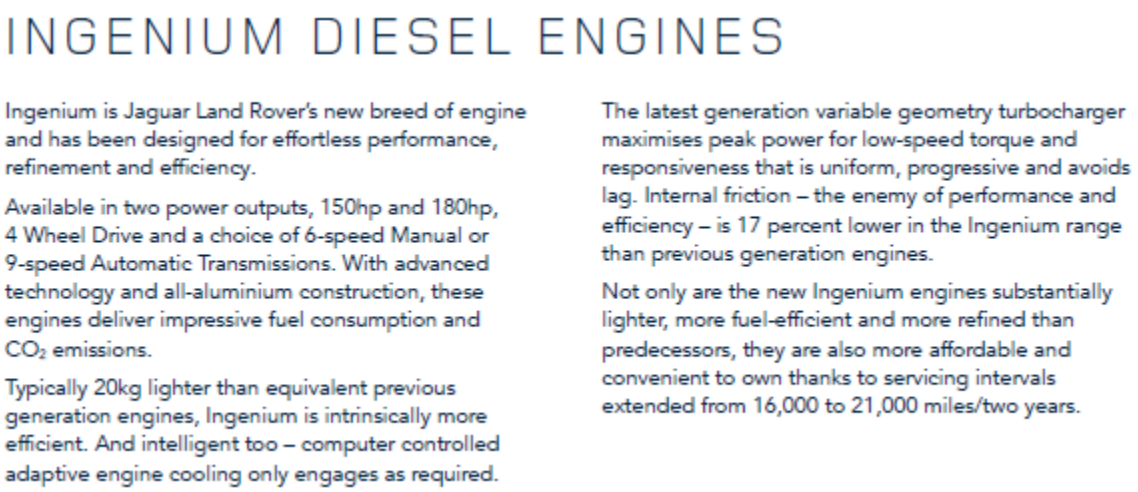
Oil Dilution on Jaguar Land Rover D8 diesel SUVs

In May 2017 an "Approved Used" Land Rover Discovery Sport SUV was purchased from a main JLR dealership. The vehicle had completed 3,200 miles from new and the electronic "Next Service – Oil Service" indication showed that the 21,000 mile "Oil Service" would be due at 14,000 miles. The owner noticed that the service mileage was reducing three times faster than the actual miles driven; he was alarmed because the financial benefits of extended service intervals had been a significant factor behind the decision to purchase that particular car. He retained a copy of the 2016-2017 Discover Sport Brochure which highlights costs of ownership prominently on page 46:



INGENIUM DIESEL ENGINES

Ingenium is Jaguar Land Rover's new breed of engine and has been designed for effortless performance, refinement and efficiency.

Available in two power outputs, 150hp and 180hp, 4 Wheel Drive and a choice of 6-speed Manual or 9-speed Automatic Transmissions. With advanced technology and all-aluminium construction, these engines deliver impressive fuel consumption and CO_2 emissions.

Typically 20kg lighter than equivalent previous generation engines, Ingenium is intrinsically more efficient. And intelligent too – computer controlled adaptive engine cooling only engages as required.

The latest generation variable geometry turbocharger maximises peak power for low-speed torque and responsiveness that is uniform, progressive and avoids lag. Internal friction – the enemy of performance and efficiency – is 17 percent lower in the Ingenium range than previous generation engines.

Not only are the new Ingenium engines substantially lighter, more fuel-efficient and more refined than predecessors, they are also more affordable and convenient to own thanks to servicing intervals extended from 16,000 to 21,000 miles/two years.

The car wasn't used exclusively for short journeys (e.g. the proverbial "school run") and the owner's driving mix included long distance commuting on dual carriageways and motorways. A search of the internet revealed that other owners were experiencing similar problems with their Discovery Sport and Evoque diesels. The matter was reported to Jaguar Land Rover's Customer Relationship Centre (CRC) and the owner joined a popular forum where he wrote about his experience.

On 28th June 2017 the car was taken to another main dealer for a free inspection under the vehicle's warranty. The service staff produced a diagnostic computer printout (from the JLR SDD system) showing that the oil dilution was 4.2%, despite the car having covered just 5,056 miles. The owner was told that his car was performing "normally" and that he should take it back for a standard oil service at 21,000 miles, on the 2 year anniversary of first registration, or whenever the "Service Required" message presented, if this happened earlier.

The garage also reset the oil dilution counter to zero restoring the service counter to 19,850 miles (this mileage always follows a reset). Not only had this action hidden a significant oil dilution problem, it also meant that this car no longer had a functioning service reminder and would exceed the safe diesel dilution level without the owner being alerted. The JLR dealership's actions were recorded on the owners' forum; there were many other similar reports going back almost a year.

One DS owner reported in July 2016 that his 8 month old DS required a service at 8,910 miles. On 29th July 2016, the Land Rover technicians expressed confusion about the service alert and nothing was done to fix the problem. An oil service that the car had requested at 8,910 miles was eventually performed at 11,900 miles on 2 February 2017 "*after over 6 months of trying*".

On 6th July 2016 one car issued a "Service Required" alert at 10,000 miles and its owner was told that the service interval setting had "*not been updated for the 2.0L [Ingenium] engine*" fitted from June 2015. On 24th August another owner complained that dealer staff "*cannot make their mind up*" whether his car should be serviced once a year or every two years, after it requested a service at 7,000 miles. In February 2017 another DS owner with the same problem was told that the service interval on some Ingenium engines was "*wrongly set to 1 year*". This pattern of confused responses to the service alert lasted for three years and the forum's "Service Interval" thread grew until there were 3,300 posts. Subsequent analysis of 100 reports from owners revealed that the average distance being driven before the first oil change became necessary was 8,306 against the figure of 21,000 miles contained in the brochure.

Despite the confusing dealer responses there is evidence that Jaguar Land Rover knew *in advance* of making the first sales that all 2.0L Ingenium diesel Discovery Sport and Evoque SUVs would suffer from systemic exhaust architecture faults causing high oil dilution and/or DPF clogging. In July 2017 JLR said that engine failure would occur if vehicles continued to be used with high oil dilution. Once the estimated dilution level reached 6% the engine oil required changing but for 16MY cars a faulty service indicator (Q627) prevented the service alert from displaying correctly on the information display. As shown by the reports on the owner forum in these cases JLR dealers casually dismissed the premature service requests as being due to a fault in the alerting system.

Owners who had been assigned a case manager sometimes received emails offering unlimited free oil changes:

Dear Mr

Discovery Sport

I am writing to you as per our conversation of Monday 10th July.

I would like to confirm that Jaguar Land Rover as a gesture of goodwill, will contribute 100% towards the oil change that will be carried out on your vehicle on 17th July 2017. This is due to the oil dilution in the vehicle and an early service warning indication.

Should the early service warning light notify you that a service is due but your vehicle is not due for its scheduled Service, Jaguar Land Rover will contribute subsequent oil changes in relation to this concern.

Please retain a copy of this letter and present it to the appropriate Retailer of your choice as confirmation of my goodwill proposal.

I would like to take the opportunity to apologise for the inconvenience caused to you as a customer and to thank you for your patience.

Should you need any further assistance please do not hesitate to contact me on the details below.

Your sincerely

Case Manager
UK Customer Relationship Centre

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E: lradvice@jaguarlandrover.co m

Jaguar Land Rover, Abbey Road, Whitley, CV3 4LF
landrover.co.uk | jaguar.co.uk

One car was collected for a free oil change in July 2017 and delivered back to the owner with a 9-page JLR service compliance notification (SCN), JLRP00100, lying on the passenger seat. This SCN states that "hardware and architecture" differences between model lines are responsible for "higher than expected" diesel dilution. The fault causes shortened service intervals on 16MY and 17MY Discovery Sport and Evoque 2.0L diesels (service notice N025). Earlier Discovery Sport and Evoque models (16MY) additionally suffered from a faulty service indicator message (SIM) which was the subject of separate campaigns (service notices N010 & N020). This fault had originally appeared as Q627 for the Discovery Sport and Evoque in December 2016.

The SIM was designed to alert drivers to the need for an oil service, preventing engine failure caused by excessive oil dilution. There's no evidence that JLR ever completed campaigns N010 and N020 and these were replaced by service action N118 on 16th Nov 2017 (updated by N118v3). N118 covered every 16MY and 17MY DS and Evoque with the Ingenium engine and stipulated that cars handed over from November 2017 must be fitted with a fully-functioning oil dilution warning. As this poster explained in February 2019, some cars will remain at risk of engine failure until N118 expires in November 2019. The failure to address the faulty SIM exposed diesel vehicles to very high oil dilution and the risk of engine failure for a total of four years between September 2015 and 30th November 2019. Engines sometimes failed in spectacular fashion due to high oil dilution, for example the subject of this report from January 2019, a 9,000 mile 16MY Discovery Sport.

On 8th August 2017 an open letter was written to Jaguar Land Rover appealing for more information about this problem based on the information contained in JLRP00100. More than two years later, the questions raised have not been answered and customers look to other owners for assistance after being told by their dealer that their "driving style" is responsible for oil dilution and DPF problems. Thousands of people have no way of knowing that they are being misled.

JLR dealers have carried out a deliberate and at times aggressive campaign of denial that serves to conceal what really happened during the development of the D8 EU6 Ingenium diesels. As a result owners are still being blamed for causing oil dilution and DPF problems by their "driving style". The dealers' apparently orchestrated behaviour transcends poor customer service and sharp business practice and continues to cause financial hardship and mental anxiety to many Evoque and Discovery owners, as illustrated by the large number of reports made to The Car Expert. Rather than being redesigned to eliminate inherent faults, the architecture looks to have been carried forward to the 2020 L551 Evoque and "face-lifted" L550 Discovery Sport mild hybrid diesels.

JLR has abandoned the 6% diesel dilution limit that in July 2017 it said would cause engine failure: the diesel dilution level triggering the SIM was changed to 10% by a software modification effected by notice N289, replacing the still-incomplete notice N025 on 13th February 2019. On 12th March 2019 Jaguar Land Rover CRC posted on the Discovery Sport owner's forum: "*After speaking with our technical and engineering team, I can confirm that N289 is a software update for early service. Its primary function is to increase the oil dilution range from 6% to 10%.*"

The meaning of "Hardware and Architecture"

In the service compliance notification, JLRP00100, JLR blamed the exhaust faults on "*hardware and architecture differences between model lines*". Despite the absence of technical details to explain these "differences", it didn't take long to work out what the underlying issues were.

Two powertrain engineers were dispatched from Jaguar Land Rover, Gaydon, to investigate multiple EGR and oil dilution problems on a faulty Discovery Sport grounded at a JLR dealership in October 2017. They expressed exasperation at being sent all over the country to repair hundreds of cars with identical exhaust faults. They told the local service staff that these problems could have been eliminated before production began if the company had heeded the advice of its engineers. Instead, JLR management pushed vehicles through its dealerships knowing that they would suffer from excessive oil dilution, shortened service intervals and, in the case of vehicles used exclusively in rural and urban environments, DPF clogging and failure of DPFs and other components.

The information provided by JLR's powertrain engineers was relayed to the customer who then shared it with other technically-minded owners via social media. When combined with the contents of JLRP00100 a picture began to emerge which could explain why excessive diesel dilution, DPF

clogging and other exhaust-related faults which affect the Range Rover Evoque (L538), Discovery Sport (L550) and Jaguar E-Pace (X540) 2.0L diesels aren't seen on Jaguar XE (X760) and F-Pace (X761) vehicles using the same engine. Additional information came from technical papers written by the catalyst manufacturer, Johnson Matthey, JLR dealership service agents, JLR Customer Relationship Centre (CRC) and JLR Executive Office.

The theory was confirmed by independent engineers and motoring correspondent Honest John who consulted Jaguar Land Rover before writing about it on 4th May 2018 in his weekly Agony Column. The accuracy of the explanation was placed beyond doubt in July 2019 with the leaked publication of another JLR document "JLR Architecture - Oil Dilution DPF Blockage Explained".

The benchmark vehicle used for comparison with the faulty exhaust systems in JLRP00100 is the Jaguar XE X760 2.0L 163HP diesel. This car uses a close-coupled oxidation catalyst/catalysed soot filter (DOC-DPF) with downstream diesel exhaust fluid (DEF) injection and selective catalytic reduction (SCR) located underneath the car. It's a typical EU6-compliant after-treatment architecture which reliably achieves 21,000 miles between services with no reports of premature oil dilution or DPF clogging. The Jaguar XE 2.0L Ingenium diesel engine is identical to the one that powers the faulty D8 vehicles.

In the Jaguar XE parts schematic below the combined DOC-DPF is the vertical canister (1) which attaches to the Ingenium turbo outlet by clamp (14) and seal (15). DEF injection is made at bottom left under clamp (18) and the SCR consists of the horizontal pipe and canister (2).

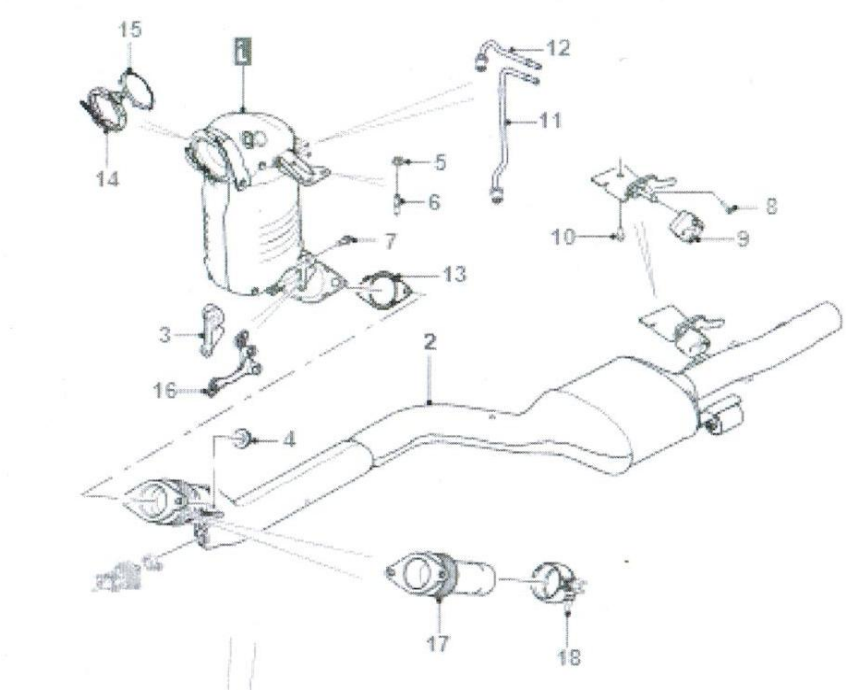

Fig 1 – Jaguar XE Exhaust

The Jaguar XE X760 went on sale with this exhaust hardware and architecture in early 2015: the first sales recorded for the Jaguar XE were March 2015 (2), April 2015 (20) and May 2015 (624). The next vehicles scheduled to receive the Ingenium engine with EU6-compliant exhaust emissions after-treatment (mandatory for all new vehicles sold from 1st September 2015) would be the Discovery Sport L550 and Range Rover Evoque L538. Until August 2015 these cars were still being sold with a transversely-mounted EU5-compliant PSA/Ford Duratorq 2.2L diesel engine.

According to the JLR engineers, it had always been assumed that the Ingenium 2.0L diesel would slot smoothly into the D8 chassis of the L538 Evoque when the time came to replace the EU5 2.2L diesel. However, at some point during the L550 engine migration program, the powertrain engineers discovered that the engine wouldn't fit into the available space.

When the Ingenium engine was initially mated to the D8 floor-pan it was found that there was insufficient space for a close-coupled DPF to be installed between the engine and the forward bulkhead. Engineering asked Design for more space but requests to change the chassis, even by a small amount, were turned down. Without additional space it was impossible to fit the Jaguar XE-style DPF system to the D8 vehicles, so a different exhaust architecture needed to be designed, tested and put into production by 1st September 2015 when EU6 compliance became mandatory. According to Honest John this was the reason that the Discovery Sport was initially released with the EU5 2.2 L diesel rather than the Ingenium engine when sales began towards the end of 2014.

At some point development began on the alternative exhaust architecture for the L550 using innovative SCR-On-Filter (SCRF®) catalytic coatings from Johnson Matthey. This alternative DPF system is not close-coupled to the Ingenium engine which prevents it from performing passive regeneration. Crucially, the new DPF would have to be positioned *behind* the Diesel Exhaust Fluid injector (unlike JLR's other EU6 diesels and the system original envisaged for the L538 and L550). In the document leaked in July 2019 Jaguar Land Rover referred to these limitations as "engineering challenges": on the D8 diesels these challenges proved to be insurmountable.

The DPF on the revised exhaust architecture couldn't passively regenerate and so required more frequent and longer-duration active regenerations. This required more post-injection of diesel leading in turn to a faster build up of fuel-in-oil dilution. Engineering knew that this would dramatically shorten the service intervals. The JLR powertrain engineers said that this was all communicated to executive management with a recommendation to change the advertised service intervals. These requests were ignored and in September 2015 JLR brought the 16MY Discovery Sport to market with 21,000 mile service intervals that its engineers knew were unachievable.

Honest John's 4th May 2018 Agony Column contained letters on the subject of oil dilution and service intervals on the Discovery Sport and this is a summary of the points made in two replies:

> The launch of the Ingenium diesel was delayed because of this (the Disco Sport started out with a Ford 2.2 litre diesel engine). But it can't be fixed in the Evoque or the Disco Sport or the E-Pace because the Freelander 2 floor-pan they are all on does not allow for a close coupled DPF. This is not a problem for high mileage drivers. But it is for low mileage drivers who use their cars for short runs in which the DPF does not get hot enough to passively regenerate. It then has to actively regenerate using post-injected diesel and if the engine is switched off mid active regen, that's when the real problems start. The engine is designed to have a close-coupled diesel particulate filter, which it does in longitudinal installations such as the Jaguar XE, XF and F-Pace. But the Disco Sport, Evoque and forthcoming E-Pace are all based on the old Land Rover Freelander platform, which is for a transverse engine and fitting the Ingenium diesel transversely in these cars does not allow enough space between the engine and the bulkhead for a close coupled DPF to be fitted. JLR's engineering solution has been for the engine to actively regenerate more frequently.

Jaguar Land Rover has not responded to these allegations, nor has it demanded a retraction. In September 2019 a private message was sent to one owner from someone claiming to work at Jaguar Land Rover. The points made echo the comments made by the other engineers and Honest John:

> I am only too well aware of the issue from an engineering perspective, and as a Contractor working within JLR for the past 7 years, you will equally understand my reluctance to reveal too much, as Business Protection habitually monitor all JLR-related forums for Staff and Contractors alike posting contentious viewpoints. All I will say is that we are all aware of the issue, all dealers and their Service personnel know the problem exists, which arose from a combination of launching the vehicle with the old PSA power-plant (which worked perfectly), without realising the penalties for having a non-EU6 power-plant by Sept 2015, and using a shared platform with L538 designed for the aforementioned engine using simple, proven DPF Euro 5 technology.
> This oversight, despite Engineering advising Design of the ramifications of shoe-horning the D180 into the architectural structure and floor-pan, was not listened to by the Design team, as unfortunately ego's are rife over there. The net result is that the 15-19MY D180 cannot ever reach its required servicing parameters. It's an engineering impossibility and anyone who says differently deep down knows this to be the case.

Selective Catalytic Reduction Filter (SCRF®)

The exhaust after-treatment hardware fitted to 16MY and later Discovery Sport and Range Rover Evoque consists of a diesel oxidation catalyst (DOC), diesel exhaust fluid injection (DEF), selective catalytic reduction filter (SCRF, including the DPF) and exhaust gas recirculation (EGR). Two videos, SCR and EGR provide a comprehensive visual overview of the complete system in operation.

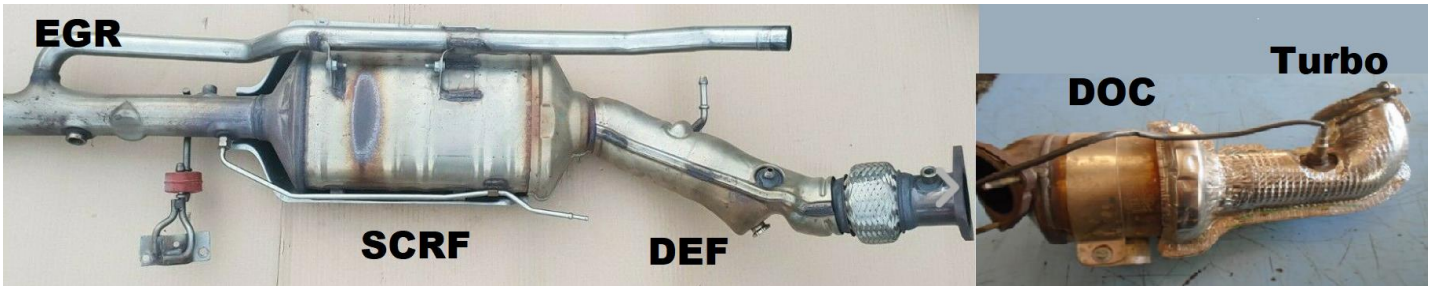

Fig 2 Discovery Sport / Range Rover Evoque Exhaust

The D8 chassis forward bulkhead prevented JLR from fitting a "close-coupled" exhaust like the schematic shown above in **Fig 1** for the Jaguar XE X760. In the letter to sales staff JLR admitted that there were "*some engineering challenges with the current layout of the architecture, affecting the proximity of the heat source (engine) to the filter and so its ability to complete the burn off of the soot in the particulate filter*". This refers to cooling effects caused by the additional pipework between the turbo outlet, DOC and SCRF.

On the Discovery Sport L550 and Range Rover Evoque L538 the SCRF is too far back from the engine for passive regeneration to occur during normal driving. According to Johnson Matthey an SCRF®-based filter performs less passive regeneration than a catalyzed soot filter (CSF) at a given temperature while an active regeneration of SCRF takes 50% longer to complete (Scientific paper 2016 / Presentation). The performance of this after-treatment system is impaired by a number of operational constraints and consequences which can be summarised as follows:

1) There is no passive regeneration during normal driving.
2) Active regenerations are required more frequently.
3) An active regeneration takes longer to complete.
4) Diesel dilution rises faster, in step with post-injection due to 2) and 3).
5) Interruption of an active regeneration is more likely due to 2) and 3).
6) There is more likelihood of a clogged DPF due to 5)

In June 2017 JLR changed its marketing materials, acknowledging that "*early service requirements may lead to customer dissatisfaction*" (JLRP00100). But why hadn't this been done when JLR first knew that there was a systemic problem with the D8 exhaust system?

1) <u>There is no passive regeneration during normal driving.</u>

Passive regeneration normally occurs under two sets of conditions: firstly, at temperatures above 250°C, by using nitrogen dioxide produced in the upstream catalyst; secondly, at high power outputs when the DPF temperature is maintained above 580°C, using oxygen from the lean air mixture. For different reasons both types of passive regeneration are ineffective on the D8 vehicles.

As shown above (**Fig 2**) on the Discovery Sport L550 the DPF is separated from the turbo outlet by two lengths of pipework (total distance 70 cm), creating an effective heat sink. The SCRF operates at much cooler temperatures than a close-coupled CSF-type DPF attached to the turbo outlet, e.g. the one fitted to the Jaguar XE. This effectively disables passive regeneration using oxygen unless the engine can be made to work extremely hard (for long periods) to overcome the heat losses.

Further problems arise due to the complex chemistry of the selective catalytic reduction process. Johnson Matthey said that an SCRF catalyst performs less passive soot oxidation compared to a CSF catalyst at any given temperature. According to JM passive regeneration occurs above 270°C ($2NO_2 + C \rightarrow 2NO + CO_2$) provided that nitrogen dioxide is abundant. But, at any temperature above 200°C in a SCRF catalyst, there is strong competition for the available nitrogen dioxide due to the simultaneous SCR reaction ($2NH_3 + NO + NO_2 \rightarrow 2N_2 + 3H_2O$) (Johnson Matthey 2016).

To comply with EU6 NOx limits, EGR and SCR have to operate permanently during normal driving, which eliminates passive regeneration by NO_2, simultaneously increasing DEF consumption, as reported by Discovery Sport owners (500+ posts). "*SCR activity is predicted to significantly retard the rate of soot removal at lower temperatures (200ºC–400ºC), where soot oxidation is predominantly by reaction with* NO_2" (Johnson Matthey 2015).

In the letter sent to sales offices, JLR made no references to passive regeneration with this system, only active regeneration: "*The soot is burnt off by effectively supplying extra fuel to the filter and then igniting it to burn off the soot*." Regarding the proximity of the SCRF to the heat source (engine) JLR confirmed that they are too far apart: "*… 70 cm apart, partially masked by a bullhead* [sic]. *This will be heavily affected by oil dilution and DPF blockage and is likely to be more common for low speed, short-duration drive cycles*."

In a letter written to one owner in October 2017 JLR confirmed that the L550 Ingenium diesel DPF temperature remains too low during normal driving for passive regeneration to occur.

- 'Typical' driving style as an average across customers is journeys of 15-30 minutes with a speed between 50 kmph and 100 kmph, which includes some drives of over an hour.
- The exhaust temperature achieved in normal driving is low and as such there is no passive regeneration and soot must be cleared through active regeneration.

2) Active regenerations are required more frequently

The D8 exhaust emissions system was originally designed to operate with both passive and active DPF regeneration (see below). However, with no significant contribution available from passive regeneration for the reasons described above, the D8 exhaust after-treatment system relies exclusively on active regeneration for removing soot and unburned hydrocarbons from the filter substrate. Active regenerations therefore occur more frequently on the affected cars compared to vehicles with a close-coupled DPF where both varieties of passive regeneration are available.

Working a diesel engine harder raises combustion temperatures, both increasing the performance of the diesel oxidation catalyst and retarding the rate of soot accumulation on the filter due to passive regeneration by oxygen. But on the D8 vehicles the maximum distance between active regenerations is still only 250 miles according to DPF System Operation & Component Description Manual dated 15th May 2015:

Active regeneration generally occurs every 250 miles (400 km) although this is dependent on how the vehicle is driven. For example, if the vehicle is driven at low loads in urban traffic regularly, active regeneration will occur more often. This is due to the rapid build-up of particulates in the DPF than if the vehicle is driven at high speeds when passive regeneration will have occurred.

The DPF software incorporates a mileage trigger which is used as back-up for active regeneration. If active regeneration has not been initiated by a back pressure signal from the differential pressure sensor, regeneration is requested based on distance travelled".

The DPF guide implies that high-speed driving, or otherwise increasing the engine power output (e.g. towing heavy loads), might create the temperatures (>580°C) required for *some* passive regeneration (by oxygen) to occur, but this will only help to achieve the maximum distance between active regenerations of 250 miles. The document implies that a mileage-based active regeneration will be triggered at this distance regardless of the type of driving or the actual soot loading on the filter.

According to Jaguar Land Rover, "typical" or "normal" driving styles (such as driving regularly at "*low loads in urban traffic")* keeps temperatures too low for passive regeneration by oxygen to occur. But the low engine temperatures associated with normal driving still result in large amounts of soot being produced which, due to the absence of any form of control by passive regeneration, then accumulates at a faster rate on the DPF screen than the system design anticipated. As confirmed by JLR, the result is that active regenerations will be required more frequently.

3) An active regeneration takes longer to complete.

A JLR video released in April 2016 said that DPF regeneration takes from 10 to 20 minutes to complete but this has been revised, removing references to 10 minutes. JLR's current video states that DPF regeneration takes 20 minutes, driving at speeds between 37 mph and 70 mph. The recently-leaked letter to dealers states that DPF regeneration "takes *about 20 minutes*". On JLR's DPF web-page it says that 20 minutes driving at up to 70 mph *should* clean the filter.

AMBER

An amber warning light indicates regeneration is required. Drive between 60km/h (37mph) and 112km/h (70mph) for 20 minutes and this should clean the filter. Failure to enable self-cleaning following a warning may result in reduced vehicle performance.

RED

A red warning light indicates that the filter is full. In this instance, please contact your local Jaguar Retailer as soon as possible.

The L550 Discovery Sport DPF Manual states that active regeneration can be achieved by driving for 20 minutes at speeds between 40 mph and 70 mph, but "*may take longer"* at slower speeds.

Active regeneration is achieved by supplying a cloud of atomised diesel to the catalyst (DOC) where heat is produced by an exothermic reaction (i.e. the diesel burns). The heat is convected to the DPF by the exhaust gas and conducted via the metallic canisters and pipework. Above 580°C the soot and hydrocarbon molecules stored on the filter are oxidised into carbon dioxide and water; the hotter the DPF temperature becomes, the faster will be the rate of regeneration. JLRP00100 states that the active regeneration times on D8 diesels are longer due to "*hardware and architecture differences between model lines*": on the D8 this just means longer pipework, as shown below.

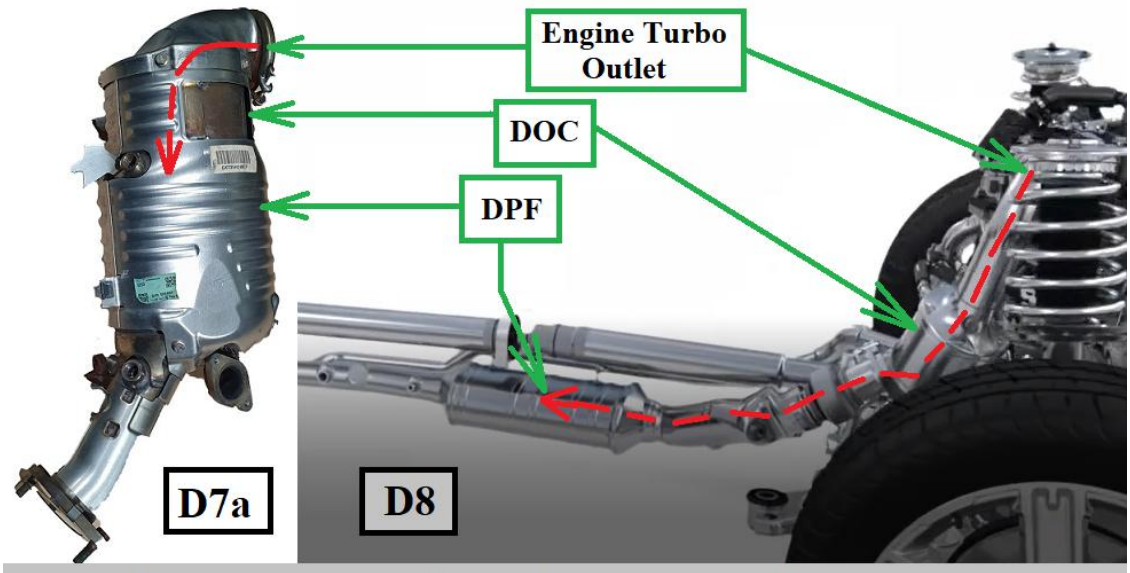

Fig 3. **Jaguar Land Rover exhaust after-treatment architectures**

The Jaguar XE oxidation catalyst and DPF are physically contained within a single canister so that virtually no heat loss occurs between the engine and the DPF. The DPF temperature remains high at all times and it requires very little additional heat to reach the temperature required for active regeneration to begin. On the D8 architecture there are two lengths of pipework separating the turbo outlet from the DOC and the DPF so heat losses are significant. The D8 vehicles require longer periods of active regeneration to heat up the DPF and maintain the temperatures required for active regeneration to continue. This is what is meant in JLRP00100 where is says that "*the duration / distance to complete a full regeneration on 2.0L diesel Evoque / Discovery Sport is longer than on 2.0L diesel Jaguar XE*".

The second major difference between the D8 vehicles and JLR's other EU6 diesels is that they utilise different catalytic coatings on the DPF monolith. On the Discovery Sport, Evoque and Jaguar E-Pace the DPF is contained within the SCRF where the complex selective catalytic reduction (SCR) reactions take place. According to Johnson Matthey, active regeneration of the SCRF coating is inferior to a standard CSF coating, even though it actually benefits by a small amount when the SCR chemical process is active. ("*A study of the soot burning efficiency of an SCRF® catalyst vs a CSF during active regeneration events*", Johnson Matthey 2016*).*

Active regeneration of a CSF (4g/L load) can complete within 20 minutes (as per JLR's current video), but a similarly-loaded SCRF regenerates only 75% in this time, *even with SCR operational*.

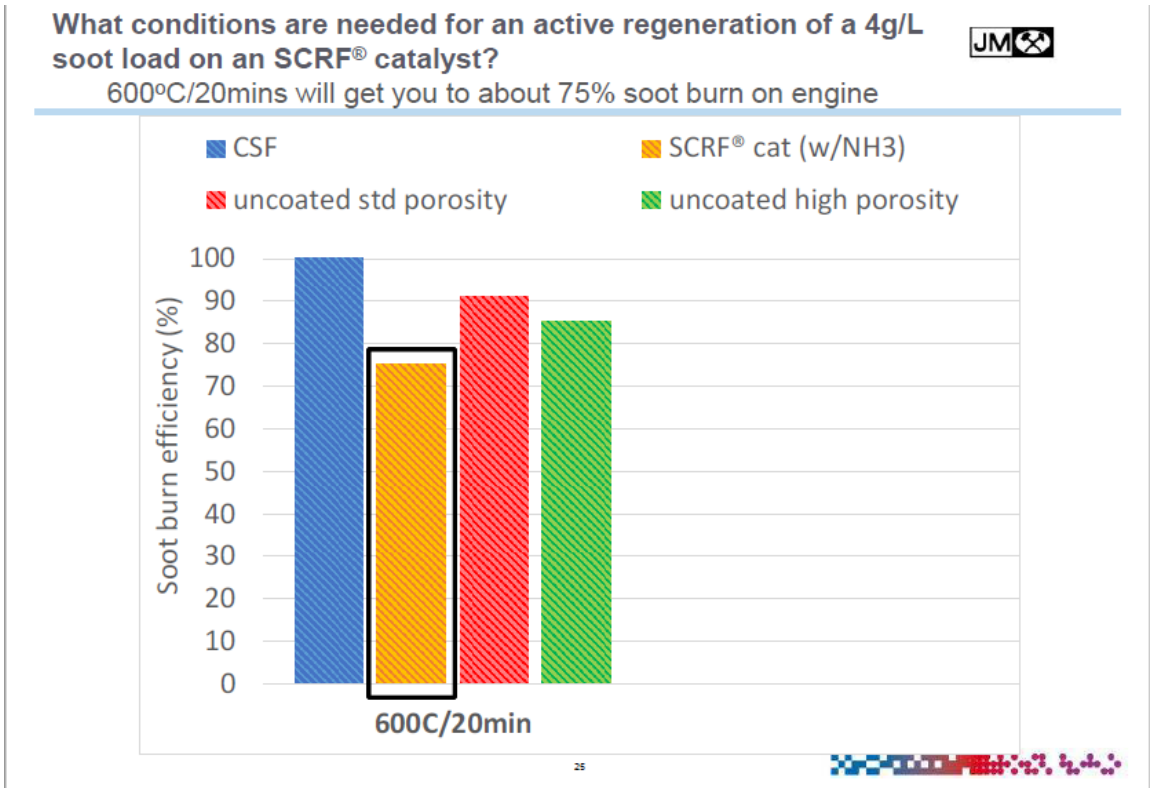

Fig 4. Comparison of active regeneration performance of SCRF® vs CSF.

The 16MY Land Rover Discovery Sport 2.0L Ingenium diesel went on sale in 2015 with claims of 21,000 mile or 2 yearly service intervals. A year later the SCRF coatings manufacturer delivered a scientific paper which implied that DPF technology such as that fitted to the Land Rover L550 DS was still under development. Conclusions drawn by Johnson Matthey in August 2016 were:

- Active regeneration efficiency of CSF is significantly higher than SCRF® at 550°C to 600°C.
- Active regeneration at 600°C for 20 minute achieves 100% for CSF.
- Active regeneration at 600°C for 20 minute achieves only 75% for SCRF®.
- A SCRF® catalyst can be "fully" regenerated (>95%) in 30 minutes at 600°C.

Johnson Matthey said that it needed to adapt a "*suitable active regeneration strategy*" as it sought ways to "*overcome the thermodynamic equilibrium limitation of producing sufficient NO_2 under active regeneration conditions for reaction with soot*". It speculated that increasing filter inlet temperatures to more than 600°C might reduce the length of regeneration events. It's not known how far JM managed to get with attempts to improve the performance of SCRF filter coatings. In the end it didn't matter because JLR found another way to increase the interval between oil changes – it simply increased the amount of oil dilution to delay the appearance of the service message.

Service action N289 (supposedly part of JLR's "*continuous improvement engineering activities*") claimed that "*additional engineering work has been completed to enable increased distances between services*". However, what the document failed to mention was that the "*engineering activities*" merely raised diesel dilution levels by 67% to dampen down customer concerns about the *"earlier than expected"* service messages.

> *"After speaking with our technical and engineering team, I can confirm that N289 is a software update for early service. Its primary function is to increase the oil dilution range from 6% to 10%."* (JLR Customer Relationship Centre 12 March 2019).

Concealing "higher than expected" oil dilution by raising the Service Message trigger in February 2019 invites the inference that JLR failed to resolve any of the "hardware and architecture" issues affecting SCRF regeneration. It is noted that SCRF does not figure in the after-treatment systems fitted to the new LR Defender which has gone back to a close-coupled DPF, according to JLR's technical and sales data.

4) Diesel dilution rises faster, in step with post-injection.

Engine oil dilution occurs due to small amounts of fuel entering the engine crankcase "*during* the post-injection phases" (JLR 2015) while the oxidation catalyst is being supplied with diesel via the engine's diesel injectors. When an active regeneration completes, or the car engine is switched off before it has completed, post-injection and diesel dilution both stop. The mechanism by which post-injection causes diesel dilution has been described scientifically on several occasions, for example Song and Choi (2008), reproduced by the Journal of Mechanical Science and Technology.

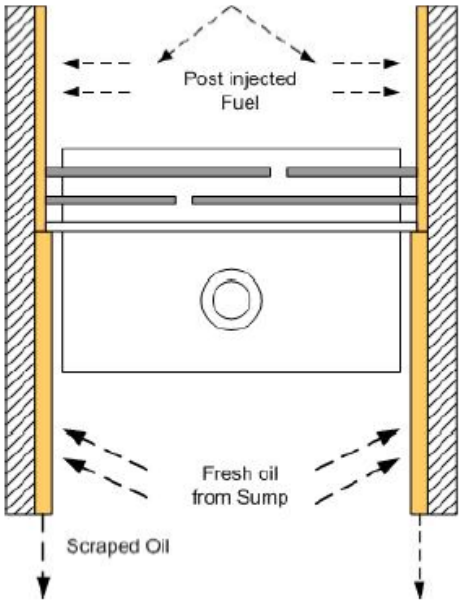

Fig 5. Diesel dilution occurs continuously during post-injection (active regeneration).

Active regenerations have to occur more frequently on the three D8 diesels because during normal driving passive regeneration fails to retard HC/PM production. Active regenerations take longer to complete due to the "hardware and architecture" effects discussed above. JLRP00100 states that diesel dilution rises faster on the L538/L550 cars because duration and/or distance to complete a full regeneration is longer, which in turn increases the likelihood of an interrupted regeneration.

An interrupted regeneration does not of itself cause diesel dilution – but it does result in more diesel dilution overall because the next active regeneration has to occur sooner. If there is an unbroken sequence of incomplete regenerations eventually the DPF will clog leading to the amber and red warning lights being displayed as described in the DPF videos.

Details of almost 100 early oil changes reported on the DS forum between July 2016 and January 2019 were collated and the data published on 12th March 2019. The average mileage before an oil change was required was 8,306, or 39.4% of the nominal service interval.

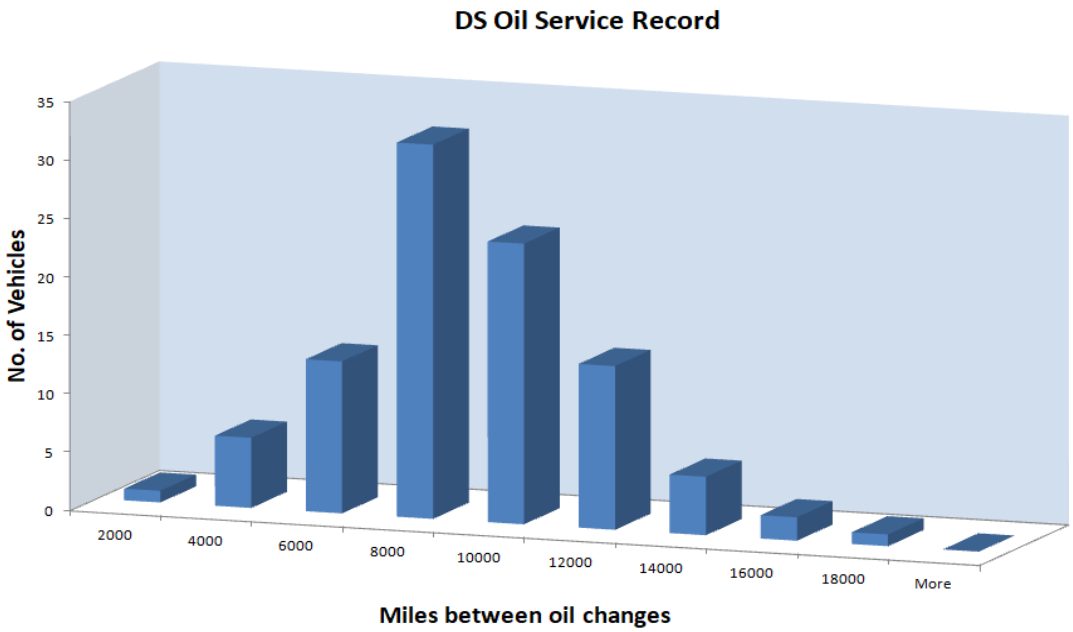

Fig 6. Engine oil change interval due to dilution – Discovery Sport L550.

A poll of 200 owners produced strikingly similar results: 45% said that their car needed an oil change due to excessive dilution before 8,400 miles, 62% before 10,500 miles (half the nominal mileage) and 72% before 12,600 miles. This poll included some 16MY vehicles suspected of having the faulty SIM: this may account for the improbable "hockey stick" effect above 18,900 miles. It is noted that this effect is not present in data obtained from the analysis of owner reports.

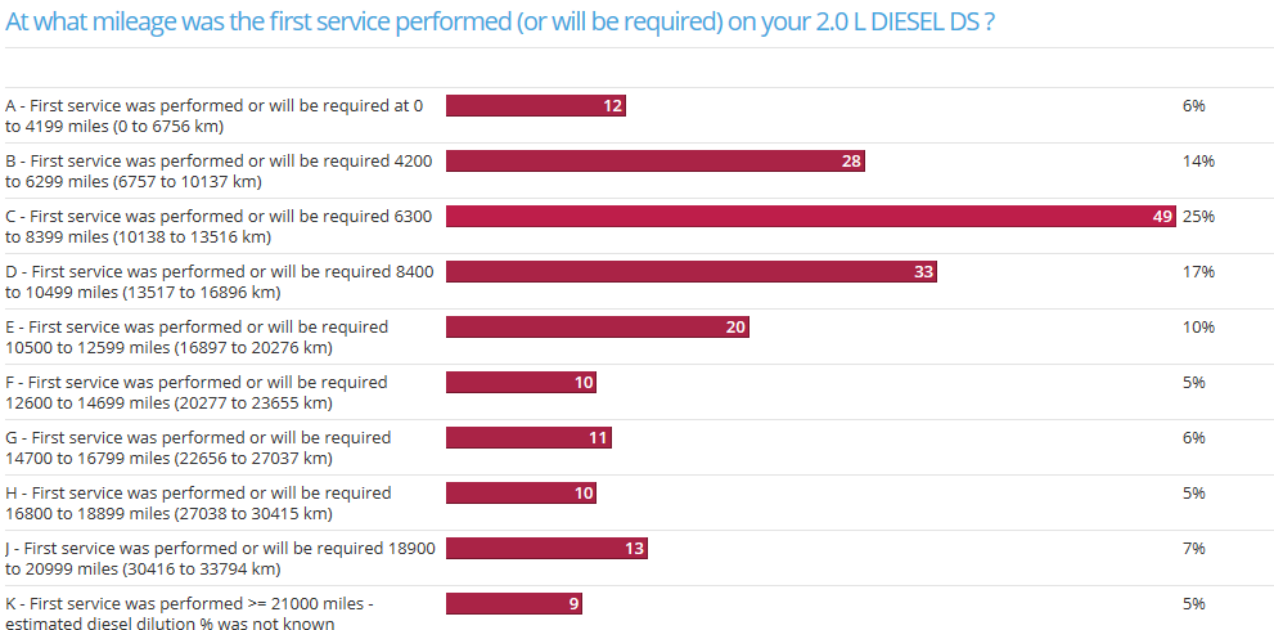

Fig 7. Poll of Discovery Sport owners.

According to one Discovery Sport forum post, JLR engineering ran a 100,000-mile 3-month ageing test on a 2017MY prototype DS and the test vehicle needed 9 oil changes at an average of 9107 miles in order to avoid engine failure. This distance closely matches the real-world data sets above.

5) Interrupted active regenerations are more likely.

Jaguar Land Rover blames diesel dilution on incomplete regenerations caused when journeys are terminated too soon but a scientific description of oil dilution due to post-injection does not support this interpretation. Publicly, JLR blames motorists for using the wrong "driving style" but this is attempting to twist the facts. The truth is that the *probability* of any given active regeneration being interrupted is higher on the faulty cars as a result of the unresolved hardware and architecture challenges. Drivers have not suddenly changed their driving habits and JLR knows this. Its engineers acknowledged that increased length of active regenerations is the root cause of the problem in JLRP00100: "*Duration / Distance to complete a full regeneration is longer. This increases the likelihood of an interrupted regeneration when a customer ends their journey*".

If a Discovery Sport L550 and Jaguar XE X760 were driven in convoy for a few thousand miles in a typical driving pattern - some high speed driving mixed with regular trips into the countryside and around town, stopping and starting at random points – then overall the Jaguar XE would require *fewer* active regenerations than the Discovery Sport and each regeneration event would be of *shorter duration*. Therefore - *based purely on probability* – the Jaguar would experience *fewer* incomplete DPF regenerations. It would spend less time performing post-injection and therefore have less diesel dilution than the Land Rover at the end of any similar driving circuit. Despite both vehicles being fitted with identical 2.0L Ingenium diesel engines, the Discovery Sport would have used up more of its "service miles" in the process and be closer to its next oil change. This is a practical application of the information provided by JLRP00100 and it illustrates why "driving style" cannot be the primary cause of excessive diesel dilution and other DPF problems on these cars: the issue begins and ends with hardware and architecture, as JLR engineers said in 2017.

The oil dilution and service interval reports from hundreds of owners provide consistent data. Too much mileage (60% of the design service interval) is being lost for this phenomenon to be casually dismissed as the result of "driving style". One owner put it like this, "You are asking us to believe that customers conveniently self-organised into two groups: one set of owners with the 'wrong driving style' walked into JLR showrooms and turned right to buy a diesel DS or Evoque – while another group, all with the 'correct driving style', turned left and instead bought a Jaguar XE or an F-Pace".

It's clearly ridiculous. But, in continuing to blame "driving style" for oil dilution and other DPF problems, that's what JLR's public position amounts to.

6) There is more likelihood of a clogged DPF

All DPFs (except passive-only systems, e.g. CRT®) require regular periods of active regeneration to clear unburned hydrocarbon molecules and soot particles (HC/PM) from the filter substrate. If active regeneration can't complete, the DPF will eventually become blocked by HC/PM.

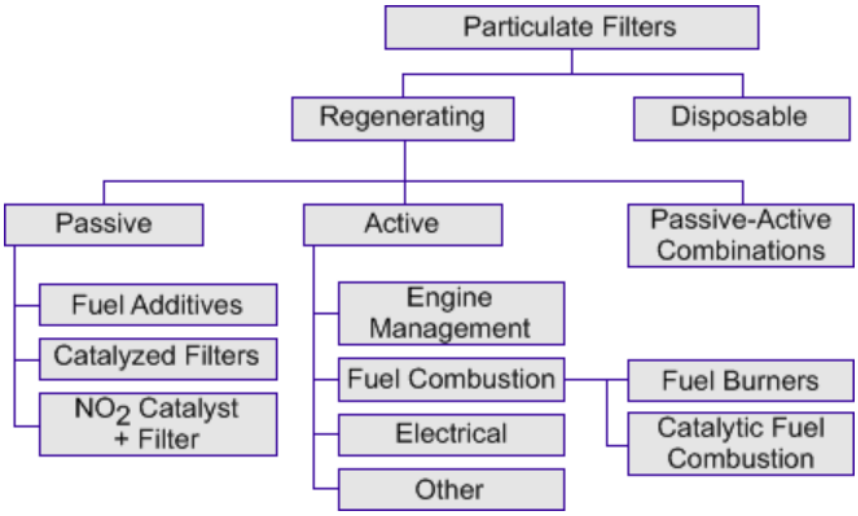

Fig 8. Classification of DPFs by Regeneration Method. (*dieselnet.com*)

Passive-active filters (e.g. DOC-CSF or DOC-SCRF) can passively regenerate part of the HC/PM load when temperatures exceed 580°C, or by using NO_2 created in the upstream catalyst (DOC). However, these chemical reactions can't keep up with HC/PM production and regular active regeneration of the DPF is needed. Jaguar Land Rover confirmed that the Discovery Sport L550 after-treatment system was originally designed to operate with passive-active DPF regeneration:

> *Two processes are used to regenerate the DPF; passive and active.*
>
> *Passive regeneration requires no special engine management intervention and occurs during normal engine operation. The passive regeneration involves a slow conversion of the particulate matter deposited in the DPF into carbon dioxide. During passive regeneration, only a portion of the particulate matter is converted into carbon dioxide. This is because the chemical reaction, which utilises nitrogen dioxide, is slower than the rate of engine production of particulate matter and is effective from 250°C (482°F).*
>
> *Active regeneration starts when the particulate loading of the DPF reaches a threshold as monitored or determined by the DPF control software. The threshold calculation is based on driving style, distance travelled and back pressure signals from the differential pressure sensor.*
>
> **(15/05/2015 - 2017.0 DISCOVERY SPORT (LC), 309-00 DIESEL PARTICULATE FILTER -SYSTEM OPERATION AND COMPONENT DESCRIPTION)**

However, due to the reasons outlined in preceding sections - confirmed by JLR's Executive office - passive regeneration does not operate during "normal driving". This requires active regeneration of the DPF to occur more frequently on the Discovery Sport, Range Rover Evoque and Jaguar E-Pace, resulting in faster oil dilution due to increased post-injection activity. The average oil dilution rate was approximately 0.75% per 1,000 miles according to the data provided by Discovery Sport owners.

If the vehicle is driven at low speed and journeys are of short duration, an additional problem arises because the DPF may not have time, or not get hot enough, to complete an active regeneration. JLR stated in October 2017 that "typical" driving consists of journeys lasting from 15 to 30 minutes, driving at speeds between 31 mph and 62 mph, plus "*some drives of over an hour*".

- 'Typical' driving style as an average across customers is journeys of 15-30 minutes with a speed between 50 kmph and 100 kmph, which includes some drives of over an hour.
- The exhaust temperature achieved in normal driving is low and as such there is no passive regeneration and soot must be cleared through active regeneration.

As discussed, this driving pattern can't create the conditions for passive regeneration to occur so its purpose must be to create sufficient time for at least one of the active regenerations to complete before filter clogging occurs. Following an uninterrupted sequence of incomplete regenerations the DPF will approach its full level and an amber warning light will illuminate. If the correct action isn't taken promptly the filter will become clogged and the red warning light will illuminate.

Many owners have experienced additional DPF problems not directly related to oil dilution (380+ posts here); some people have reported that there is insufficient time between the appearance of the amber and red DPF warning lights for drivers to take the action recommended by JLR. When this happens the filter blocks unexpectedly, the red light illuminates and the car normally has to be recovered to a JLR dealership for a forced regeneration or, in some cases, for replacement of the DPF. JLR has published several engineering bulletins relating to these types of problems.

i) Faulty SCRF;
ii) Amber DPF Warning Light;
iii) Red DPF Warning Light.

Despite JLR's claims that its D8 vehicles are "performing normally" it's obvious that the company is aware of several serious problems related to this exhaust after-treatment system. The situation is aggravated in that most of the problems are *systemic*, leaving dealers unable to carry out repairs or apply fixes: instead they tell drivers that they have caused the problem themselves with an incorrect "driving style". Additionally a few faults are connected with specific manufacturing issues, for example the issues described in SSM73697 above, where hardware (SCRF) isn't matched to the correct software version.

Conclusions

Due to unresolved "engineering challenges" Jaguar Land Rover 2.0L diesel SUVs built on the D8 floor-pan since 2015 (Range Rover Evoque, Land Rover Discovery Sport, Jaguar E-Pace) are not fitted with a close-coupled diesel particulate filter. The engine and DPF are masked from one another by a bulkhead and positioned too far apart, causing heat losses. The DPF performs no passive regeneration during normal driving. Active regeneration is achieved by late post-injection of diesel fuel, resulting in engine oil dilution due to a continuous, in-cylinder process.

On the affected cars, active regeneration is required more frequently and each event takes longer to complete than on similar cars equipped with the same engine. More post-injection is required which causes oil dilution to rise faster than expected. The probability of a journey being terminated during an active regeneration event is higher, further accelerating oil dilution and increasing the probability of DPF blockage. It is important to note that these issues are aggravated by (not *caused by*) low-speed, short duration drive cycles.

When oil dilution reaches 6% the engine oil and filter must be changed to prevent possible engine damage caused by inadequate lubrication (dilution was increased to 10% from February 2019). According to Total, excessive diesel dilution reduces oil viscosity and washes oil from vital parts of the engine impairing lubrication. Poor lubrication causes metal surfaces to rub against one another increasing friction and accelerating wear of bearings and other components. Oil samples removed from more than thirty Land Rover Discovery Sport vehicles since 2017 contain high levels of iron and other metals, something which is normally associated with premature engine wear.

Emissions Durability Testing

Ash accumulation limits the service life of a DPF in proportion to the total mass of soot that it processes during regeneration. To protect consumers and the environment Regulation (EC) No 715/2007 requires that a durability test of exhaust system components is performed to demonstrate that the emissions system functions correctly after at least 100,000 miles. In relation to a 100,000 mile ageing test (an acceptable means of compliance with Regulation 715/2007) of a 17MY prototype Discovery Sport L550, a JLR engineer remarked that: "*the test was interrupted on no less than 9 occasions (requiring 9 oil changes), as the dilution was too high to continue the test without the engine failing*". This matches empirical data supplied by owners regarding in-service oil dilution. If the 100,000 mile durability test was completed *before* type approval was granted, then it follows that this manufacturer must have been aware, prior to September 2015, that "higher than expected" oil dilution *was* going to occur during normal driving (emissions durability tests take 3 months at an average speed of 50 mph). Alternatively, if the emissions durability test was *not* completed on production versions of the L538/L550 2.0L diesels before they were released for use on public roads, this must raise questions regarding the integrity of the type approval process.