MACS Service Reports

MOBILE AIR CLIMATE SYSTEMS ASSOCIATION ©

By Mike Bailey, MACS Technical Correspondent

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Understanding the Compressor

We have all been there.

A vehicle comes into your bay and a compressor is diagnosed. It may still turn…or not. Maybe the driver hub freewheels with no resistance, perhaps it is noisy, or it could be locked up solid. Sell the job, a flush may be performed, then a reman or new compressor and the obligatory dryer are installed along with a recharge. Post-repair testing and gauge readings confirm the system is again healthy. Send it.

A week or two later the same vehicle is back in your service bay and the compressor is dead again. What Happened? How can this scenario be avoided?

There are many factors to consider for a compressor to survive in the challenging underhood environment. Tiny engine bays have necessitated smaller compressors now sometimes mounted down near the crank pulley, catalytic converters attached to the exhaust manifold, cooling system(s), and the A/C itself shedding heat from the cooling module, wildly varying RPM, filter/dryers, and a much smaller refrigerant charge have to be taken into consideration. If these variables stay within design limits, the compressor will do its thing and the customer will be happy.

Technicians can reduce the chance of a compressor "comeback" by keeping all these factors in mind during inspection and service. It seems like a lot to remember, however understanding how the things live in this environment will help technicians work toward most of these points becoming routine checks that are unconsciously performed during service.

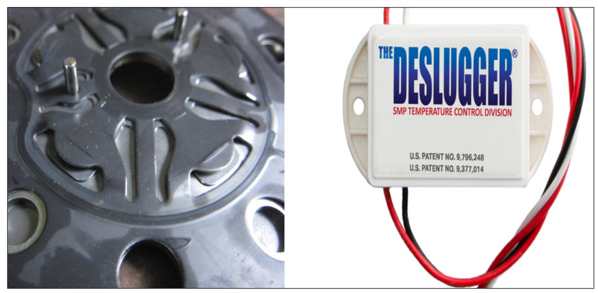
The down-low

That noise on system start-up again. Turn the system on, hear the "click' of the clutch and wait for the cool air. Instead, a "growling" or possibly a clutch/belt squeal is heard from the compressor before things quiet down and get cool. Compressor slugging is a real issue. On many vehicles we can not "service it out" during repair. It may be an inherent issue within the system design.

"Slugging" is the compressor clearing liquid from its cylinders on start-up, after sitting, before it can start compressing vapour as designed. A compressor is not a liquid pump, and liquids generally can not be compressed. The liquids in the compressor causing slugging are refrigerant and lubrication oil.

Consider what happens during slugging.

Refrigerant oil will be expelled out of the cylinder by the piston moving toward the reed plate. The liquid oil squeezes past the reed, into the discharge port and then out toward the condenser. The oil does not cause a "hydraulic lock" as the reed valve is easily pushed open by the exiting oil, but the volume of oil may not be able to be expelled quickly enough. Cylinder pressure then spikes, and the compressor may be damaged.



Mike Bailey / Four Seasons

Figure 1: *Slugging can damage reed valves. A "Deslugging" module will cycle the compressor rapidly on start up. Rapid cycling on start up allows the safe pump-out of any liquid refrigerant or oil which has accumulated after sitting for a specific amount of time.*

There is more bad news. Oil and refrigerant mix. Droplets of liquid refrigerant will be mixed in with the oil. Pushing this oil/refrigerant out of the cylinder causes a pressure spike. Rising pressure increases temperature. When the temperature rises, the liquid refrigerant may boil and expand (system high side pressure has not built up yet), which intensifies the "growling". If the liquid in the compressor is mostly refrigerant, the same noise will be heard but it can be more pronounced.

Will slugging damage a compressor? Yes. The rapid expansion of liquid refrigerant to vapour can overstress the reed plate and physically damage the reed valve. If the compressor is engaged and brought up to a high RPM almost instantly (consider turning the system on with the engine at high RPM) the internal stresses of trying to compress the oil and the flash-boiling of refrigerant droplets can break piston rings and reed valves. Depending on the type of compressor, swash plate slider shoes may be overloaded and piston rods in variable displacement units can be bent. Bad news all around. See Figure 1.

If the specific year/make/model is prone to slugging by design, there is little a service technician can do to change the system design. Installing an "anti-slugging" module may be the cure. This module is installed in the compressor clutch coil circuit. These modules rapidly cycle the clutch on/off upon start-up to safely clear the compressor of liquid, before allowing the 100% duty cycle of the clutch relay to run the compressor as designed.

As service technicians we can reduce the chances of either causing slugging or aggravating slugging in a vehicle prone to the problem.

1. Strictly adhere to the manufacturer's refrigerant charge specifications. Research TSBs before service to determine if slugging is a problem and possible changes to refrigerant charge specs.

2. Take the time to carefully balance the oil charge during service. Strictly adhere to manufacturer's instructions on oil balancing when replacing components. Be mindful of previous service and possible oil overcharging. A complete system flush and manual draining of oil from the compressor may be in order if you suspect oil overcharging. Start from scratch if in doubt and install the OEM specified volume of oil after flushing.

3. Install an anti-slugging module if the vehicle is prone to slugging. Consult TSBs to determine if the vehicle in your bay is a candidate. See Figure 1.

Staying cool

Sure, the end game is to cool the passenger compartment. What about cooling the compressor? Manufacturers have taken compressors from being right on top of the engine in a relatively "cool" environment and tucked it away in a tiny space, possibly between a subframe and an engine block under an exhaust manifold, bolted to the engine. Sometimes you can barely see the thing.

What cools a compressor? There are several ways a compressor sheds heat. Some are intended and some are happenstance.

Air flowing over the compressor body will carry a small amount of heat out of the unit. Mounting pad contact to the engine block will also remove some heat. Neither of these are considered major contributors to compressor cooling though.

Heat from the compressor is typically shed through the condenser. That is right…refrigerant and oil returning to the compressor from the evaporator can still absorb and carry heat out to the condenser.

Some vehicle and evaporator designs will superheat the refrigerant vapour before returning it to the compressor. Still, enough heat can be added to the refrigerant and taken away to keep the compressor working.

Lubrication and refrigerant level

Most technicians are aware that refrigerant carries oil. During service we need to add the appropriate amount of the correct oil to keep the compressor working.

Consider the average vehicle that comes in for Air Condition service. Electrical and air flow problems are common, but studies show the most popular failure to be low refrigerant charge or the system is empty.

When a system is in good health and functioning properly, the compressor might run forever. When that same system develops a small leak, the system will continue to operate until the refrigerant level reaches a point where the control system will intervene and turn the system off. Operation and environmental conditions may allow it to run again for the short term without the customer noticing, but eventually modern systems are shut down when the controller determines the charge is too low.

Let us examine what happens to a compressor in this scenario. If refrigerant carries oil to and helps to cool the compressor, what happens as the system continues to operate as the charge leaks out?

Exactly…the low refrigerant level causes reduced oil flow back to the compressor. A small refrigerant leak can have the system operating at a below-optimal level of charge for an extended period in possibly severe conditions. This can result in compressor damage. See Figure 2.

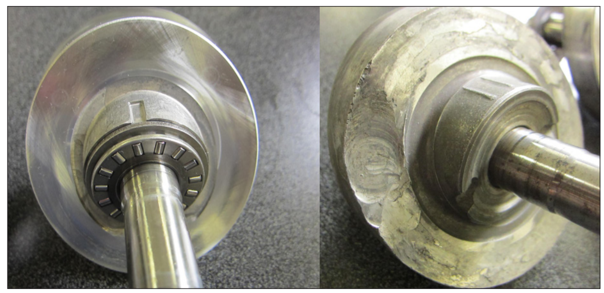


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Figure 2: *A healthy swash plate (left) and a damaged swash plate (right) caused by a leaking system, running undercharged for an extended period.*

Figure 3 shows a GM R4 Radial compressor. This compressor model functioned perfectly fine as a light weight and space saving unit. It replaced the old Frigidaire A6 in the early days of Orifice Tube systems. Unfortunately, back then technicians could "top up" or even recharge leaking systems. These systems held a large refrigerant charge and would run for a decent amount of time with a small leak. As the system ran and the refrigerant level dropped, the compressor ran on a reduced amount of oil. This resulted in the unit eventually seizing solid after starving for oil and grinding its innards to bits while discharging them into the system. The low pressure/cycling switch was supposed to protect the compressor, however continuous cycling as the charge dropped only added to the oil starvation problems. Accumulator/dehydrators left in service during repair also contributed to R4 compressor failures. Saturated desiccant would break apart and plug the oil return hole at the bottom.

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Figure 3: *GM's R4 compressor would fail from reduced lubrication due to leaks causing a low refrigerant charge.*

Why did that Frigidaire A6 rarely seize up? These early compressors which also included the York/Tecumseh and Chrysler V2 designs had built-in features which allowed them to operate without refrigerant in the system. They

Figure 4: *York and Tecumseh used "dip and splash" to lubricate the rotating and reciprocating parts. These were used in older light duty and heavy-duty applications until recently.*

incorporated an oil pump and sump into their design. The York/Tecumseh design in Figure 4 uses a dip-and-splash system to lubricate the internal parts. The Frigidaire A6 in Figure 5 and Chrysler V2 (not pictured) used gear-type pumps to lubricate the internal parts. These compressors could operate for a long time without refrigerant in the system.

The lower compressor shown in Figure 5 represents a modern compressor. No oil-pump. A swash plate or scroll design, shown in Figures 6 and 7 require continuous, adequate refrigerant and therefore oil flow to survive in its environment.

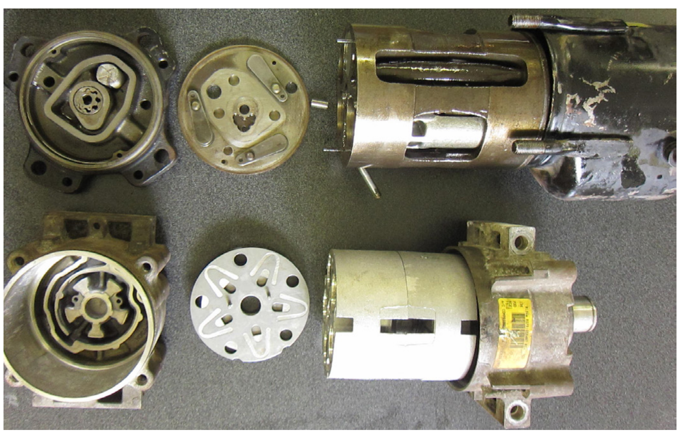

Figure 5: *Old school Frigidaire A-6 compressor on top. That "bump" in the compressor body (far right) is the oil pan and the tube extending from the inner assembly is the oil pickup. You can see the oil pump gears in the rear head (far left). This compressor was noisy. You can see the oil pump drive is broken off the rear of the swash shaft. Below is a Ford FX10 compressor that is typical of most modern swash-plate units. No oil reservoir or oil pump. It is fully dependant on refrigerant to supply oil.*

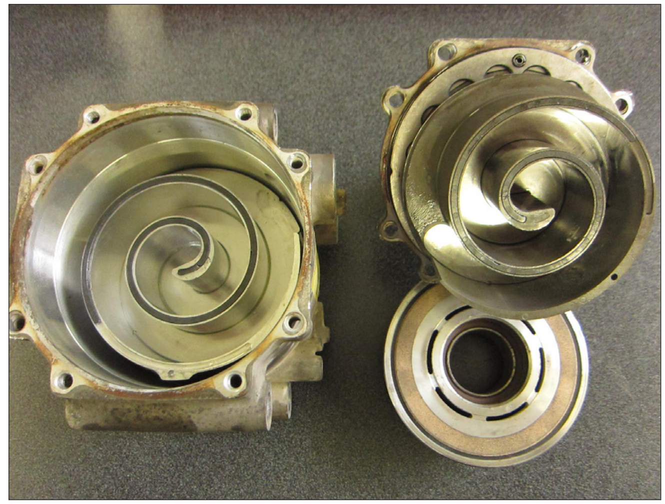

Figure 6: *Automotive scroll compressors also rely on refrigerant to supply needed oil.*

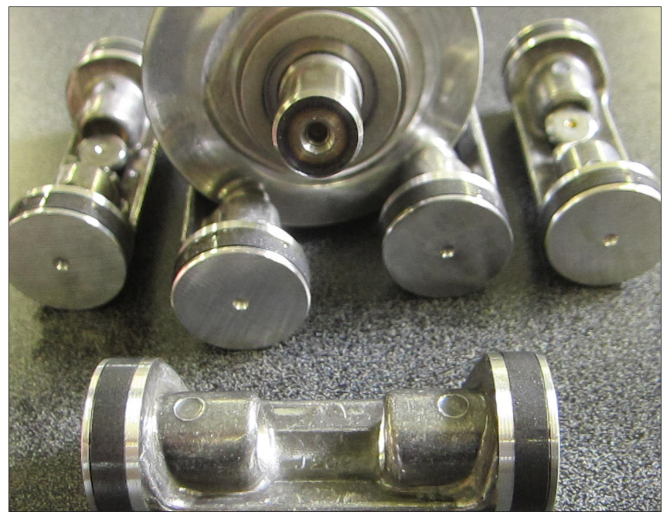

Figure 7: *A swash plate allows for "fixed-displacement", opposing cylinder operation.*

Famous quotes

This vehicle is in your bay, you have now diagnosed a failed compressor. Many technicians will run with it and quote a compressor, flush and dryer. Not so fast. Can we make sure we have all the bases covered before quoting the job? We all agree that a complete inspection and diagnosis can minimize warranty comebacks and can grow both sales and customer confidence. Having to make a second (or third!) call to update an estimate is embarrassing and unprofessional.

Many of the following have been covered in this publication at one time or another. Listed are a few more points to ponder before quoting the job, all in one place. Some are personal preference.

- PERFORM A LEAK TEST… to avoid the failures mentioned earlier in this article!
- IDENTIFY THE SYSTEM… to determine a course of action. Orifice tube or TX valve? Where will the most compressor debris be deposited in the system?
- IDENTIFY COMPONENTS… is that a muffler or filter? Can it hold debris? Can that debris be flushed out or should it be replaced?
- TAKE A HISTORY… has the system been serviced in the past?
- COMPONENT DESIGN… can I flush that condenser, or should it be replaced? Is that a filter/dryer, an old school receiver/dryer or just a filter?
- HOW DID THE COMPRESSOR FAIL…is it noisy or did it self-destruct during use, grind its internals to bits and deposit that debris throughout the system?
- HOW MUCH OIL REMAINS…in the system?
- IS THE REMAINING OIL CONTAMINATED…with grindings and debris?

- FLUSH GUN AND SOLVENT…to remove debris on the high side of the system?
- CLOSED SYSTEM FLUSHING… should I use liquid refrigerant and my recovery machine to remove all remaining oil contaminated with compressor grindings from components I will not or can not replace?
- LIQUID FILTER… can I add a filter on the liquid side to capture debris that cannot be removed from components being re-used?
- SUCTION FILTER… can I add a filter to the suction side to protect the new compressor I am installing?
- FILTER/DRYER CHANGE OUT… Food for thought…on a larger more expensive system, it may be beneficial to complete repairs and run the system with the new filter/dryer for a period. The new filter/dryer is replaced again as a preventive measure, after it has had a chance to capture any remaining debris from the system. The best technicians repairing larger expensive systems do this to ensure the system and compressor does not fail due to remaining debris.

Variable levels of confusion

Have you ever found yourself checking pressures of an A/C system, and something just looks “off”?

The system may cool perfectly but wow; is that high-side pressure gauge reading low!

It may not be cooling properly but the low-side pressure gauge reads properly.

Before heading over to the diagnostic dart board or firing the parts cannon, take a moment to do a bit of research. Check service info or even get an eye on the compressor.

It is sometimes challenging to find the information you need, or it may not even be noted in the service manual, but in order to test ANY system properly, technicians need to determine if the compressor is FIXED or VARIABLE displacement. Figures 8 and 9 provide a few design characteristics which can help technicians identify a variable displacement compressor.

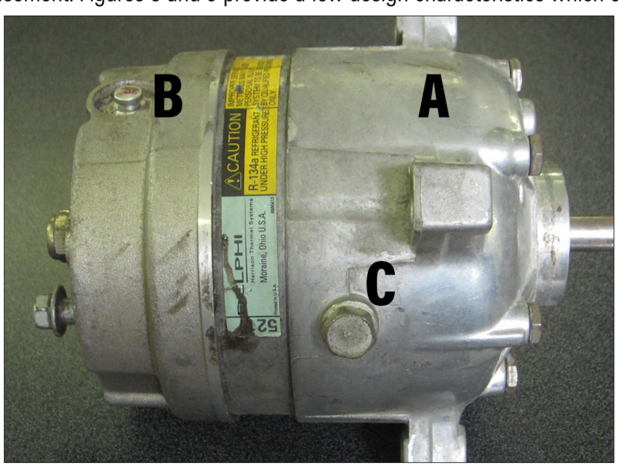

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Figure 8: *A few characteristics of variable-displacement compressors: A) The “nose” of a variable displacement compressor is typically rounded or of reduced diameter compared to the rest of the compressor body. This “taper” can be accomplished because the pistons face the rear. B) The control valve, located in the rear head, can be mechanical (shown) or electronic with a plug or wires. C) Many have a plug in the main body to allow for oil balancing during service.*

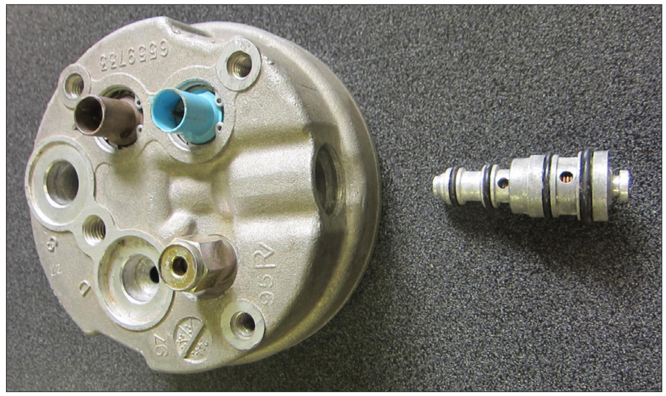

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Figure 9: *The control valve is mounted in the rear head of the compressor and can be mechanical in design or electronic (Figure 15). Another “clue” to identifying a variable displacement compressor is the casting bulge to accommodate the valve.*

This is important. Gauge readings will only make sense under high heat-load conditions. If a technician does not “set the vehicle up” properly, diagnosis can be incorrect. When this happens, the vehicle may leave the shop cooling nicely with a happy customer at the wheel. Give it a bit of time and there is that vehicle again. The customer, shop owner and the technician are now unhappy.

“Comebacks” cost money, and customers

Keep in mind, comebacks cost money. Even worse, the vehicle may leave the shop the second or third time with the same problem.

Shop owners, counter staff and technicians turn into the nicest people when something goes wrong! We are great folks already, but to keep a customer happy we really pour it on. Think back and this may sound familiar.

The customer brings the vehicle back. He or she may decide to wait. Or Not. If they wait, a technician is more than likely going to be pulled off a paying job to address the comeback. Cost #1.

Paying work is outside waiting to come in, but the comeback takes priority. Cost #2.

The technician assigned to the comeback is going to diagnose the entire system again. If the “best tech” is assigned to the comeback, shop revenue drops again. Either way, the technician is probably being paid to fix the comeback. Cost #3.

If the same component, say the compressor is diagnosed again, our supplier will probably supply the part at no charge provided we can document the initial replacement unit was correctly installed. Though the supplier may have a program to cover labor on the warranty replacement, the supplier warranty labor rate may be nowhere close to your door rate. Cost #4.

Warrantying the job, we are probably not inclined to recoup the cost of incidentals like O-rings, refrigeration oil, hardware, shop supplies or refrigerant. Cost #5.

In the event of a misdiagnosis and another component is found faulty, well, this is where we fall all over ourselves to keep the customer happy. The full door rate probably will not be charged for labor, if even charged at all. Parts may be invoiced at cost or just given away to get the job out the door. Cost #6.

Did someone drive the customer home and pick them up? Did the shop put them into a courtesy vehicle? Cost #7.

And so on. Air conditioning service is expensive for both the customer and the repair shop.

I get calls from shops and technicians all day for many different issues.

For A/C, they are sometimes in the third or fourth trip through the comeback loop with a vehicle. If it is a refrigeration issue with the HVAC system, the first thing I need to know is if the compressor is VARIABLE or FIXED displacement.

Variable beginnings

General Motors developed their Variable Displacement Orifice Tube (VDOT) system in the 1980s. The system was developed for many reasons including drivability, passenger comfort and fuel economy.

Think back. Way back. To the 1990s. Manufacturers were downsizing their vehicles, engine displacement and number of cylinders was shrinking. Now take that four-cylinder (carbureted) Chevrolet Cavalier or Oldsmobile Calais for a drive. Overall performance was less than stellar through the entire rpm and vehicle speed range.

Turn on the air conditioning and hit the highway. Cruise along at 55 MPH for a bit and let the cabin temperature stabilize and turn the blower speed down. How did manufacturers stop their evaporators from freezing? Turn the compressor off. Let the evaporator warm up a bit and turn the compressor back on. Systems typically used a thermostatic switch or a low-pressure cycling switch to cycle the compressor and stop evaporator freeze-up.

Another consideration was that "humid smell" discharged from the HVAC ducts when the compressor is cycled off and the evaporator is warming up. Many customers find the odour disagreeable and some may become uncomfortable as the humidity in the cabin rises.

On a V-8, compressor cycling was barely noticed. Now cycle the compressor on that small GM with the four-cylinder engine we mentioned earlier. Customers had real issues with vehicle speed fluctuation, bucking and surging as the compressor was cycled to control evaporator temperature. Now add a lock-up torque converter to the mix.

The Variable Solution...100% Duty Cycle Clutch

Many 'fixes' were attempted to reduce compressor-induced speed fluctuation, bucking and surging. Someone came up with the idea to leave the compressor ON. This idea was used in the 60s and 70s but required an STV, POA or EPR valve installed at the evaporator suction line. This system is not practical for modern vehicles.

The solution was the V5 compressor. Variable Displacement five cylinders. Early versions ran the compressor 100% of the time whenever the A/C was running, including Defrost. Later versions have deleted the magnetic clutch on the compressor and permanently drive the compressor input hub using shear pins to attach it to the belt pulley.

Variable benefits

Switching to variable displacement provided the following benefits...

- Speed drop, bucking and surging are eliminated
- Cost savings by eliminating the clutch (some models)
- Reduced belt and tensioner stress
- Continuous oil and refrigerant circulation
- Stable duct discharge temperature
- Improved dehumidifying and stable cabin humidity
- Improved mileage

Variable Operation

We can begin our understanding of variable displacement operation by discussing a mechanically controlled, variable displacement compressor and the LOW/SUCTION side of the refrigeration system. **Everything about variable displacement is designed to control low side pressure, and therefore evaporator temperature.**

Rather than turn the compressor off as the evaporator approaches freezing, reduce the stroke of the compressor cylinders. Reducing the stroke reduces the displacement. Reducing the displacement reduces the amount of refrigerant being pumped. Reducing refrigerant volume in the evaporator decreases the amount of refrigerant available to absorb heat. As a result, the exact amount of refrigerant is supplied to the evaporator to absorb the required heat, without the core temperature dropping below freezing.

Remember learning about the Pressure/Temperature relationship? The lower the refrigerant temperature, the lower its pressure. The higher the refrigerant temperature, the higher the pressure. That Pressure/Temperature chart is now useful again. I recommend having one on hand for the refrigerants your shop is servicing. Yes, they are different.

For ease of explanation, take a mechanically controlled, variable displacement compressor and set the control valve to maintain suction line pressure at 30 psi. Put another way, the only thing the control valve is going to do is command the compressor to maintain 30 psi on the suction port of the compressor, representing 30 psi in the evaporator core (with minor variables not worth mentioning here). See Figure 9.

26	-3.3	50.0	22.9
28	-2.2	52.4	24.5
30	-1.1	55.0	26.1
32	0.0	57.5	27.8
34	1.1	60.2	29.5
36	2.2	62.9	31.3
38	3.3	65.7	33.1

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Figure 10: *Pressure/Temperature relationship. Left column represents degrees Fahrenheit. Right column represents gauge pressure.*

Figure 10 is taken from a pressure/temperature chart. To use this chart, look up the refrigerant temperature in the left columns (°F or °C). Follow the same line to the right and the chart tells you the pressure the refrigerant will be at, resting, captured in either a tank or in the plumbing of a system (provided the charge is adequate to maintain at least a single of drop of liquid refrigerant somewhere in the system). In the chart, 29.5 psi (R-134a, second pressure column) represents refrigerant at 34°F (1.1°C).

We can also use the chart and look up the pressure reading to determine the temperature of the liquid refrigerant in the evaporator core. If we read 30 psi on our low-pressure gauge, we see 29.5 psi in the chart. Close enough. The chart tells us that our 30 psi represents close to 34°F (1.1°C). BOTH are above the freezing point of the condensate / water on the evaporator core fins. The evaporator will NOT freeze.

Instead of the compressor being turned off, the control valve modulates the stroke to maintain evaporator pressure and therefore temperature. Stroke is infinitely variable between minimum and maximum depending on heat load. A GM V-5 compressor can operate at a minimum stroke volume of 0.6 CID up to a maximum displacement of 8.3 or 9.2 CID depending on model.

Minimum stroke = LOW heat load
 infinitely variable
Maximum stroke = HIGH heat load

More on heat load later!

Different Strokes

The burning question. How do we control stroke?

MOST variable displacement compressors use pressure to control stroke. The compressor design is typically axial and very closely resembles an axial hydraulic pump. The piston rods are connected to a wobble plate. The wobble plate is split with bearings in between so the input can spin while the pistons wobble plate is forced into linear motion and piston reciprocation as it is held from rotation with a guide pin. See Figure 11.

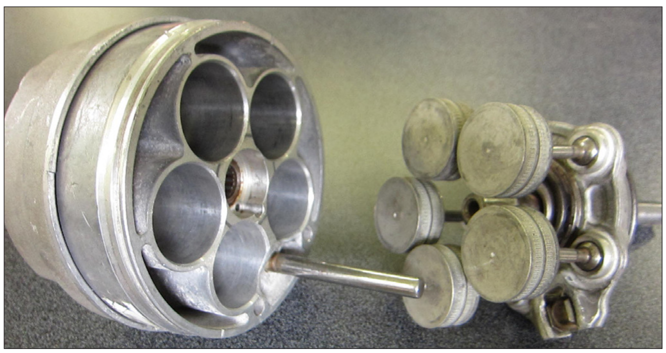

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Figure 11: *GM V-5 pistons connected to the wobble plate and the cylinder block.*

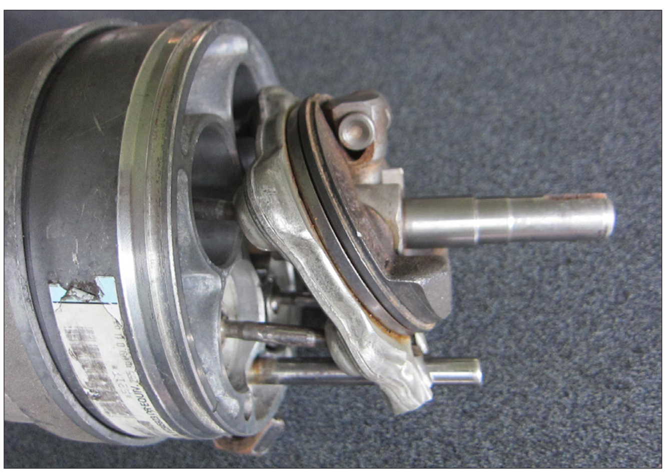

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Figure 12: *The wobble plate shown is on a large angle, at* ***Maximum Stroke****.*

Figure 12 shows the wobble plate and pistons in maximum stroke. The wobble plate is on an extreme angle compared to the cylinder bores. As the wobble plate turns, pistons are pushed to TDC (Top Dead Center) on discharge. On intake stroke BDC (Bottom Dead Center) pistons are maximum distance from TDC…therefore maximum stroke. This is the natural state for the compressor. The spool in the control valve is exposing the crankcase directly to the suction port and suction action of the pistons. Low crankcase pressure behind the pistons allows maximum stroke. Maximum stroke provides maximum refrigerant flow to move the maximum amount of heat.

Figure 13 shows the wobble plate and pistons in minimum stroke. The

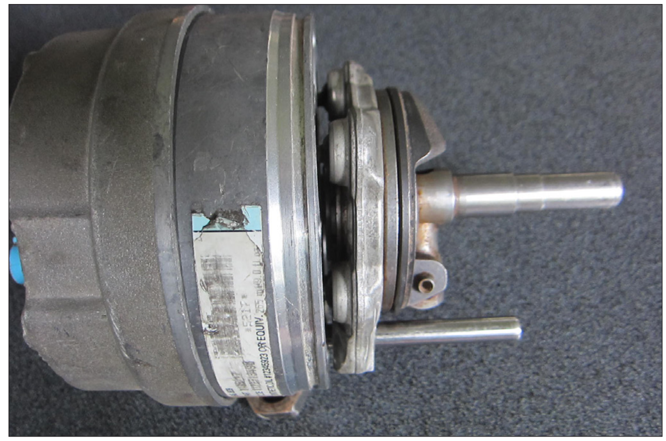

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Figure 13: *The wobble plate shown is on a slight angle, at* ***Minimum Stroke.***

wobble plate is almost perpendicular to the cylinder bores. As the wobble plate turns, pistons are pushed to TDC on discharge. BDC is limited to a small linear distance…therefore minimum stroke. The spool in the control valve is routing discharge pressure into the crankcase behind the pistons. This is the reason the pistons have rings facing both ways. The rings facing the crankcase seal the crankcase pressure in the crankcase. Here, the high pressure behind the pistons is forcing the pistons toward TDC/minimum stroke. The wobble plate is designed to stop at minimum stroke and can NOT be forced to zero stroke. Minimum stroke provides minimum displacement, therefore minimum refrigerant flow, to raise evaporator pressure/temperature to just above freezing and avoid condensate freezing on the core.

Why not zero stroke? Zero stroke represents zero refrigerant flow. Zero refrigerant flow represents zero oil flow. Remember the compressor runs continuously if the clutch driver is pinned or when the A/C is engaged on the control head. At zero stroke the wobble plate would still be spinning, but without oil flow. The wobble plate and shaft bearings would burn up.

In the winter, systems with a magnetic clutch will not engage the clutch if the ambient temperature is too cold. This is typical of systems with which we are familiar, including cycling clutch systems.

As mentioned, systems without a magnetic clutch have the compressor drive hub pinned to the belt pulley. The wobble plate is constantly turning with the engine running. During the winter in cold climates, the compressor operates at minimum stroke almost exclusively.

Charge level is exceedingly important for compressors with pinned drive hubs. As discussed, low refrigerant level represents reduced oil flow. Pinned drive hubs can not be disconnected and a refrigerant leak will ultimately lead to compressor failure. Find. Those. Leaks.

Service Variables

Now that we know why variable displacement has taken such a foothold in the industry and the basic operation of controlling stroke, we can apply this to testing. Always remember, refrigerant leaks represent shortened compressor life via reduced oil supply.

Just the nature of a variable displacement system can throw a curve ball into what is usually a routine diagnosis.

In compressors using a MECHANICAL control valve as seen in Figure 9, the function of the valve must be considered during initial pressure diagnosis. The scenario is as follows.

A vehicle comes into a shop with poor to non-existent cooling performance. The compressor is running 100% of the time but the pressure readings are close to those in Figure 14. The service technician has yet to take the training to become familiar with variable displacement compressors and proceeds to diagnose the system as a cycling-clutch type.

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Figure 14: *DO NOT get fooled with these readings on a variable displacement system. These readings represent a low refrigerant charge.*

Analyse the readings. Low-side pressure is at 30 psi and steady. This may vary +/- three or four psi depending on conditions. For most of us, 30 psi represents a reasonable low-side pressure gauge reading under moderate conditions. The compressor does not cycle and is running constantly.

The technician analyses the system based on their knowledge of a fixed-displacement system where the compressor will cycle if the charge is low. The fault can not be a restriction since the compressor is running and low-side pressure is not dropping below 30 psi. If the refrigerant charge is low, a low-pressure switch will turn the compressor off, right? The high-side pressure is much lower than expected but well above low-side pressure.

Sometimes I poll live classes at this point in the analysis. Over 3/4 will diagnose the compressor. Their logic for this diagnosis is low side pressure is steady and a low charge cut-out switch has not turned the compressor off. The compressor is not capable of developing the required pressure for the system to operate and is damaged inside.

This diagnosis may be the case for a cycling clutch system, however do you remember the main function of that mechanical control valve? The ONLY thing it is programmed to do is keep the suction pressure close to 30 psi. On compressors with mechanical control valves, even with a low charge, the control valve will force the compressor to maintain that pre-set 30(ish) psi even though the system has no chance of performing properly due to a lack of refrigerant.

This scenario continues with the shop selling the customer a compressor, dryer, and recharge. The system performs perfectly after repair, the customer gladly pays the bill and off they go. Two or three weeks later, the vehicle is back with the same exact symptoms and gauge readings. The technician condemns the new compressor and the exact same repair is performed again. Under warranty.

I have helped many shops with this exact scenario. One shop went through FOUR new compressors before the jobber asked me to have a look. The compressors they replaced were not defective. What did they miss? The systems were leaking. In the case of the four compressors, the evaporator was leaking.

Rule #1 for diagnosing variable displacement compressors must now be... "ALWAYS confirm the refrigerant charge is correct before proceeding with diagnosis". If the proper charge corrects performance problems, find the leak.

Modern Variables

Variable displacement compressors perform so well that many manufacturers have installed them in most of their vehicle line-up. The variable displacement compressor was also upgraded over the years. Not really. Variable displacement compressor design is extremely reliable. What did change was compressor control. Instead of the mechanical spool-type control valve, many are now electronically controlled by a computer using PMW (Pulse Width Modulation). The theory of controlling stroke and wobble plate angle using crank case pressure is identical, though now electronically controlled. Electronic control valve is shown in Figure 15.

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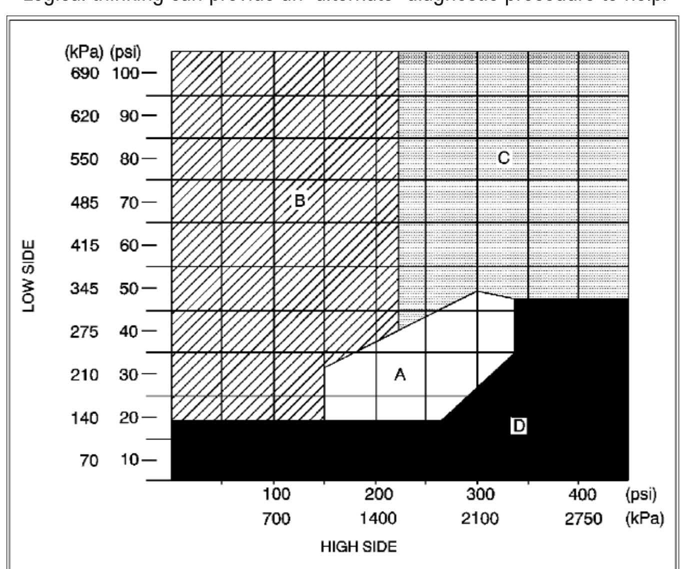
Figure 15: *An electronic solenoid-actuated control valve is the common choice for most manufacturers lately.*

Diagnostics

OEM diagnosis of variable displacement compressors can be confusing. Service information may not even acknowledge the compressor being variable displacement. You may be instructed to set the vehicle up under specified parameters such as sun load, ambient temperature, RPM etc. From there you are told to plot your readings on a diagnostic chart but with little explanation of what you are doing. Depending on ambient conditions, your plotted readings could land in the middle, the edge or completely miss the "sweet spot". See Figure 16.

Logical thinking can provide an "alternate" diagnostic procedure to help.



Courtesy of GENERAL MOTORS CORP.

Mike Bailey

Figure 16: *GM diagnostic chart for the V-5 variable displacement system.*

The following procedure will exercise a mechanical control valve as well as test computer control of an electronic control valve on most vehicles. Think "heat load".

If we place the system under severe stress by creating a large heat load, it should respond by commanding the compressor to maximum stroke. If I continue testing by removing the previously applied heat load, the system should respond by forcing the compressor to minimum stroke. This can be accomplished in the service bay without special tools.

Maximum Heat Load...Step 1

Configure the vehicle and record.

1. Gauges connected
2. Hot Engine
3. Hood open
4. Fresh air (cabin filter OK)
5. Temp to full "COLD" (not MAX)
6. High blower
7. Mode set to DASH and FLOOR
8. Open windows, closed doors
9. Stabilize and record readings
10. LOW-Side reading ______psi
11. HIGH-Side reading ______psi
12. Ambient Temperature ______°F
13. Duct Temperature Left ______°F
14. Duct Temperature Right ______°F
15. Clutch Duty Cycle ______%

Theory: The HOT ENGINE and HOOD OPEN will provide a large amount of heat which we can use to load the refrigeration system. The FRESH AIR and HIGH BLOWER settings will draw hot air off the engine and across the evaporator core. This will warm the evaporator core and is detected by an evaporator temperature sensor on an electronic system, or the mechanical control valve will detect rising suction pressure. Mode set to DASH and FLOOR and WINDOWS OPEN allows less restriction and more air flow across the evaporator.

The system should respond by forcing the compressor to maximum stroke. **IN MAXIMUM STROKE gauge readings should be the same as a fixed displacement compressor under the same severe conditions.** High-side gauge reading will vary depending on humidity but should be at least ambient plus 100 psi. The Low-Side gauge reading will rise above 30 psi. Why? We are loading the evaporator core with so much heat the liquid refrigerant in the core is completely vaporized mid-way through. This will superheat the vapor on its way out of the core, increasing pressure. The engine cooling fan should also run continuously on high speed.

Measure the temperature of the air entering at the cowl. A system pulling that temperature down 30°F at the interior ducts is working very well.

Keep the system running and proceed with Step 2.

Minimum heat load...Step 2

Quickly change HVAC settings as follows.

1. RECIRCULATED air
2. Temp to FULL COLD
3. LOW blower
4. Mode set to DASH and FLOOR
5. CLOSED windows and doors
6. Stabilize and record readings
7. LOW-Side reading ______psi
8. HIGH-Side reading ______psi
9. Ambient Temperature ______°F
10. Duct Temperature Left ______°F
11. Duct Temperature Right ______°F
12. Clutch Duty Cycle ______%

Theory: In Step 1 an extremely high heat load was applied to the system. Step 1 also cooled the vehicle interior and the air handling system. We are now using this to our advantage in Step 2.

Step 2 will largely reduce total heat load on the system. Switching to RECIRCULATED air will now pull that cool interior air the system produced over the evaporator. LOW blower will move less of that cool interior air (still containing heat) over the evaporator. Closing the windows stops warm outside air from entering the vehicle.

The evaporator, now cooling "already cooled air" will approach freezing, Low-Side pressure will temporarily drop a few psi and the system should respond by driving the compressor to Minimum stroke. Watch the High-Side gauge. As the compressor is forced to minimum stroke the High-Side gauge will drop steadily and heavily, possibly ending up at around 100 psi. When readings stabilize the compressor should be in MINIMUM stroke and discharge air temperature will have dropped lower than it was after Step 1.

Reverse the HVAC settings and the system should then respond by moving the compressor back to Maximum stroke.

Remember this testing is cause and effect produced by evaporator temperature.

Poor airflow over the evaporator can cause it to operate too cold if the air containing the intended heat can not flow over the core as it should. This will "latch" the compressor into minimum or less than required stroke. Confirm cabin filter is clean, ducts are free of rodent nests and the evaporator does not have a thick film of refrigerant oil and dust blocking airflow.

Videos of the described Variable Displacement tests and other goodies are available on the author's website *www.theautoprof.com* under the Technician Resource tab. ❖

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Editors: Elvis Hoffpauir, Steve Schaeber
Production Designer: Laina Forcey
Manager of Service Training: Steve Schaeber

Mobile Air Climate Systems Association
P.O. Box 88, Lansdale, PA 19446
Phone: (215) 631-7020 • Fax: (215) 631-7017
Email: membership@macsmobileairclimate.org
Website: www.macsmobileairclimate.org

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2.	A	B	C	D
3.	A	B	C	D
4.	A	B	C	D
5.	A	B	C	D
6.	A	B	C	D
7.	A	B	C	D
8.	A	B	C	D
9.	A	B	C	D
10.	A	B	C	D

1. PWM stands for ______.

a. Power Wide Modulation
b. Premium Warehouse Marketing
c. Pulse Wide Module
d. Pulse Width Modulation

2. True or False: As the temperature of a conductor increases, the resistance of the conductor decreases.

a. True
b. False

3. Two technicians are discussing diagnosing blower motor current draw. Technician A says that an ammeter must be connected in series within the blower motor circuit while it is running. Technician B says the leads from an ammeter can be connected in parallel across the blower motor feed and ground. Who is correct?

a. Technician A
b. Technician B
c. Both technicians A and B
d. Neither technician A nor B

4. Current goes ______ when _____ goes ______.

a. Up when resistance goes down.
b. Down when resistance goes up.
c. Up when voltage goes up.
d. All of the above

5. True or False: When measuring resistance, the ohmmeter must be placed in parallel across a circuit that is powered up with a functional load.

a. True
b. False

6. Two technicians are discussing voltage drop testing. Technician A says that the motor may have to be isolated from its control module and powered up with fused jumper leads directly to power and ground. Technician B says that the speed and condition of the motor can sometimes be determined with this test. Who is correct?

a. Technician A
b. Technician B
c. Both technicians A and B
d. Neither technician A nor B

7. A PWM blower motor module defaults to ______.

a. Off to prevent battery rundown when the module detects a problem.
b. Low speed to prevent evaporator icing.
c. Afterblow-enable to allow the evaporator to dry off and prevent odors.
d. High speed to prevent windshield fogging or icing.

8. A 3-phase BLDC motor's current draw ______.

a. Goes positive and negative.
b. Uses less current than a conventional motor.
c. Does not use brushes.
d. All of the above

9. Two technicians are discussing a PWM blower motor. Technician A says that the duty cycle output of the blower module controls the motor speed. Technician B says that the blower speed goes up as the module's frequency output goes down. Who is correct?

a. Technician A
b. Technician B
c. Both technicians A and B
d. Neither technician A nor B

10. A 3-phase BLDC fan motor control module ______.

a. Pulses each motor winding every 120 degrees.
b. Defaults to off when there is a problem.
c. Produces a high voltage sine wave in order for the blower to operate.
d. Sends power, ground and a variable voltage into the blower motor.