REPAIR GUIDE FOR

DENSO COMMON RAIL INJECTOR REPAIR

DISCLAIMER

THE FOLLOWING DOCUMENT IS BASED ON THE RESULTS AND EXPERIENCE GAINED FROM STRIPPING, REBUILDING AND TESTING NEW GENUINE DENSO INJECTORS USING HARTRIDGE ALL-MAKES TEST EQUIPMENT.

THE INFORMATION CONTAINED WITHIN IS NOT INTENDED FOR USE AS A SUBSTITUTE TO THE GENUINE DENSO REPAIR PROGRAM. IT'S CONTENT IS FOR INFORMATION PURPOSES ONLY AND IS TO BE USED AS A GUIDE AND INTRODUCTION TO DENSO COMMON RAIL INJECTOR REPAIR.

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Introduction

Technical and repair information surrounding Denso Common Rail injectors outside of the Denso network is limited and scarce, yet their use and presence within the Australasian diesel market is widespread.

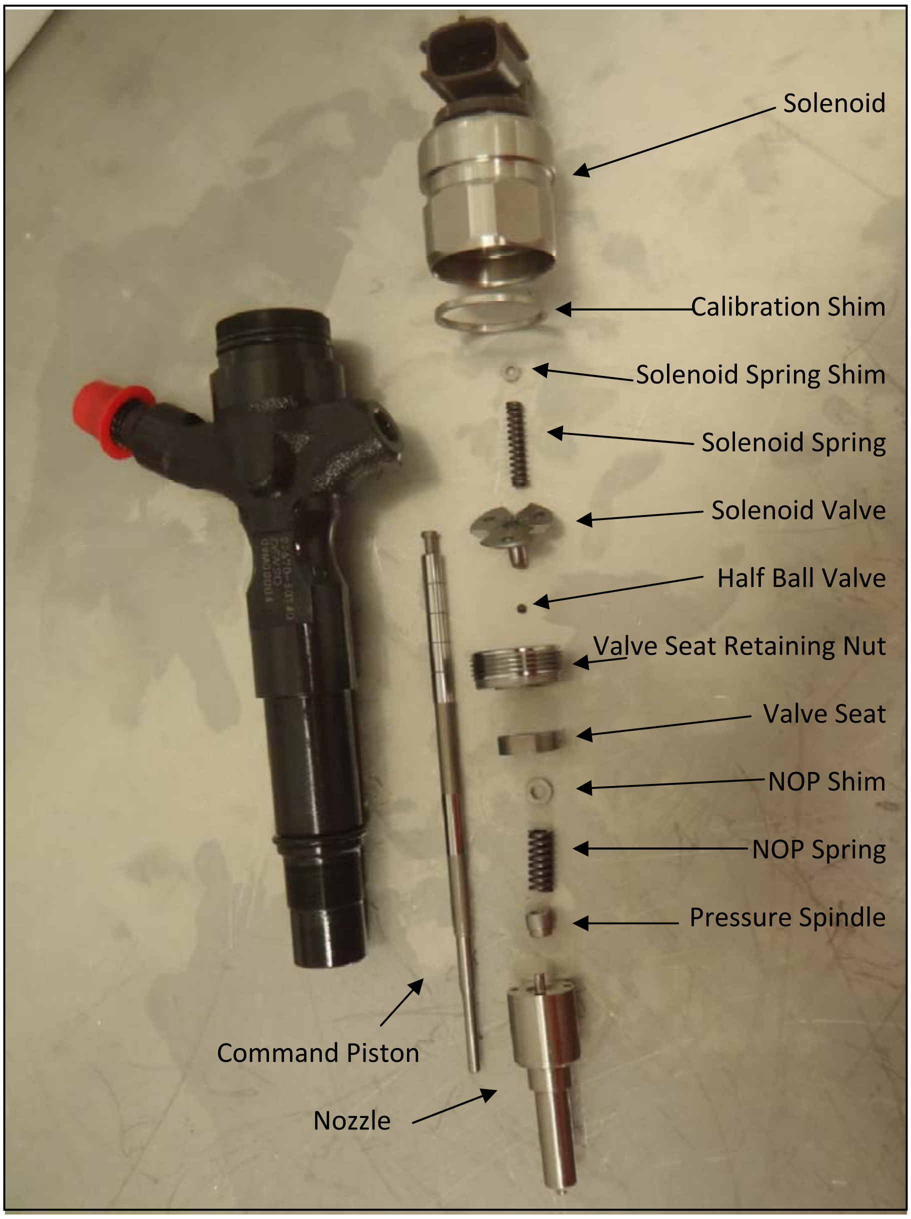
The following document aims to provide a guide to using the tooling and shim kits together with genuine and non-genuine parts, to strip, rebuild and test Denso ‘G2’ type common rail injectors. The information herein has been gained from the dismantling, rebuild and consequent flow and response testing of new Denso CR injectors using the Hartridge Cri-PC and IFT-70 all-makes programme. Alterations to the shim adjustment of individual injectors were made and the results recorded. These results have been used to determine what effects any changes to the shim adjustment have on the overall performance of the injector.

Correction codes (QR codes) cannot be written and produced for any Denso injector using this information. The production and creation of QR codes requires complex software and intricate flow testing using genuine Denso/Hartridge authorised equipment. Denso CR injector repair involves stringent clean room practices and very tight quality control on build tolerances. Please take this into consideration when attempting any dismantling of Denso CR injectors.

Hopefully this guide will provide an insight into what can be achieved with tooling available outside of the Denso official repair programme. Consideration should be given to the importance of correction codes when undertaking any adjustment or unofficial repair of ANY common rail injector that uses a correction code.

Component Overview and Identification:-

The photo below shows an exploded stripped Denso G2 injector and labelled components:-



Dismantling

The following dismantling, rebuild and test instructions are based on the use of the CR injector kit (part number – 850901) and Shim Kits (850276, 850296, 850301) available to purchase from Diesel Distributors, together with genuine and non genuine repair parts.

STEP 1 – Solenoid Removal

Figure 1

Figure 2

Figure 3

Mount the injector upright in the vice using the correct holding jaws, depending upon the body type and using the 27mm ‘crow’s foot’ gently loosen the solenoid (fig 1). Once loose continue to loosen by hand and CAREFULLY and GENTLY remove the solenoid, taking care not to drop the solenoid valve spring or tensioning shim (Fig 2).

Remove the ‘fuel calibration shim’ that will either still be sat on the injector or sat up inside the solenoid body (Fig 2).

The solenoid valve can then be removed using long nose pliers. TAKE CARE NOT TO DROP THE ‘HALF BALL VALVE’ (Fig 3). This is situated in the end of the solenoid valve. It is small and very easily lost!! – (Replacement valves and half ball valves are available through Diesel Distributors).

STEP 2 – Valve Seat Removal

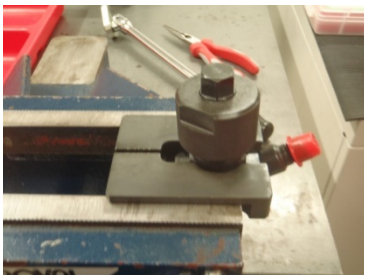




Figure 4 Figure 5 Figure 6

Insert the Three Pronged Valve Seat Socket into the guide (Fig 4), ensuring that the 3 prongs are located in the 3 holes in the valve seat retaining screw and then screw the guide over the socket. Tighten the guide all the way down by hand until it is felt to 'bottom out', then unscrew by approximately 1/8th of a turn (Fig 5). We need to ensure that the inner 3 pronged socket will turn, whilst maintaining maximum support from the guide, minimising the risk of the socket tilting.

WARNING – This nut is usually very tight!. Use a suitable breaker bar and a 14mm socket placed over the hex on the 3 pronged socket to undo the valve seat retaining nut (Fig 6). If unsuccessful, use an electric heat gun to apply GENTLE, MODERATE heat to the nut, then using the brass drift, strike the nut and re-try. **DO NOT USE A BLOW TORCH!! Excessive heat will damage the injector!**

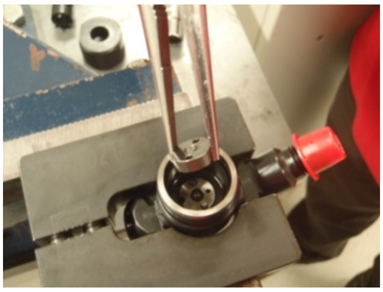
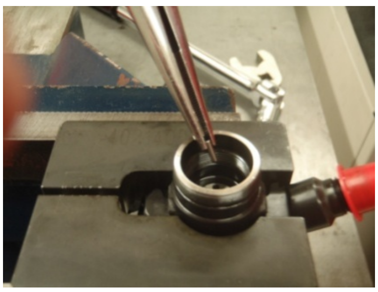




Figure 7 Figure 8 Figure 9

With the valve seat removed (Fig 7), carefully remove the 2 locating dowels (Fig 8). Remove the injector from the holding jig and turn upwards, whilst holding your hand over the open end of the body (Fig 9). The command piston should slide out, or at least begin to protrude from the bore. Withdraw the piston from the body. If there is no movement of the command piston at this point, it may signify that it is seized or tight. If this is the case, then it can be left in situ to be removed after the nozzle end has been dismantled.

STEP 3 – Cap nut Removal

Remount the injector in the holding jig with the nozzle assembly pointing upwards.

Figure 10

Figure 11

Figure 12

As with the valve seat retaining nut, the nozzle retaining nut can also be notoriously tight. One method that can be used to remove the nut more easily and minimise the risk of damage to the body thread and locating dowels involves the use of a pipe cutter to score the cap and 'free' the thread prior to removal. It is common practice to renew the cap nut on CR injectors anyway, so the cap nut will have to be discarded and a new one (available from Diesel Distributors) will be fitted on rebuild.

To remove the cap nut, score a line **no deeper than 0.5mm** approximately **15mm** from the base of the nut (opposite to nozzle side) around the cap nut (Fig 10). Then, using a good 15mm single hex socket, undo the nut. There is a 15mm crow's foot supplied in the kit, but this is best reserved for tightening, if using an injector aligning jig.

Once the injector cap nut has been removed, the nozzle can be removed along with the locating dowels (Fig 11). Finally, remove the injector body from the jig and carefully turn over, whilst holding the needle spring and remove the spring and spring tensioning shim (Fig12).

If the command piston was not removed earlier due to being tight or seized, then it can now be gently tapped out from one end. USUALLY, IF THE COMMAND PISTON REQUIRES FORCE TO BE REMOVED, THE INJECTOR BODY AND PISTON CAN BE CONSIDERED UNSERVICABLE AND NOT WORTH REPAIRING.

Inspection

Solenoid assembly

Figure 13

Resistance checks should be made to the solenoid. The specific resistance measured will depend upon the type of injector and should be compared to a new unit. The resistance recorded on the particular G2 injectors that we tested was approximately 0.5 – 0.7 Ohms.

Obvious signs of any damage to the outer casing or splits/cracks on the electrical connector should be observed. Check for erosion/corrosion of the electrical terminals and ensure that the inner surface of the solenoid is clean and free from dents etc (Fig13).

Ensure that the solenoid spring is in good condition. It may be a good idea to check and record the length against a new one.

Solenoid Valve and Half Ball Valve assembly

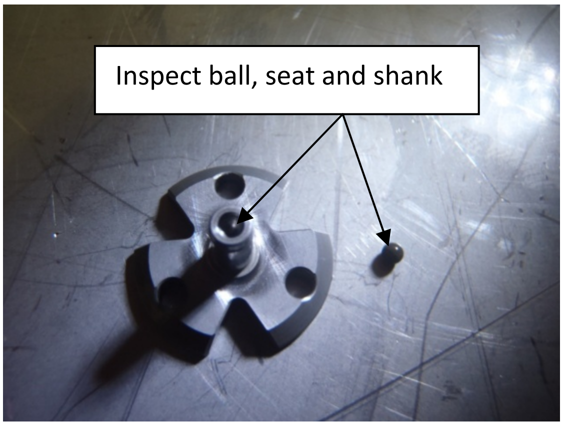


Figure 14

Check the condition of the solenoid valve assembly , paying particular attention to the half ball valve face and the seat inside the valve stem. The flat face of the half ball valve is responsible for sealing the control chamber, so it must be in good condition with no erosion or wear. These components are best inspected under a microscope. Check the conical seat that the ball seats on inside the valve, as well as the valve stem for any signs of wear, scratches and erosion (Fig 14).

Renew both components if there are any abnormalities or doubt on their condition (both available from Diesel Distributors).

Valve Seat and Retaining Nut

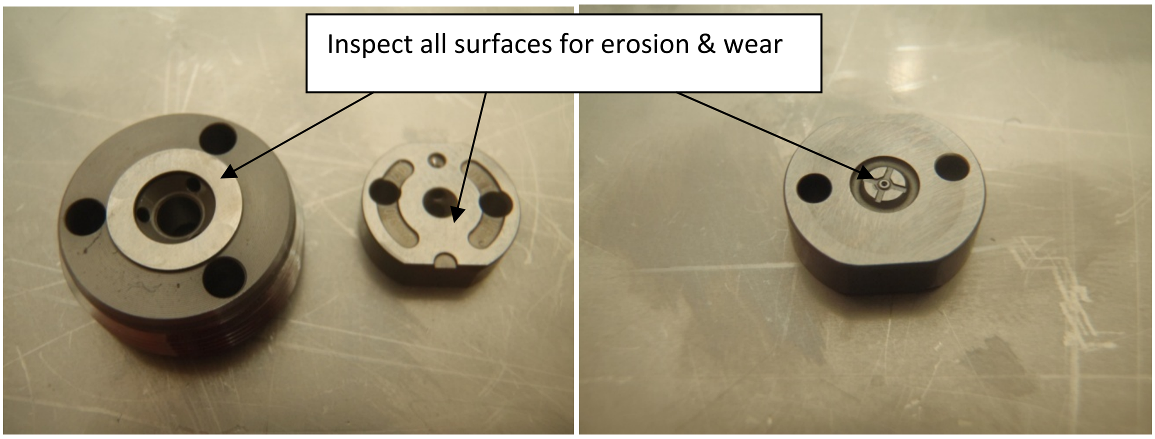


Figure 16

Inspect the valve seat for erosion and wear (Fig 16). As with the ball and valve assembly, this is probably best viewed under a microscope or other magnification equipment. If there are any marks across the seating area that would suggest a sealing problem – renew the valve seat (available through Diesel Distributors).

Inspect the sealing face of the retaining nut for signs of erosion and wear (Fig 16).

Due to the very fine tolerances involved in CR injectors, lapping of the sealing surfaces of these components is not recommended. Any attempt to lap the surfaces should be undertaken with the utmost care and with the use of VERY FINE lapping pastes.

Command Piston & Injector Body

Figure 17

Check the piston for scoring and wear marks along with the inner bore of the injector. If there is considered to be excessive scoring or wear on either component, then the unit will more than likely be scrapped (Fig 17). The piston should be clean, free from scoring and move freely inside the injector bore with no ‘snagging’ or tight spots.

Nozzle Assembly, Pressure Spindle and Spring.

Guidelines for inspecting the nozzle assembly can be considered the same as for any conventional nozzle. Check for excessive wear or scoring on the needle shank and seat and renew the nozzle if necessary. (Genuine and non-genuine nozzles are available from Diesel Distributors, depending upon application and availability).

Check the spring for condition and the spindle for excessive wear on the spring seat.

Re-Assembly

When re-assembling any common rail components, clean practices should always be observed and the utmost precaution should be taken to avoid any contamination of the components before and during assembly.

WARNING - The torque values mentioned in the following procedure are a SUGGESTED VALUE based upon our experience and NOT Denso specification.

STEP 1.2 – Valve Seat Assembly

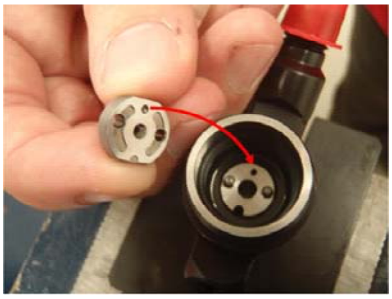


Figure 18

Figure 19

Figure 20

Mount the injector in the holding jig and place the 2 locating dowels into their bores on the top face of the injector (these dowels are larger in length and diameter to the nozzle locating dowels). Ensure that the valve seat is the correct way round before inserting it into the injector. The bore on the underside of the valve needs to be aligned with the bore hole on the injector face (Fig 18 & 19).

Using the 3 pronged socket, insert and hand tighten the retaining nut into the injector with the sealing face towards the valve. Screw the guide over the socket, ensuring that the socket can still move, but with maximum support from the guide and tighten to 70-75 NM (Fig 20).

STEP 2.2 – Solenoid & Solenoid Valve Assembly

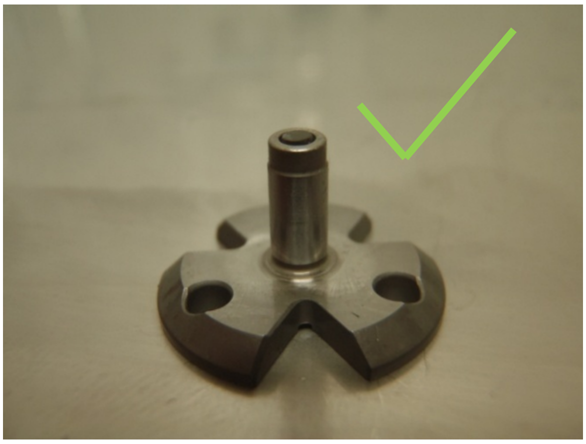


Figure 21

Figure 22

Fit the half ball valve into the solenoid valve stem and ensure that the **flat face** of the half ball valve is **visible** and **level** with the stem. DO NOT INSERT THE VALVE STEM INTO THE VALVE SEAT IF YOU CAN SEE THE SPHERICAL PART OF THE HALF BALL VALVE (Fig 22). IT MUST BE THE FLAT SIDE (Fig 21).

Figure 23

Figure 24

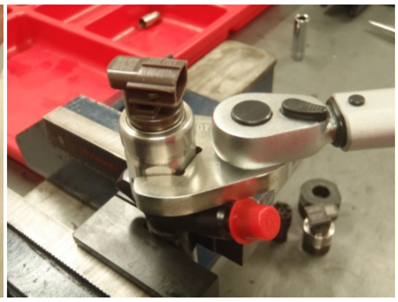


Figure 25

The half ball valve should stay in the valve stem when turned over and inserted on the valve seat. Once the valve stem is in position ensure it is free by rotating it (Fig 23).

Place the fuel calibration shim on top of the injector (Fig 24).

Next, insert the solenoid spring shim and solenoid spring into the solenoid and carefully fit the solenoid onto the injector, ensuring that the spring seats in the centre of the valve and hand tighten. Once hand tight, tension the solenoid assembly to 10-12 NM (Fig 25). OVERTIGHTENING OF THE SOLENOID ASSEMBLY CAN HAVE AN ADVERSE AFFECT ON THE OPERATION OF THE INJECTOR AND MAY RESULT IN DAMAGE TO THE SOLENOID.

STEP 3.2 – Nozzle and Cap Nut Assembly

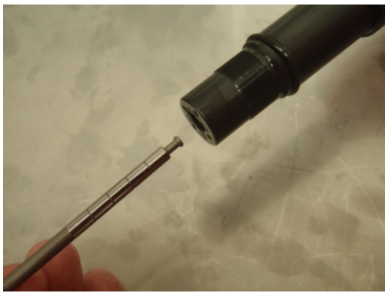


Figure 26

Figure 27

Figure 28

Re-position the injector assembly in the jig with the solenoid towards the bottom.

Insert the command piston into the injector body with the main shank machined with grooves towards the solenoid end (Fig 26).

Next insert the nozzle opening pressure shim and the spring into the central injector bore and then insert the pressure spindle on top of the spring with the smaller diameter facing the nozzle needle (Fig 27.)

Insert the locating dowels into the sealing face and place the injector over them. Place the (new) cap nut over the nozzle and screw down until hand tight (Fig 28).

Ideally some kind of injector clamping rig should be used to unsure alignment of the nozzle, if you can find something or manufacture anything suitable to hold the body. The arrangement pictured below (Fig 29) features the Stanadyne Injector Aligning Tool (Part # 29617). An injector aligning tool was not used in this exercise and no operational problems were experienced, however it would be better to use one if available to minimise the risk of misalignment or breaking the dowel pins.

Figure 29

Testing

All testing of the Denso CR injectors used to obtain the information given here was completed using the Hartidge CRI-PC and the IFT-70. (both available from Diesel Distributors)

When testing Denso Common Rail injectors the following elements should be observed to evaluate and determine the functionality and condition of the injector:-

- 1 Nozzle opening pressure
- 2 Injector Response Time
- 3 Fuel Delivery
- 4 Back leakage
- 5 Back leakage temperature

Each of the above will be discussed in more detail in the following guide which hopes to provide an understanding of what effect altering the shim adjustment has on the injector's performance.

1. **Nozzle Needle opening pressure**

   This can be set by the shim that sits behind the nozzle spring. The nozzle opening pressure setting on a G2 injector will have an effect on fuel delivery and **Response Time (see further down in section 2 for definition)** particularly at lower engine speeds and rail pressures**.** If the opening pressure is set too low, the idle delivery and pre-injection will increase. If the opening pressure is set too high the idle and pre-injection will decrease and response time will increase. Fuelling and response time at main fuelling settings will remain largely unaffected.

   We can set the opening pressure with the use of a Hartridge IFT-70 injector function tester that can actuate the solenoid whilst the user can observe the spray pattern and control the rail or feed pressure. This exercise could possibly be performed with a conventional injector tester and a multifunction CR injector trigger box such as the IFT-C (available from Diesel Distributors).

   THIS TEST SHOULD BE CARRIED OUT AND SET (IF NECESSARY) BEFORE ANY FLOW TESTING OF THE INJECTOR.

- Mount the injector into the machine and connect the high pressure pipe and appropriate electrical connector.

Figure 30

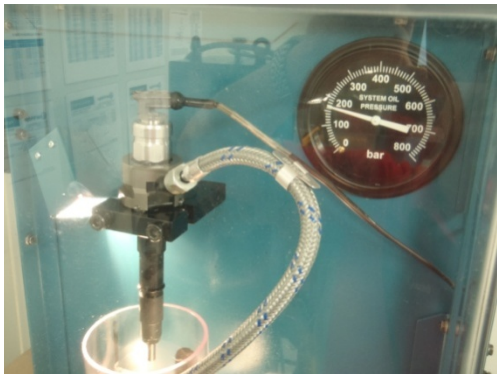


Figure 31

- Using a large pulse width of around 2.5 m/s and low injection speed of say 100 injections per minute (IPM) (Fig 30). Set the feed (rail pressure) to zero and gradually increase until the fuel can be seen to inject. At this point take note of the pressure on the gauge at which injection started to take place. (Fig 31).
- The opening pressure on the particular Denso injector tested was approximately 130-140 bar. This figure may differ depending upon injector part number. It will be up to the user to gain some specifications from new injectors.
- If the pressure needs to be adjusted, then the opening pressure shim will need to be changed to increase or decrease spring tension accordingly. Since the nozzle cap nut will not have been put into service the loosening and re-tensioning should not cause any issues and should be able to be re-used after removal.
- A check of the spray pattern and general operation of the injector can then be performed whilst still mounted on the IFT-70 after the opening pressure has been checked. As a general rule – there should be no more than 30-40% back leakage delivery compared with fuel delivery on full load settings (e.g. 500bar – 1200PPM – 1.2 m/s pulse width when using the IFT-70).
- If the injector is functioning properly with basic delivery, back leakage and spray pattern all satisfactory, the injector can be flowed more accurately with the Hartridge CRI-PC or AVM2 with CR injector all-makes capable of checking fuel delivery, back leakage and response time at high pressures (1600 bar +).

2. Response Time

Simply explained – this is the time taken from when the ECU sends a signal (current) to the injector to when the actual injection takes place.

It is an important factor in determining the condition of the injector. In general - increased response time points towards a poorly functioning injector. On vehicle effects of poor response time can show as white smoke, rough running, idling problems, detonation (knocking) and poor performance.

Injector response time is an important factor for the ECU to be able to 'compensate' drive pulse for recalculating fuel quantities for on vehicle 'learning' of QR codes.

Response time can be affected by opening pressure, command piston condition, nozzle condition, solenoid valve condition and solenoid efficiency. Anything that can effectively 'slow down' the operation of the injector will result in increased response time.

If response time can be read and seen then a clearer picture can be gained from the injector test on the general condition of the injector, as opposed to only relying upon measuring delivery and back leakage. It can be considered important in our diagnosis of injector condition. It can be affected by changing fuelling shims and opening pressure.

Typical response times recorded for the Denso injectors tested were in the region of 430-490 µs for higher pulse width and pressure settings (full and mid load scenario). Response time will generally increase at idle and lower pulse widths and pressures (idle, part load and pre-injection). Typical idle response times may be around 490-560 µs.

Again, the above figures are based upon the testing of certain Denso injectors and to gain a more thorough understanding of injector specific response time figures, new injectors would need to be tested and results recorded.

3. Fuel Delivery

After the opening pressure has been set and the injector has been tested for basic function it can then be properly flowed for a more in depth test on the Hartridge AVM2-PC with injector all-makes kit or the Hartridge CRI-PC.

The injector needs to be given a 'test plan' of settings from which the results can be recorded. These varying settings should put the injector through differing test situations that would best simulate various engine conditions. An example of these test conditions has been included below for reference:- (Fig 32).

TOYOTA 23670-0L090 BEFORE ADJUSTMENT								
Injector #								
Pressure (bar)		Speed	Pulse width (µs)	Delivery ml/st	Back Leak ml/st	Response (µs)	Return Temp °C
Idle	400	350	750	12.4	14.9	489	39
Mid Range	1000	800	800	49.3	22.8	432	40
Full Load	1600	1500	1000	95.2	33.8	418	50
Static Leak	1600	1000	0	0	0	0	52
Pre-Injection	600	1000	500	9	14.7	452	49
Mid Range	800	1200	800	39.9	19.6	446	51
Start	950	150	1000	64.2	105.6	551	48

Figure 31 – Test Plan Example

Once a set of tests or 'conditions' have been decided upon, they can then be used as a generic test plan for almost all injectors. The test plan is then used to record the results from new injectors and used for comparison against used or 'repaired' units. A database of results can be built up and tolerances can even be formed by testing multiple new units and taking average readings, from which tolerance bands can be decided.

If the flow results from a used or repaired injector are deemed to be 'out of spec' when compared to a test result from a new injector then the fuel delivery can be altered by changing the **Calibration Shim** which sits in between the solenoid and the injector body. CHANGING THIS SHIM WILL HAVE AN EFFECT ON THE OVERALL FUEL DELIVERY OF THE INJECTOR.

To INCREASE the fuelling a THICKER shim must be fitted

To DECREASE the fuelling a SMALLER shim must be fitted.

0.1 mm difference in shim size will equate to an approximate 7% change in fuelling across the whole range of the injector. However, the **response time** will also change as we have effectively changed the total distance that the solenoid valve has to travel. In an effort to counteract the resulting response time change, the **solenoid spring shim** can be changed to try and limit the resulting difference in response time. Although a difference in response time is seen when the solenoid spring shim is changed, it is minimal and does not return to the original results after a main calibration shim alteration.

It would therefore be prudent to make only small alterations to the calibration setting when considering any changes to the fuelling of the injector.

Changing the solenoid spring shim will also affect fuel delivery as well as response time, as we are reducing or increasing spring tension on the solenoid valve, making it easier or harder for the solenoid to pull up the valve. Again, consider the effects to the fuelling throughout the range when attempting any shim adjustment.

4 Back leakage & Back leak Temperature

The amount of back leakage fuel that a CR injector produces is an indicator of the internal sealing and condition of the injector. Any problems with the sealing of the solenoid valve or the nozzle needle will show up as high back leakage. Usually, if high back leakage is experienced it will be seen in every test and can indicate valve seat problems, solenoid valve problems and nozzle sealing or wear issues.

Back leakage temperature is also worth monitoring, as any excessive leakage of high pressure fuel within the injector will cause the temperature of the back leakage to rise. This is because the high pressure fuel created in the rail is a lot higher temperature than the lower pressure of the back leakage, therefore any excessive rise in back leaked fuel will show up as a high back leak temperature.

Correction Coding & Batching

CR injector correction coding is important and allows the CR system as a whole to compensate for mechanical and hydraulic tolerances within the injector. No two injectors will naturally flow the same and the vehicle ECU can compensate for this by altering the pulse width to individual injectors when the correction code given to the injector during manufacture is programmed into the ECU.

We cannot produce this code with conventional all makes equipment. It requires a considerable investment and OEM backing to do so.

One method of trying to limit the problem of our inability to produce an individual correction code is to 'batch' injectors. This method involves flow testing and adjusting the fuel delivery on injectors so that the differences between them are minimal. Say for instance we had around 30 injectors that were 'repaired' and flow tested. The batching concept assumes that out of those 30 injectors there would be 'sets' that would display similar flow and response characteristics. These injectors could then be further 'fine tuned' with minor adjustment to make them as similar to each other as possible.

Sets of 4 or 6 injectors are then sold or fitted together to minimise any major differences in flow.

Another concept is to build lengthy data base on the flow rates of differing new injectors from same part number family by recording their flow and response characteristics and the code on that particular injector. Over time a database can be built and any future injectors that displayed similar results to a previously recorded unit would be given the code from that similar flowing new injector. This would be a long and complicated process, but not impossible.

SUMMARY

There are parts, test equipment and tooling available through Diesel Distributors to service and test Denso CR injectors. There is no concrete set of instructions or test data to produce a perfectly repaired product. There is however, an opening to be able to offer something more than just a new unit in box.

The repair concept offered here is to enable the user the ability to 'learn as you go' and base repairs on data obtained from new units.

Hopefully, the information in this document is enough to get you started.

For further information please contact:

Diesel Distributors Australia – Peter Hunter peterh@ddal.com.au

Diesel Distributors New Zealand – Kevin Morris kevin@dieseld.co.nz

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