INJECTORS, O-RINGS AND STRANGE LEAKS.

This article is based on my own subject research, personal experience from dismantling a set of injectors in my shed after they had failed on a work mate's car and invaluable advice from a very knowledgeable and helpful overseas source who works on these engines on a daily basis (thanks !) I hope this information will in some way help owners of vehicles fitted with 4JX1 3.0 TDI engines, who may be faced with strange symptoms such as rising sump oil level, diesel in coolant circuit, etc. to diagnose the source of their problems.

I do not profess to have a detailed knowledge of all aspects myself - I am an enthusiastic amateur rather than an automotive professional. Furthermore, I accept no responsibility for what readers choose to do with this information.

Background.

The 4JX1 diesel engine was one of the first of the modern high performance diesel engines delivering previously unknown levels of torque and power. The engine was manufactured by Isuzu in Japan and fitted to their range of 4WD vehicles sold around the world in the period 1998 – 2004, or thereabouts. This vehicle was sold in Australia under the Holden brand as the Jackaroo 3.0 TDI.

The engine itself has two separate oil circuits. The first circuit provides oil lubrication to the bearings, camshafts etc., as in a conventional engine. The second circuit is fitted with two pumps in series, delivering high-pressure oil for operation of the diesel injection circuit. Both circuits circulate through the sump, fitted with a separate pick-up pipe for each circuit.

The high-pressure oil for operation of the injectors is fed into a common header pipe, attached to each of the four injectors, which inject diesel fuel into the engine. This header pipe is located under the engine cover, below the intercooler.

Injector Operation

When the engine is running, the injectors are fired at the correct point in the cycle by an electrical signal from the engine management computer, which acts on a solenoid fitted to the top of each injector. The solenoid causes a small valve in the top of the injector to open momentarily, which admits a small amount of high-pressure oil from the header into the injector body. This oil moves a piston within the injector, which in turn, pressurises the slug of diesel in front of the piston, and injects it into the cylinder.

The injectors themselves are 'graded' after manufacture and a code is marked on top of the injector body. Grading is done by carefully testing each injector on a specialised test device, which feeds a set of standard parameters (fuel pressure, electrical signal, etc..) into the injector. The device then records the specific performance of the injector and then grades it. When the injector is fitted to an engine, the grade has to be input into the engine management computer, so that the precise amount of fuel is delivered at exactly the correct moment for the engine to run correctly. This programming is done during assembly of the engine before it leaves the factory, and would not normally require changing unless new injectors are fitted to an engine. Failure to do this can result in severe engine damage, such as melted pistons due to engine running too lean.

Symptoms Experienced.

My interest was sparked when a work mate told me about a problem he had with his Jackaroo 3.0 TDI whilst returning from a recent long distance holiday trip. The first sign of trouble was excessive exhaust smoke when accelerating away after descending a hill. He called at a Holden dealer who alerted him to a possible engine problem that could cause the oil level to rise and vague mention of what to do if it did. Fortunately, little change occurred in oil level during this time. On return from holiday, he took the vehicle to a local Holden dealer for the 80k kms service, who advised to "change O-rings" at the same time as a precaution.

Here's what happened over the next few weeks :

Visit	Work Done	Result
No. 1	O-rings between injectors and sleeves changed as per advice at the 80 k kms service.	700 kms later, noticed oil on floor under car and sump oil level rising. Returned to Holden.
No. 2	Crankshaft shaft seal changed.	Oil level still rising, returned to Holden.
No. 3	Previous O-rings changed for second time.	Oil level still rising, returned to Holden.
No. 4	Same O-rings changed for third time.	Oil level still rising, returned to Holden.
No. 5	This time, the O-rings between sleeves and cylinder block were also changed.	Oil level still rising, returned to Holden.
No. 6	Pressure test revealed leaks from within two of the injectors.	Set of four injectors replaced with new units, problem solved.

We spoke several times during this saga trying to work out what was causing the oil level to rise, even though the 'O-rings had been changed'. We discovered there were several O-rings associated with the injectors - the following section of this article attempts to explain the location, purpose, etc.. of the various O-rings fitted in and around the injectors.

Once the new injectors had been fitted I offered to dismantle the old units to try to find the cause of the problems. This was partly through engineering curiosity and also to see if it would be feasible to repair the old injectors for reuse at some future date. The current price (Australia) for a set of four injectors is approx AUD 1800.

Diagrams 1 and 2 show the overall injector assembly. Each injector was carefully dismantled, and the component parts cleaned and visually inspected. Refer Diagrams 3 and 4 for dismantled parts. The overall condition of each injector appeared to be very good, with very little sign of wear on any of the metal parts. By contrast, the small, green coloured O-ring at the heart of each injector had suffered very serious deterioration. Refer Diagrams 5 and 6 for typical condition of these O-rings. During operation, this had obviously allowed the pressurised diesel to leak within the injector body and escape into the oil return to sump, and so cause the sump oil level to rise.

Refer ring to Diagram 1, the most common O-ring failures appears to involve those at Locations A and B - fortunately these can be replaced fairly easily. Failure of the O-rings at Locations C and D are more serious because they require replacement of the injectors themselves, which is a costly business. Of these, the O-ring at Location C appears much more likely to fail due to it's hostile operating environment.

O-Ring Location

Each injector is fitted within a machined sleeve, which itself is fitted into the cylinder head. There are three distinct groups of O-rings of interest :

- one O-ring between injector body and sleeve - accessible by removing injector from sleeve.
- two O-rings between sleeve and cylinder head – accessible by removing sleeve from engine (injector must be removed first).
- two O-rings inside the injector assembly which are only accessible after dismantling the injector – more about this later.

O-Ring Failures

All the O-rings in this area are exposed to heat and pressure in varying degrees depending on their location and purpose. They all provide a seal between fluids of one type or another. Depending on location, the O-rings are exposed to the lubricating oil circuit, cooling water, diesel fuel and injector oil circuit. Generally, failure of an O-ring will permit fluid to pass from the high pressure side to the low pressure side.

<table>
<tr><th>O-Ring Location (See Diagrams)</th><th>Fluids Sealed</th><th>Symptoms</th><th>Note</th></tr>
<tr><td>Location A - between sleeve and cylinder head</td><td>- diesel fuel
- engine cooling water</td><td>- diesel leaks into coolant
- coolant overflows
- smell of diesel in coolant</td><td rowspan="2">Easiest O-rings to change.</td></tr>
<tr><td>Location B - between injector and sleeve</td><td>- diesel fuel
- engine lubricating oil (drains back to sump)</td><td>- diesel leaks into sump
- sump level rises
- oil may leak from shaft seal
- oil overflows into crankcase breather
- engine may run on own oil
- possible runaway engine</td></tr>
<tr><td>Location C - within injector body. Dynamic seal on piston.</td><td>- diesel fuel
- injector oil (drains back to sump</td><td rowspan="2">- diesel leaks into sump
- sump level rises
- oil may leak from shaft seal
- oil reaches crankcase breather pipe
- oil sucked into engine intake
- engine may run on own oil
- possible runaway engine</td><td rowspan="2">Not commercially viable to replace O-rings inside injectors. New injectors are very expensive.</td></tr>
<tr><td>Location D - within injector body</td><td>- diesel fuel
- engine lubricating oil (drains back to sump)</td></tr>
</table>

At the engine design stage, the precise rubber compounds for each O-ring would be selected by the designers according to the chemical nature of the fluids, operating pressure, temperature etc., to which they will be exposed during service.

All these O-rings, except for those fitted to the pistons inside the injectors (C above), form a static seal between stationary parts. In contrast, the failed O-rings (C above) are subject

to very rapid, reciprocating dynamic forces as the injector piston moves up and down as a normal part of engine operation.
Each operation of the injector involves this piston moving up and then down to deliver a carefully metered amount of diesel fuel into the cylinder at the precise moment in the engine cycle. As such, these must be the most critical O-rings in the entire engine, in terms of operating environment and correct engine operation.

At idle, the oil pressure being exerted on the low pressure side of the injector plungers is approx 5 Mpa (725 PSI). The plunger magnifies this by a factor of 7 x (ratio of piston face areas), so that the resulting pressure of the diesel being injected into the engine is over 35 Mpa (5000 PSI).

To get some idea of the work these particular O-rings do, consider an engine doing 2400 rpm, at approx 100 km/h for 100 000 kms. Each injector fires once per two engine revolutions. In this theoretical journey, each injector would fire :

100 000 / 100 = 1 000 (hours) x 60 (minutes) x 2400 / 2 = 72 million times.

In this journey, if the fuel consumption is 10 litres per 100 kms, and total fuel used = 10 000 litres. This is a four cylinder engine, therefore the fuel flow through each injector will be 2 500 litres. Therefore, the volume of fuel delivered per injector operation is : 2 500 000 (mls) / 72 000 000 (cycles) = 0.035 mls per cycle. The injector plunger piston is approx 5 mm diameter, therefore the stroke at this engine load is about 1.8 mm.

I realise this is a simplistic calculation, but gives some idea what the injector O-rings are subjected to during their normal course of operation. Of course, the engine and road speeds will vary, also different gears will be used, etc. etc.. The stroke will increase or decrease according to the engine load, etc.. under the dictates of the engine computer. Also, the injectors may only last 50 000 kms in which case it would have done ‘only’ about 36 million cycles – still a remarkable achievement.

Suggested Actions for Owners

- Ensure the correct type and grade of oil is being used in the engine. Correct operation of every part of the injector oil circuit is critical to the successful operation of this engine. The piston within the injector has to move exactly the correct distance to deliver the correct quantity of fuel, and operate at exactly the right moment in the engine cycle, for the engine to run correctly. Selection of a good quality oil, of suitable viscosity, clearly plays a vital part in this.

- Check sump oil level regularly (at least once per week), and be aware that a rising oil level could be the start of other problems.

- Keep a wary eye open for fluid loss or leaks such as oil leaks from engine seals, or the smell of diesel in the coolant.

- Holden Jackaroo owners - contact Holden and enquire whether the Campaign 03-H-03 has been done on your vehicle. Note this Campaign relates to the injector sleeve sealing O-rings, which according Holden : “can deteriorate and cause fuel to leak into the crankcase”. If not, book it in – Holden should do this free of charge.

- At each 80 k kms service interval, replace the O-rings between injectors and sleeves, and between sleeves and cyclinder head, as a precaution. This will add little to the

overall cost of the service, as the mechanic will already be working in this part of the engine, checking and adjusting the valve clearances.

- If the oil level in the sump rises to the point that it enters the crankcase breather pipe, the engine may start to run on it's own oil. In this situation, in Holdens words : " this may result in an unintentional increase in engine speed, and possibly vehicle speed". If this happened, it would cause most people to get very alarmed, especially if it happened in heavy traffic, driving at high speed, etc.. The engine will no longer respond to normal throttle operation, and will continue to run even with the ignition switched off.

- In extreme cases, engines have been known to red-line and self destruct. In the UK, there have been cases of engines being replaced free of charge by Isuzu.

- If a motorist is unfortunate enough to experience a run away engine, the best advice is to immediately steer in a safe direction, engage the highest possible gear and jump on the footbrake and hand brake together to stall the engine. Only depress the clutch or engage neutral as a last resort as this will allow the engine to spin freely out of control. This will be alien to most normal driving, and against normal instincts. Failure to stop the engine at this point may lead to a very expensive engine rebuild. Staying on a high traction surface eg bitumen would be better than driving onto loose sand – spinning wheels would have little braking effect on the engine. Do not turn off the ignition before the vehicle comes to rest, to avoid locking the steering wheel.

Recalls / Campaign Work

It seems the problems described in this article have long been recognised by the engine manufacturer Isuzu. They have instigated various Service Campaigns / Recalls and actually changed the sealing material within the injectors (from rubber O-ring to ceramic seal). However, the level of service provided to vehicle owners in different countries has been different.

Initially, there was great reluctance by Isuzu (UK) to accept responsibility. In the UK recently, there has been extensive activity by Isuzu to replace faulty O-rings, replace injectors and in some cases to replace complete engines which have run away and self destructed as a result of failed injector sealing. This must be very encouraging to UK vehicle owners.

The vehicles were sold in Australia by Holden (GM) as the Jackaroo. In Australia, these problems appear to be little understood by the general Holden dealer network. There has been a single campaign to replace injector sleeve sealing O-rings, but no indication of replacing the injectors themselves.

Early injectors (up to Serial No. 519266) used a rubber O-ring material (green colour probably Viton) but later ones were fitted with ceramic seals instead. Whenever owners are having injectors replaced, they should ensure only later model injectors (ie after 519266) are fitted, as these will have the most recent ceramic seals.

Based on extensive experience in the UK, my overseas contact advised that all injectors fitted to early vehicles up to about 2001 (ie those fitted with rubber O-rings prior to later ceramic seals) are likely to have a problem at some point, and would need to be replaced. From 2001 onwards, it seems if they are going to go, they fail early (say approx 30 k kms). Failure of the later model injectors (ceramic seals) appear to be very rare.

My own 1999 3.0 TD has now covered 139 k kms with none of these problems yet. I assume it is fitted with the early model injectors, so I now check the oil level etc. very regularly.

The relevant Campaign Notice is available at the Product Recalls Australia website : http://www.recalls.gov.au/view_recall_detail.php?Recall_ID_Auto=13023

Can These Injectors be Serviced ?

These injectors were designed by a joint Caterpillar / Isuzu collaboration. The injectors are classed as non-serviceable, and are intended to be replaced at the end of their service life rather than repaired. The injectors are precision assemblies of components machined to very close tolerances.

My overseas contact advised that changing any of the internal components in the injector could affect it's grading - without the specialised test device it is not possible to determine if the grading has changed from original manufacture. Therefore, commercial servicing of these injectors is unlikely to be viable.

However, in practice, it is technically possible to replace the O-rings and reassemble the injector providing great care is taken. If the injector is in otherwise satisfactory condition, and the internal O-rings are replaced with the correct size and equivalent or better material, I believe this will have very little effect on the injector grading. This may be an option for owners of higher mileage vehicles, faced with the alternative high cost of new injectors.

Whether an owner decides to try this route may depend on the age (and thus value) of the vehicle relative to the cost of set of new injectors. If the vehicle is a tired old workhorse nearing the end of it's life for several other reasons, replacing the O-rings inside the injectors might be acceptable as an economical fix. However, if the vehicle is in otherwise top condition, it would probably be more appropriate to replace the injectors with new ones, fitted with the improved ceramic seals.

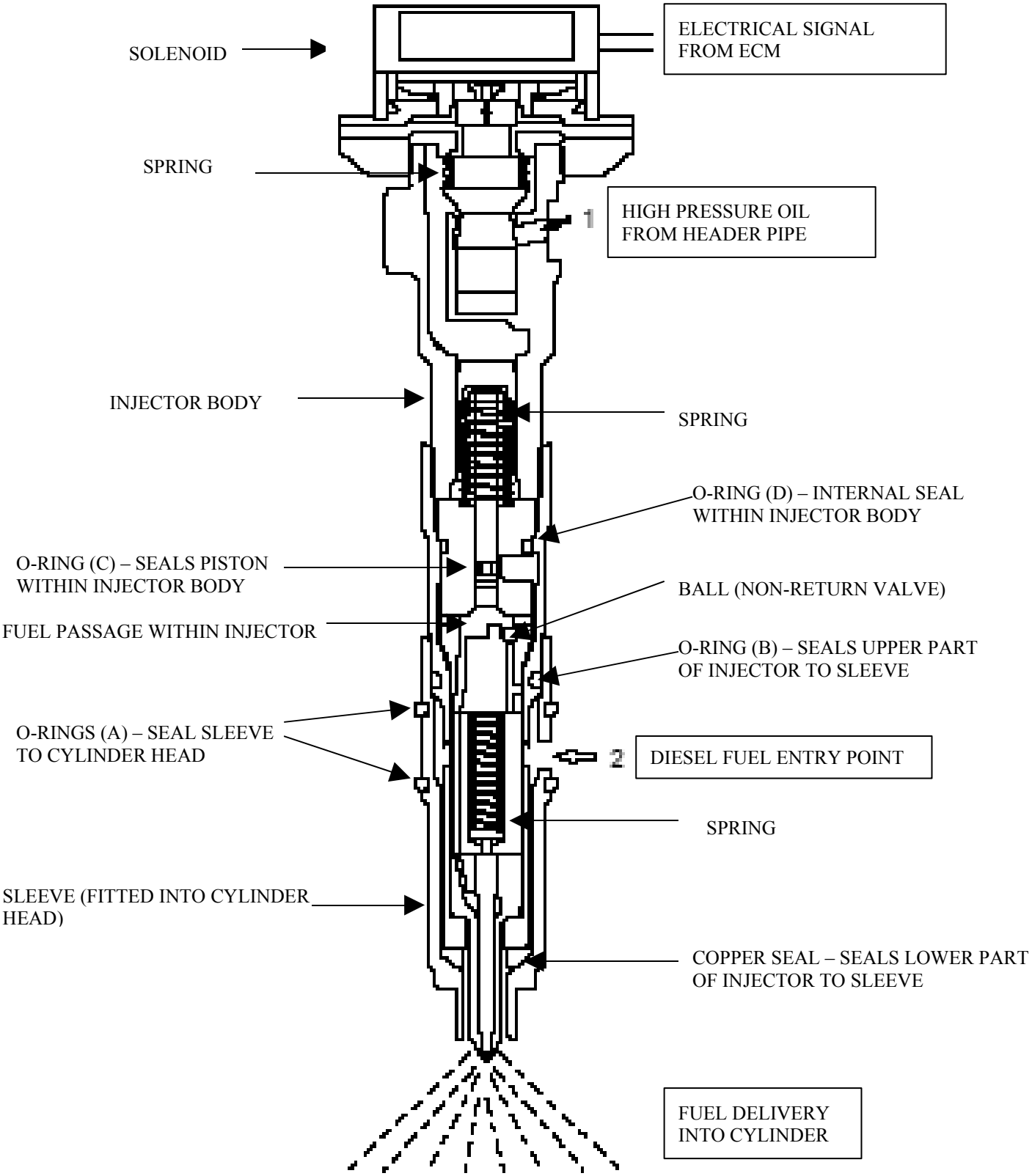

DIAGRAM 1 - CUT-AWAY SECTION OF INJECTOR SHOWING LOCATION OF O-RINGS

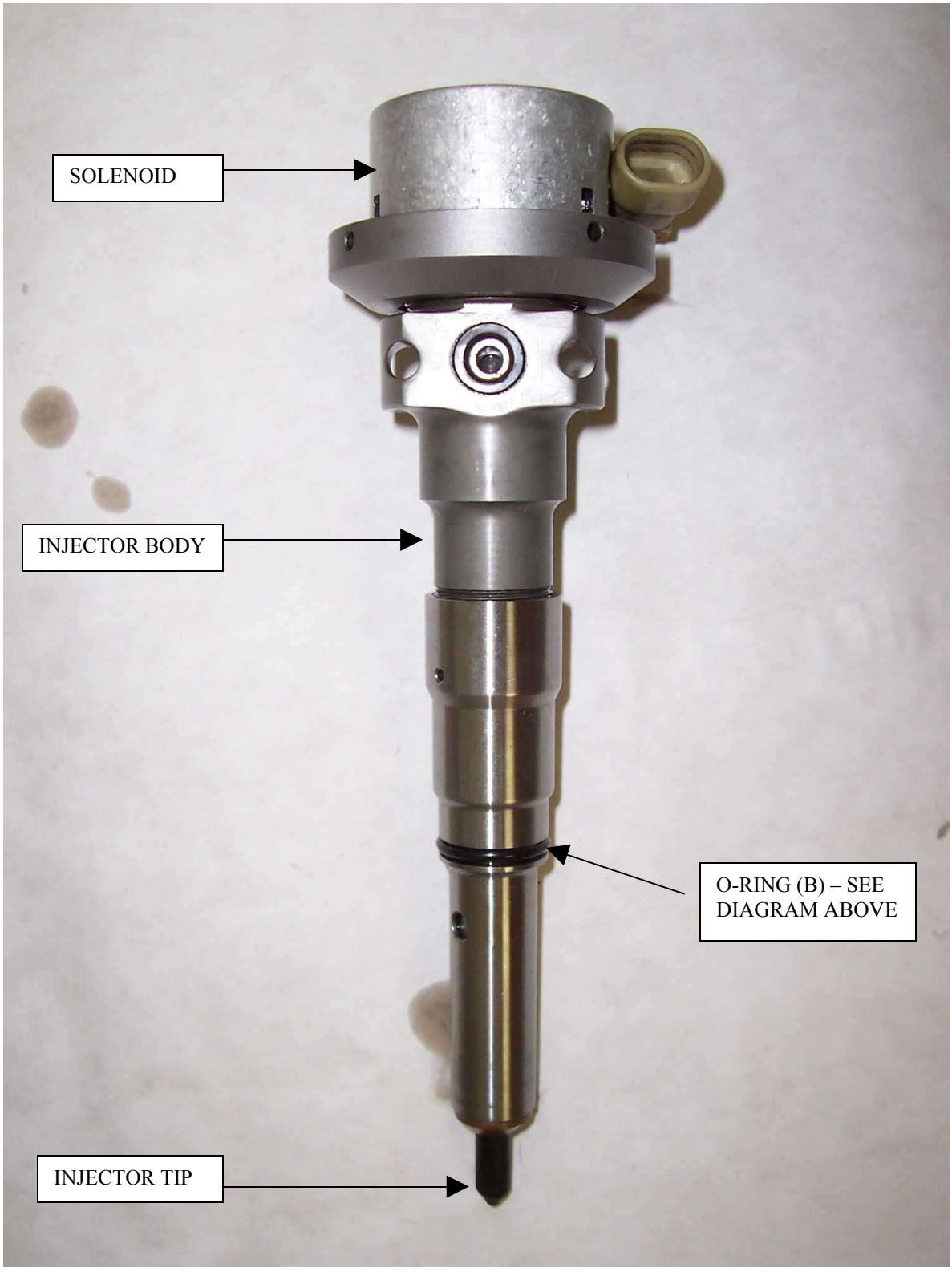

DIAGRAM 2 - INJECTOR AS REMOVED FROM ENGINE, PRIOR TO DISMANTLING

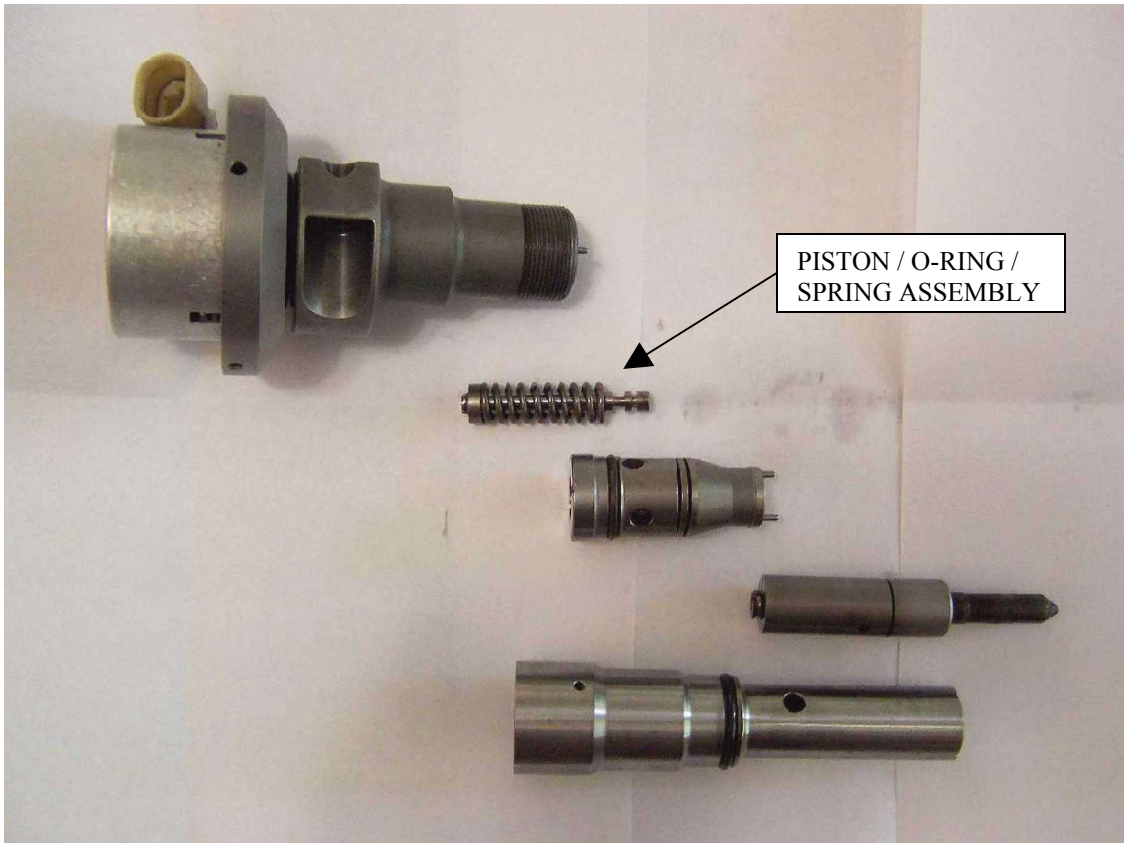

DIAGRAM 3 - INJECTOR DISMANTLED INTO COMPONENT PARTS

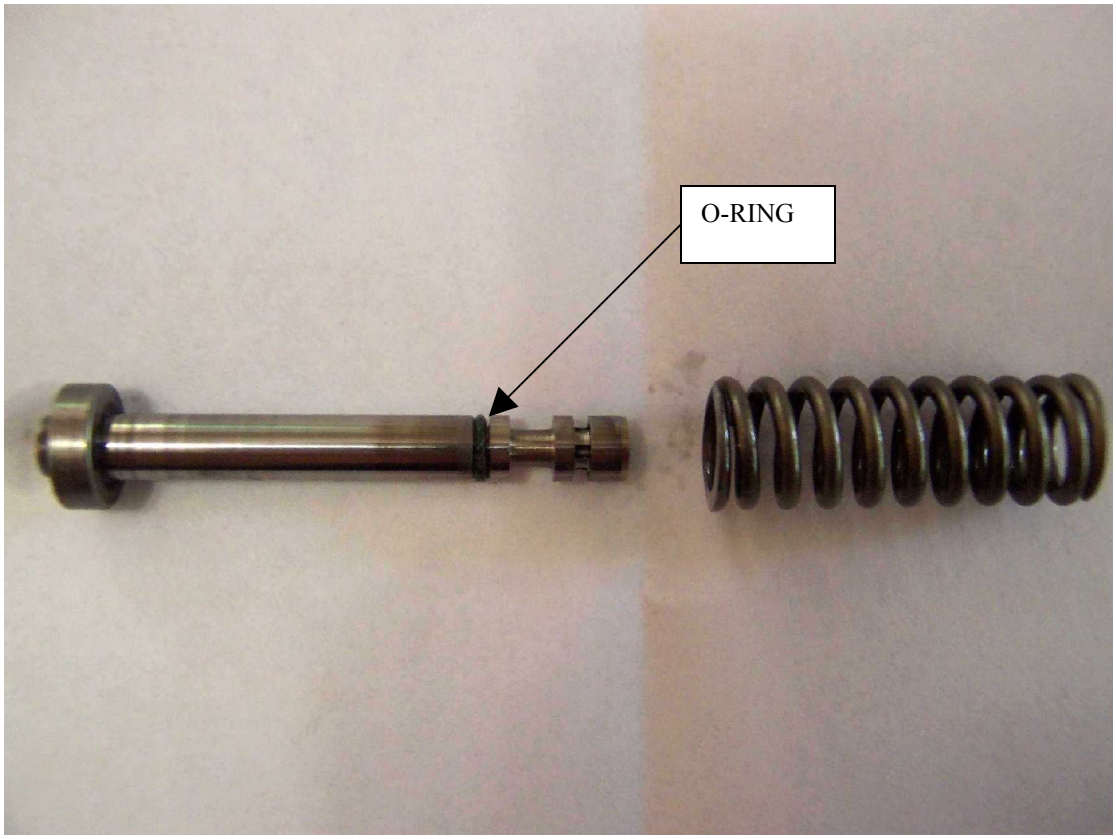

DIAGRAM 4 - PISTON / O-RING / SPRING (REMOVED FROM INJECTOR BODY)

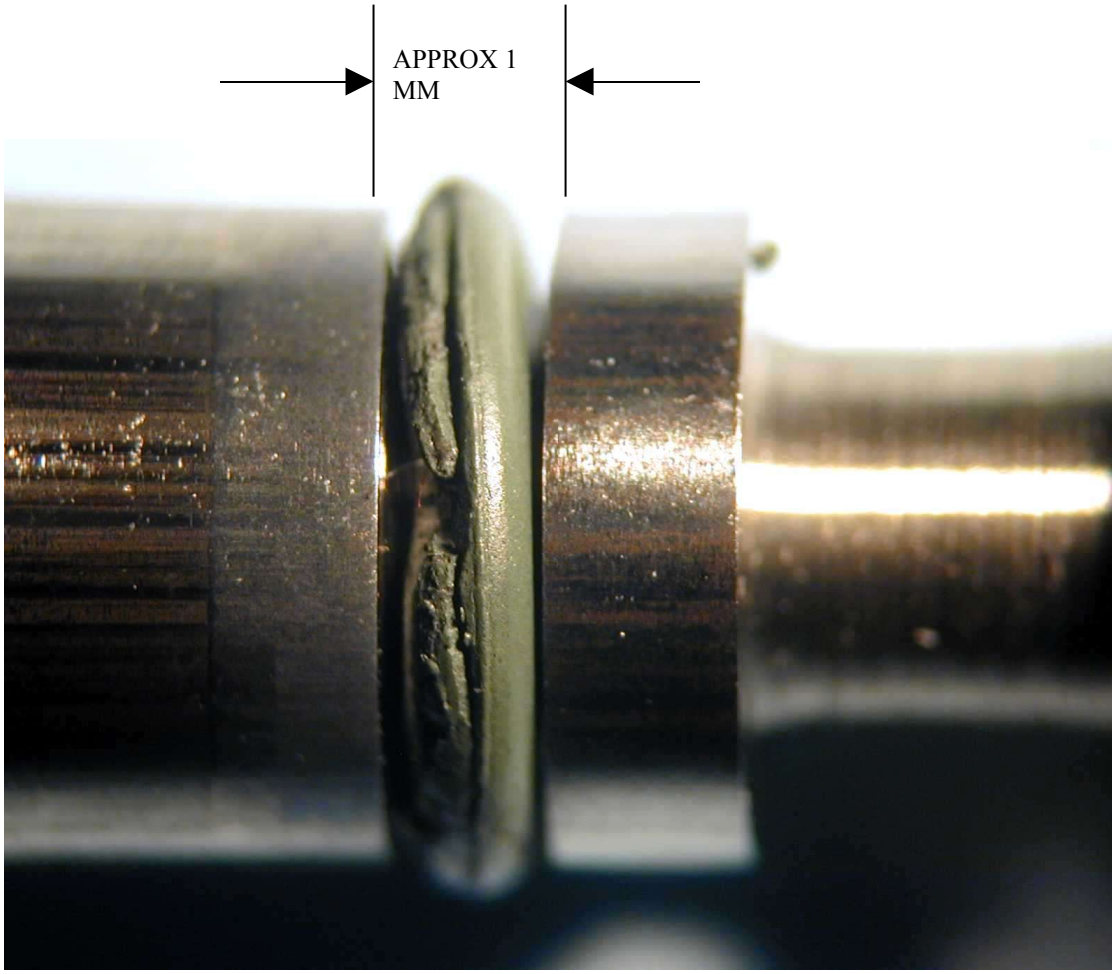

DIAGRAM 5 - HIGH MAGNIFICATION PHOTO SHOWING O-RING IN GROOVE ON PISTON

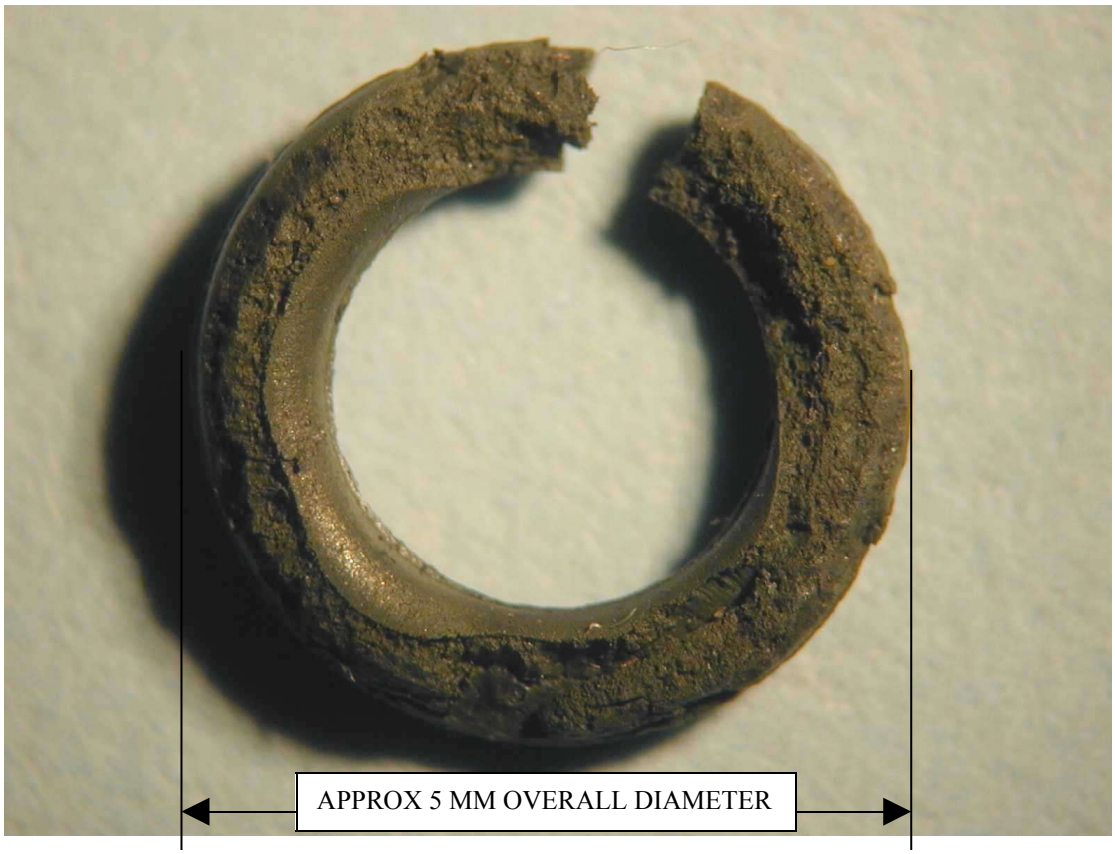

DIAGRAM 6 - HIGH MAGNIFICATON PHOTO SHOWING MASSIVE DETERIORATION OF O-RING