There won't' be any water or condensate inside the compressor. However after the air has cooled down [in the air storage tank] the air cannot hold the moisture any further and condensation is unavoidable. Condensate/water will be collected at the bottom of the air tank. The water/condensate/ ethanol mix must be drained from time to time and so none of it should enter the system. In theory if someone might forget to empty the tank over a long period of time and drives a lot it could happen that water enters the main valve (when you hit a pothole for instance and the condensate in the tank flies in all directions inside). However I have never heard of this happening. Just remember to drain the condensate every month or depending how much you drive.

The air tank and the conditioning of the air is designed in a way to keep the system free of water. In order to make sure moisture in the air is not causing any problems Mercedes decided to mix ethanol with the air (see my article AAA about the antifreeze device). The mixing happens right after the air filter in the antifreeze device when fresh air is sucked in thus avoiding any icing during winter. Ethanol is essential for the air mix in winter. Furthermore ethanol is recommended at all times even especially in warmer/ humid climates as it acts like a 'conditioner' for the enclosed system. Seemingly ethanol gas in the air has a good effect, winter and summer.

Example Two

The second example explaining the gas laws is the simple fact that compressed air will change pressure if the temperature is changing.

This example may be theoretical. Imagine you drive your classic car during a hot day in the desert of Nevada, ambient temperature at 100F. The air tank is fully charged at 18 bar at 120F [322 Kelvin]. Then you park the car outside and ambient temperature will drop over night to 50F [283Kelvin] with a delta T of 50F your pressure in the tank will drop to [using Guy Lussac P1/T1 = P2/T2]:

P2= T2*P1/T1 283* 18bar/ 322= 15.82bar

This means you are losing pressure in the tank (and in your air springs!) over night without losing any air molecule (assuming no external leak in the system).

Caused by temperature drop your car would be losing pressure in the air springs, which would drop the car over night respectably. It is a linear equation. And if the axle valves are working correctly the system would adjust the car's height and take additional pressure from the tank to pump it back up if the height differential is triggering the axle valve. This will pump up the car to the defined height again and of course it will reduce support pressure.

The next day the temperature rises and pressure rises and The car will be too high at some point and will trigger the axle valve's exhaust (A-valve). The system will exhaust air in order to correct height.

If this car is standing for some days in this environment with great ambient temperature swings the pressure in the tank will rise during day and fall during night as does the pressure in the air spring. It is like inhaling and exhaling. If the temperature difference is great enough to trigger height adjustment the system will lose tank pressure without having a leak… every day it will lose some air until the tank is at a threshold pressure equal to the air spring pressure (say 6 bar). From here on the car will not reach its proper height any more and 'hang low'. Of course this example is an extreme ambient situation.

Example Three

The third example shows how much air is in the air suspension system. I had reported this before and it shows the law: P*V = constant (Boyle Mariotte) if T is constant or

P1*V1/T1 = P2*V2/T2

With this we can calculate how much air the support group can hold. Let's assume we have the 5.5-liter air tank and we neglect suspension lines and devices …and temperature swing. With 15 bar pressure we carry 5.5liter @ 15 bar = 82.5liter @ atmospheric pressure (5.5liter * 15 bar = 82.5liter *1 bar)

Just imagine every time the car is on the oil pan the compressor has to pump 82.5 liters of air.

The last example shows what the system is not designed for. Instead the compressor is designed for idle mode for most of the time. With idle I mean that the compressor is doing almost no work (and it draws very little energy). That is the design.

Dismantling the Compressor

We briefly touched on the compressor saying it might look similar to a small single cylinder 2-stroke engine.

If we look at the diagram with all the parts [diagram to be drawn and pictures shown] indeed we have parts we would almost see in a simple gas engine, for instance a single cylinder 50ccm two stroke engine.

We have the crankshaft with bearings, ball bearing 6303C on pulley side and brass bushing on the engine block side. Some models have the power steering pump attached on the block side (6.3 and 300SE). Some models (3.5, 4.5) have a plug here. In all compressors a double shaft seal is used at the crankshaft pulley side.

The V-belt pulley driving the crankshaft is slightly different in the various models depending on the engine rpm. Outer diameters vary with 6.3s and some 600s using a double pulley. The pulley is keyed to the crankshaft and centered by a cone connection.

The compressor crankcase in cast aluminum has an opening on the pulley side for installation of the crankshaft. The cast iron plate holds the main ball bearing and has a radial seal ring. This cap is mounted and sealed onto the crankcase leaving only little axial play for the crankshaft.

The crankshaft is connected to a hollow piston rod with a brass bearing and thrust plate secured by a snap ring.

The piston is connected to the rod with a hard steel piston pin and a brass bushing. The piston has 4 piston rings, 2 compression rings, 2 oil control rings (how what are these rings called exactly?)

The cylinder mounts on the crankcase with gaskets and 4 studs, nuts and washers.

The cylinder head is composed of 2 parts: the cast steel valve plate, which holds the two reed valves and the aluminum head housing with the 2 ports (suction port and pressure port).

With the compressor on the bench we can start with dismantling. We are not describing each and every step, preparations or the tools being used. There are basic tools needed but also a couple of special tools Testing tools are helpful although not absolutely required. Special parts and even some machining is involved if the brass bearings are damaged. Please note that you are self-responsible and at your own risk if you decide to take the compressor apart.

Step 1 - Removing the Pulley

The cone connection between crankshaft and pulley can be difficult to take apart as it requires some force to do.

First remove the thin nut. If it is tight use an air wrench or something similar. Please do not put any force/pressure on the pulley because it is made of case iron. The material cracks and breaks very easily. In order to get the pulley off the cone seat –again- you should not apply any force on the cast iron pulley as it might be damaged. Never use a puller! The best technique is to hold the compressor slightly over a wood/soft surface (like a sand bag), grab it at the pulley by hand, best with a helper holding the pulley as evenly as possible. Then use a brass hammer and 'massage' the end of the crankshaft. The connection will eventually break loose and the compressor shaft will disengage

Step 2 – Removing the Cylinder Head with Valve plate

This is relatively easy. Remove the 4 M6 bolts and take the aluminum head and steel valve plate off. The valves can be removed now or later.

Step 3 – Cylinder

Remove the 4 M6 nuts at the bottom of the compressor and pull the cylinder. The piston is born.

Step 4- Piston and Piston Pin

You see the piston open. The piston pin can be removed by hand or with a little help of punch after taking the snap rings off.

Step 5- Piston Rod and Ball Bearing Plate

It is the time to remove the piston rod. You see the rod and (thrust plate) locked in place on the crankshaft by a big snap ring. Open that snap ring with appropriate pliers and move it down the shaft as much as you can. You cannot yet fully remove it as the shaft still sits in the backside brass bearing.

Then remove the cast iron bearing plate. Open the 3 M6 bolts, use the brass hammer once again carefully from the backside or use a slide hammer on the front thread M12 of the crankshaft (the back side of the 3.5, 4.5 liter engines have a steel plug and you rather pull the crank shaft). You can move the crankshaft by now pushing the rod off its seat. The crankshaft is loose now but still is connected to the ball bearing and bearing plate. The ball bearing /crankshaft assembly can be removed now from the plate. Remove the pulley key before. And pull the bearing off the shaft with a bearing puller.

Step 6 – Disassembly and Inspection of the Cylinder Head

The cylinder head can be studied and inspected separately without complete disassembly of the compressor. This can be done with the compressor on the bench before you take everything else apart. In the W112, the W109 6.3 and the 600 the compressor head could be even inspected with the compressor in situ. However this might be for an emergency only. It is much better to have the unit on the bench.

If you decide to check the cylinder head in situ, removing the pressure and suction lines and removing the head bolts will open up the head.

Inspecting and changing of the check valves seems to be simple enough. You need to remove the head parts and have a compressor repair kit (buy from Mercedes part number), then change the check valves and gaskets.

As simple as changing the check valves might seem there is not necessarily a guaranty that the new valves work properly. Without precise measuring instruments the performance of these sensitive valves is not easily predicted. The output of the compressor is mostly depend on the tightness of these valves, which depend on the flat and tight position of the reed blade on the valve seat, a ring in the steel head plate. If the seat is worn there is not much to improve the tightness of the valve without re-machining/ grinding the valve plate.

I have developed my own performance criteria for these valves and where I am testing each valve directly for air tightness before installing as described before.

The condition of the valve plate of the head must be as perfect as possible. The plate must be 100% perfectly flat including valve seats. This can be seen only with a fine straight edge. In a worn head the steel rings are probably worn down relative to the surface of the plate. This might be only 5/100 of a millimeter but enough to make the valves leak. Therefore a new reed blade will not seal good enough.

If you simply changed the check valves and your compressor doesn't have the output you hoped for… the reason is leaking valves. Poor initial output might improve and 'self heal' over time if you are lucky but it probably won't (if you have a worn valve plate). If you have hardly any output to raise the car there is probably not much hope that this will turn out to be a good compressor in the future. In fact I have seen newly 'repaired' compressors with new valves, which did not pump at all. I'm assuming of course there was no pressure testing done before the install, and the customer was very frustrated after paying a lot of money for a non-functional compressor. Installing new reed valves in a worn head will not work.

Failing New Reed Valves what now?

New reed valves can leak after install in an old compressor if you have no tools to measure valve seats and air tightness before install. Often time ring seats in a high mileage cast steel valve plate are worn down.

If the head valve seats are okay and your compressor doesn't pump don't be afraid to tear down the compressor head once again. There is no other way.

The valves should seal relatively well if they are dry. People might think with a thick layer of engine oil these parts will probably seal better but valves are actually designed to seal in a relatively dry state meaning only a minimal layer of oil, which would be the 'natural' inside a healthy compressor.

If the reed valve is not positioned tight to the head (steel part of the head which has precisely machined flat surfaces) the result will be a leaking valve. And if the valve is leaking there will be low output.

My advice is to verify -after you put the check valves in a good head- that the new flat reed valves are sitting very accurate, 100% flat and tight relative to the steel head. This is sometimes difficult to accomplish with the big donut valve as it is clamped at one side and probably has a gap. There should be no gaps…not even 1/10 of a millimeter that allows air to bypass the valve. It can be troublesome installing and removing the compressor head numerous times without improving results.

When I am working on this part of the compressor I am pressure testing the check valves and their air tightness in the shop with precise instruments and methods. With pressure differentials and leak down tests I can predict the performance of the finished product. Only positive pressure testing guarantees proper performance of the compressor installed in the car.

I have tested old compressors out of curiosity that came into the shop for repair and some of the old valves- to my surprise- were very tight with only minimal pressure loss. Some of the valves were much tighter than any new valves I installed. Mostly only one of the two valves is tight and the other one is leaking resulting in poor output.

Good tightness of some old reed valves tells us that reed valves can improve with some mileage. Rings of the valve seats work their way into the reed valve (very minimal) and you see the rings imprinted in an old reed valve. However the tightness was also coming with very contaminated valves and the contamination actually 'sealed'.

Again the break-in phase of new reed valves can bring some improvement but I would not count on it. The compressor has to pump per spec right from the start.

Bearings

Like in an engine the crankshaft /rod and piston are moving and need proper bearing and gliding surfaces with proper play. With worn bearings the compressor is becoming loud. If you hear mechanical noises bearings have to be inspected and replaced. The compressor is using a ball bearing at the pulley side of the crankshaft; all other bearings are brass bushings. The ball bearing typically does not wear much and if it does it is easy to exchange.

Worn Brass bushings have to be removed with special tools and new sleeves machined from proper brass alloy (using 12-15% lead for the 2 crankshaft bushings). The crankshaft's gliding surfaces have to be inspected, measured and corrected if deeper marks developed.

A worn piston pin should be replaced along with the brass pin bushing.

Air Compressor Rod with new Bornze Bearing Sleeves

Cylinder and Piston

The piston has 4 rings that glide in the cylinder. A high mileage compressor often shows worn piston rings and black soot in the cylinder head, which indicates excess engine oil finding its way to the head.

The main problem is that engine oil might get into the air suspension's semi closed circuit and contaminate the system. This is often visible inside the main valve at the pressure-reducing valve.

The cylinder has to be inspected and measured. If within specs a light cylinder hone and new piston rings will solve the problem.

Assembly of Compressor

Before all repaired parts of the compressor (head plate and reed valves, crank shaft, piston and rod) get installed the aluminum parts will be cleaned or sandblasted. New hardware and seals (shaft seal, rubber seal ring for the bearing cap, new gaskets, new ball bearing, new studs, nuts and bolts) will be installed.

Assembly will be starting with the crankshaft, ball bearing plate and rod in the aluminum housing followed by the piston, cylinder and cylinder head with reed valves.

Health Test for the Air Pump

After the rebuilding of the compressor proper output of the compressor can be tested as stated before.

I am testing the compressor after assembly with a pressure gauge installed at the pressure port. With a hand crank the compressor should easily reach 2-3bar or more.

With the compressor driven by the engine it should be able to increase air pressure in the tank from 12bar to 14 bar within 90 seconds at engine speed or 2000rpm.

For this test a pressure gauge installed at the tank (Schrader valve) or at the main valve is needed. At the main valve remove the pressure switch and install a 20 bar /300psi pressure gauge with a male M12 x 1,5 connector and seal ring. With a helper let the engine idle at 2000rmp and check the pressure gauge with a stopwatch in hand. With rising pressure the start the stopwatch at 12 bar and check the time until the pressure reaches 14 bar. If within 90 seconds you are the lucky winner.

Martin Werminghausen

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