Understanding the Modern Automotive Air Conditioning System

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VARIABLE DISPLACEMENT COMPRESSORS

Electronic Control Type

DENSO VARIABLE CAPACITY COMPRESSOR 6SEU16C

The latest generation variable compressor is the DENSO S6EU16C fitted to a range of current vehicles including obviously selected Toyota models and the VE Commodore.

It varies from the Delph V5/V7 and CVC7 in that it has the following characteristics:

- It is a clutchless compressor.
- it has a torque limiter plate with a maximum instantaneous torque setting. Above the valve the limiter plate will rupture disengaging drive to the compressor.
- Torque limiter plates are vehicle specific. Their valves change - ensure the correct pump is fitted. (Manual and auto trans vehicles may be different - **Be Careful!)**
- This compressor starts in the NO STROKE mode and goes into the FULL STROKE mode softly (after an electronically controlled delay period). This is essential to minimise torque loading and subsequent failure of the limiter plate.
- This compressor cannot be used in any application for which it was not designed and cannot be used in dual evaporator systems where a second evaporator has been added.
- The general operational guidelines and testing for full stroke/no stroke operation are the same as the for the earlier generation pressure controlled variable pumps except the electronically controlled pumps can be ‘driven’ via a scan tool.

There are however some important considerations when testing these systems that must be accounted for to explain these we need to look at how the pump is electronically driven.

OVERVIEW

ELECTRONICALLY CONTROLLED VARIABLE COMPRESSORS

The basic operating strategy of filling the crankcase from the discharge side of the compressor to de-stroke the pump is unchanged. Where the variation comes is that instead of using a pressured operating bellows to control crankcase pressure (high and low side feed into the crankcase) we now use a Pulse Width Modulated (PWM) driven valve. By varying the pulse width we effectively control the operation of the valve to control the ‘bleed’ into and out of the crank-case. The important thing to realise here is that we are no longer relying on low side pressure to control de-stroke we now have to factor in the electronic over-ride strategies.

The second main difference is that these are clutchless pumps, so instead of disengaging the clutch as a safety precaution (i.e. over-pressure sensing from a switch or transducer) we now de-stroke the pump fully.
The latest generation variable pumps are superior in function however there are some tricks and traps to consider in testing its modes of operation.

Lets explain the two systems and compare them....

PRESSURE CONTROLLED VARIABLE PUMPS

The de-stroking or full stroking of this pump was basically determined by the low side pressure. The basic presumption is that if the refrigerant drops below 191 kPa in the evaporator the temperature of the refrigerant is below 0°C. In a ‘perfect’ evaporator under low heat load (cool cabin, re-circulate mode, low fan speed) the evaporator could in theory ‘ice up’. In systems such as this the manufacturer would have a ‘set point’ of 191 kPa (28 PSIG) which was effectively the control valve setting. These control valves were used in late model systems fitted with thin walled, high efficiency evaporators. Earlier systems that used less efficient heat exchangers (thicker walled serpentine types) had to have refrigerant inside the evaporator at below 0°C in order to drive the evaporator fins themselves down to 0°C - 1°C. In these systems the control valve setting could be as low as 150 kPa (26 PSIG). This would give us a refrigerant temperature of -4°C and a fin temperature of 0°C - 1°C given the head gain through the fins and tubes.

Service Tip:

Under no circumstances should the control valve be changed for one of a lower value. If this is done under low heat load conditions the evaporator will ice up with possible failure of the compressor due to liquid slugging of the pump, particularly after short rest periods.

DIAGNOSIS TIPS AND TRICKS

If a pump is going into de-stroke prematurely of failing to go to the full stroke position in operation there are a lot of factors to consider prior to condemning the pump.

1. Charge Rates

If the charge rate is low then there will be insufficient LIQUID refrigerant to feed the TX valve at the required rate. It is not the volume of refrigerant feed to the TX that is the primary consideration - it is that it is in LIQUID FORM. It is the boiling off of the refrigerant in the low side that gives us our expansion to ‘keep the low side pressure up at acceptable levels.

Service Tip:

Most technicians have seen the result of a low charge and its effect on low side pressure in a conventional system. When conducting ‘manual’ charging and our put liquid refrigerant into the high side first, then start the vehicle up, the low side pulls into a vacuum - even though there is a reasonable quantity of refrigerant in the system. The reason for the very low low side is that you are feeding vapour to the TX valve and subsequently have low levels of expansion in the evaporator.

The problem with low pressure in a pressure controlled variable pump is that it will automatically go into de-stroke - even on a 40°C day.

Service Recommendation - If the pump is de-stroking prematurely or is in full de-stroke, ALWAYS recharge the system to recommended levels prior to condemning the pump.

2. Blocked or Restricted TX Valves or Orifice Tubes

This will give similar results to a low charge rate. Insufficient feed to liquid into the evaporator will result in a reduced expansion in the evaporator and a subsequent reduction in low side pressure. Result..... de-stroking of the pump.

Service Tip:

If after correctly charging the system the pump is still prematurely de-stroking check for a full evaporator. If the evaporator is not full rectify the problem. The first stage is obviously the replacement of the TC Valve or orifice tube.

3. Internally blocked evaporator, suction hose or inlet screen into the pump.

Diagnosing this fault will depend on the point of blockage and the position of the service port. If the evaporator is internally blocked the pressure will pull down quickly to set point and the pump will de-stroke. You will see this on your low side gauge irrespective of the position of the port.

If the suction hose is blocked or de-laminated it will depend on the point of blockage COMPARED TO the service port position. If the blockage is 'downstream' of the service port the low side pressure will read high, even though the pump is de-stroking.

If the suction filter is blocked at the pump the low side gauge will ALWAYS read high, because the only place there is actually low pressure is inside the pump.

Service Tip:

It is important to explain to customers (in simple terms) the undercharge issue. If the system is low on refrigerant on a 30°C + day the pump will automatically de-stroke with a subsequent loss of air conditioning performance. In the 'old days' you simply lost some performance because of lack of flow of refrigerant (not a full evaporator). Now you still have this problem PLUS the pump destroking.

Give some consideration to selling an air conditioner service check for $29.95 (or whatever) to check pressures, performance, hoses, cooling system drive belts etc, then discount the 'main' air conditioning service IF it is required.

ELECTRONICALLY CONTROLLED VARIABLE COMPRESSORS

OPERATION AND STRATEGIES

The main variation in the latest generation pumps is that the destroking function is no longer done by a pressure bellows that operates from low pressure, it is primarily controlled by an ‘air off’ thermistor that measures the temperature of the air leaving the evaporator.

There are however two other main inputs that can over-ride this signal.

- Pressure transducer that can (via the air conditioner ECU) de-stroke the pump if pressures are either too high or too low.

- The Go/No Go signal from the main engine ECU. There are a number of signals that input the engine ECU that may de-stroke the pump, but the main two are throttle position and engine speed (too high and too low).

- As a calculation from the inputs the air conditioning ECU controls the pulse width or duty cycle to energise the control valve.

- The control valve controls the crankcase pressure to change the angle of the swash plate thus the capacity of the compressor.

- ***It is now where the difference in operating strategy comes...***

- The ‘old’ system started off in full stroke mode and with pressure being bled into the crankcase pushed on the underside of the pistons to drive it into de-stroke.

- The new system starts off in NO stroke mode on initial engine start then goes to full stroke mode (subject to ECM control).

The sequence is as follows:

Initial start up - the control valve coil is de-energised and the control valve is OPEN. This allows for the same pressure to be on either side of the piston and a spring elongates to tilt the swash plate to the MINIMUM PUMPING STROKE POSITION.

When the air conditioner ECU determines the compressor should ‘start pumping’ the coil is energised. This closes the valve and the pressure n the crank chamber decreases. This means the pressure in the pumping chamber is greater than the pressure in the crankcase. This compresses the ‘tilt spring’ to bring the pump into full stroke mode. THIS IS WHEN MAXIMUM AIR CONDITIONING IS REQUIRED.

If we continued to operate the system and the air off temperature decreased (down to 1°C) the ECU will once again de-energise the coil to OPEN THE VALVE to increase crankcase pressure to de-stroke the pump progressively.

This has a number of advantages...

- Very low 'torque engagement' spikes on the compressor.
- Allows for the use of a torque limiter plate for compressor protection (see explanation next).
- Allows for accurate ramping and timing of idle speed control.
- Minimises 'belt dance'.
- Allows the air conditioning ECU to de-stroke the pump in emergency situations (i.e. high engine temperature).

COMPRESSOR PULLEY AND TORQUE LIMITER PLATE

This is a clutch-less type pump. It consists of a drive hub and pulley and a limiter plate to transmit drive to the input of the compressor. There is no 'electromagnetic clutch'. Under normal operation the pumping/no pumping function is TOTALLY DONE by de-stroking the pump.

Because there is no torque engagement spike we can now fit a maximum torque limiter place to protect the pump in the event of excessive compressor loading (i.e. liquid slugging).

Service Tip:

If a limiter plate is replaced it is critical the replacement matches the vehicle, because the torque response of the engine determines the rupture valve of the torque limiter plate.

Under no circumstances must this compressor be used on 'normal' systems for which it was not designed. It is obviously a highly refined system that works only with the designated electronic control strategies.

COMPRESSOR CURRENT CONTROL (PWM CONTROL)

Ideally this test is done using a scan tool.

IMPORTANT NOTE:
Check and record any DTC's set for the vehicle as another module, sensor or communications error could be causing the HCM, A/C control module or ECM to send inaccurate signals to the compressor ECVD.

- Set HVAC controls to A/C on, highest blower speed, maximum cold, face mode, front doors open and engine at idle. Record the temperature drop of the evaporator on the scan tool or manually.

  Must drop more than 5 degrees in one minute. If it does the compressor is okay. If it does not, go to the next step.

- If this does not occur, use the soft key or drive key on the scan tool to engage the compressor to maximum output. The display should read PWM approximately 87% and the evaporator temperature should reduce. After six seconds the compressor will turn off with the PWM at zero percent.

  If it went to 87% and then back to zero, the ECD circuit is operating okay. If it did not, go to the the next step.

- Check wiring for open circuit from the HCM to the EVCD.

  If there was an open circuit, repair it and retest. If there was no fault, go to the next step.

- Check wiring for short circuit from the HCM to the EVCD.

  If there was a short circuit, repair it and then retest. If there was no fault, go to the next test.

- With the ignition off, disconnect the 14 pin HCM connector. Check the resistance between terminals T12 and T13. If it between 8.5 and 15.7 ohms retest at the EVCD 2 pin connector. If these tests show the EVCD is faulty, replace the compressor. **Ensure you follow the start up procedure for the new compressor.**

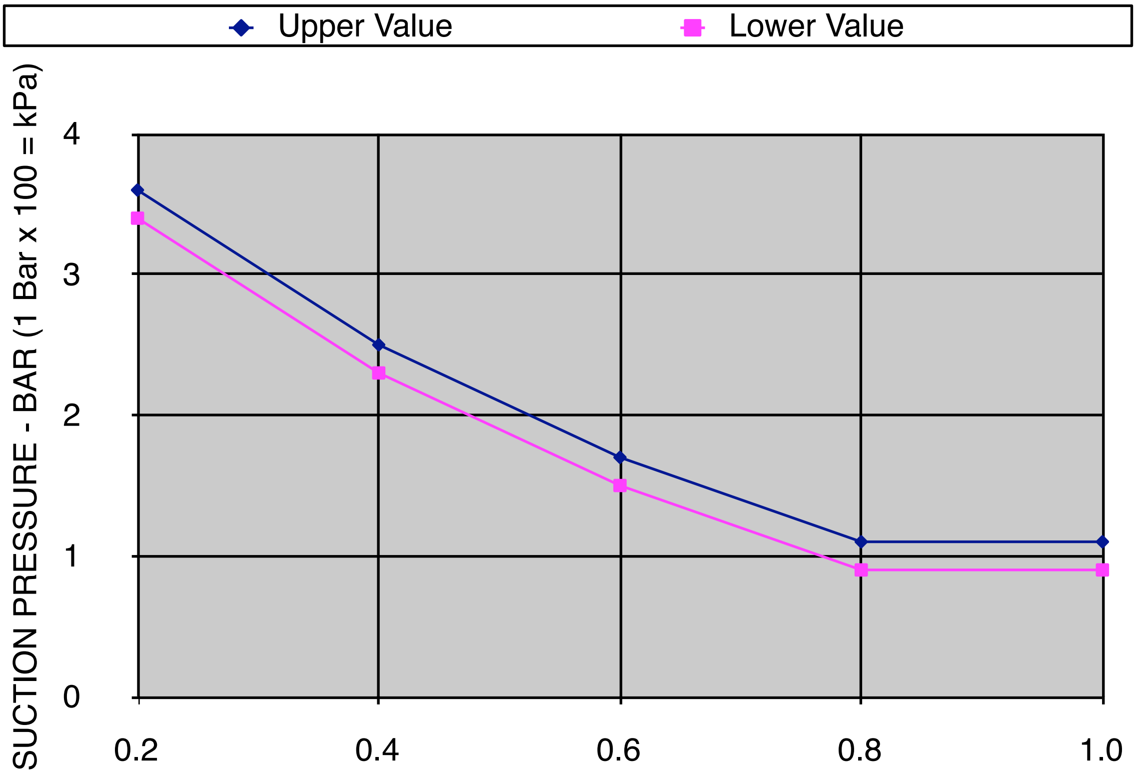
  If the EVCD tested okay, go the the next step.

- Carry out an evaporator temperature sensor test. Check for resistance across Terminals T1 and T2, and compare it to the resistance and temperature graph or table to ensure the evaporator resistance is okay. If it is not, replace the temperature sensor.

  If the evaporator sensor is okay, go to the next step.

- Go to IRC temperature control test. If you get no response, replace the HCM.

SUCTION PRESSURE VERSUS ECVD CURRENT CONTROL



ECVD CURRENT CONTROL (AMPS)

As the graph shows, the minimum suction pressure is altered according to the PWM changes at the ECVD.

The higher the current value (PWM) provided from the HCM to the ECVD the lower the compressor suction pressure minimum.

When the requirement for compressor OFF is commanded the ECVD current value will be low, causing the suction pressure to be high, the compressor operates at the minimum displacement (output).

When a situation arises where compressor damage could occur such as low or high pressure in the A/C system, maximum engine rpm reached or excessive coolant temperature, the HCM alters the PWM (current) to the ECVD to reduce to the minimum stroke (output) or in other words the OFF position. Low PWM (current).

Testing for correct operation can be carried out by using Tech 2 or scan tool selecting data display and PWM signal which will be displayed as a percentage value between 0% and 100%. A display of 0% would indicate that the compressor is OFF (minimum stroke) and a display of 80 - 100% would indicate that the compressor is at maximum stroke (output). A/C pressure gauges will be required to monitor A/C system pressures as part of the A/C system performance testing.