PD CEN/TR 17548:2020



BSI Standards Publication

Automotive fuels — Diesel fuel market issues — Abrasive particles investigation report

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee PTI/2, Liquid Fuels.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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November 2020

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Automotive fuels - Diesel fuel market issues - Abrasive particles investigation report

Carburants pour automobiles - Problèmes concernant le carburant diesel - Rapport d'enquête sur les particules abrasives

Kraftstoffe - Marktprobleme bei Dieselkraftstoff - Untersuchungsbericht zu abrasiven Partikeln

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European foreword

This document (CEN/TR 17548:2020) has been prepared by Technical Committee CEN/TC 19 “Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin”, the secretariat of which is held by NEN.

This document primarily addresses quality issues that can be associated with abrasive particles in diesel fuel that can cause wear damage to high pressure common rail fuel injection systems.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

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Introduction

At the CEN/TC 19/WG 24 meeting on 18 October, 2017 in Zurich, Switzerland there were technical presentations describing serious vehicle fuel injection system wear and damage problems in Northern Germany and the Southeast of the United Kingdom. A CEN task force was formed in January 2018 to investigate these abrasive wear issues in order to establish the root cause and make recommendations.

After a year of investigations of market fuels, refinery product streams and field issues, the task force produced a summary report detailing the findings of the fuel quality investigation and vehicle fuel injection system damage caused by this contamination with respect to the work on European (diesel fuel) standards. CEN/TC 19 requested to have this report published as a CEN/TR, parallel to implementing the advice and recommendations in standardization and the market.

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1 Scope

This document describes the investigation into diesel vehicle common rail fuel injection system damage and excessive wear problems in a number of countries across Europe since 2014 carried out by CEN/TC 19/WG 24 Abrasive Particles Task Force.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 590:2013+A1:2017, *Automotive fuels - Diesel - Requirements and test methods*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

4 Symbols and abbreviations

For the purposes of this document, the following symbols and abbreviations apply.

ARA	Antwerp Rotterdam Area
CONCAWE	Conservation of Clean Air and Water in Europe
DFA	Downstream Fuels Association
DLC	Diamond Like Carbon
DMV	Diesel Motor Vehicle
DPF	Diesel Particulate Filter
EU	European Union
FAME	Fatty Acid Methyl Ester
FBT	Filter Blocking Tendency
FIE	Fuel Injection Equipment
HD	Heavy Duty
HDEP	Heavy Duty Engine Platform
ICP	Inductive Coupled Plasma
ICP- AES	Inductively coupled plasma-atomic emission spectrometry
ICP-MS	Inductively coupled plasma-mass spectrometry
IPTV	Incidents Per Thousand Vehicles
LD	Light Duty
MDEG	Medium Duty Engine Generation
M+H	Mann and Hummel

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MIS	Months In Service
MS	Mass spectrometer
MWV	Mineralölwirtschaftsverband e.V.
NCV	Needle Control Valve
NOK	Not OK
OEM	Original Equipment Manufacturer.
PKW	Passenger Car
PRV	Pressure Regulating Valve
Rail	Fuel Rail
SEM	Scanning Electron Microscope
Van	Light Duty van
UKPIA	UK Petroleum Industry Association

5 Description of fuel injection equipment problems

An increasing number of fuel injector warranty claims have been reported by a number of vehicle manufacturers (Daimler, DAF, CNH Industrial, PSA and Volvo) and Fuel injection equipment manufacturers (Bosch and Delphi). Both heavy duty and light duty vehicles are affected with modern high pressure common rail diesel fuel injection systems of various vehicle configurations.

Investigation clearly shows internal damage to fuel injector moving parts, internal valves and pressure relief valves causing internal injector leakage, engine malfunction indicator light illumination, engine power loss, poor idle stability and in some cases complete engine shutdown.

PSA have reported the following vehicle field experience:

— 71 % of cases: on board light and engine power loss

— 21 % of cases: engine shut down during the driving

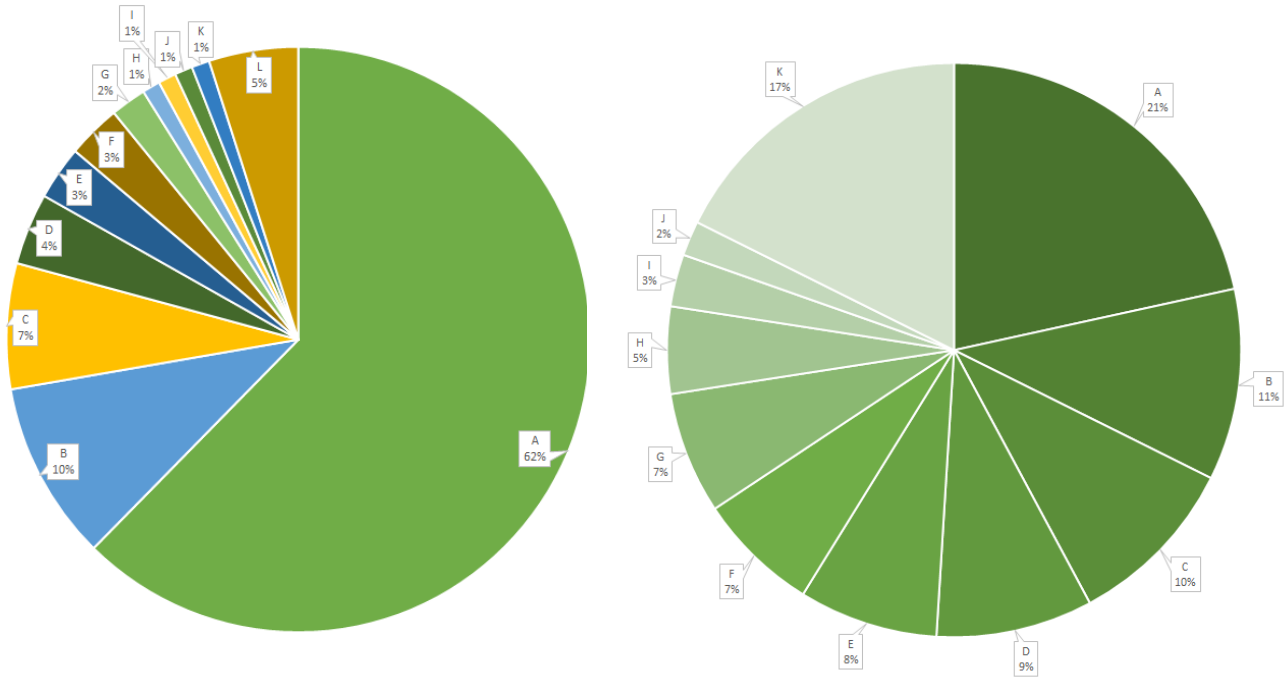
— 8 % of cases: idle instability

— vehicle minimum mileage: 4,451 km

— vehicle maximum mileage: 130,970 km

Only certain areas of Europe are affected with the highest numbers of vehicle incidents reported in Northern Germany, the Southeast of the UK followed by Northern France and a small number in Spain. See Figures 1 through 15 for the reports on the incidents. The vehicle manufacturers have reported a small number of failures elsewhere in Europe but these are deemed as isolated incidents. Failures are more common during the winter in the January/March timeframe (see Figure 7 and 10).

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a) Claims by country **b) Claims in Germany only**

Build year 2016, repair year 2017, status 08/2017

Key

a) Claims by country

A Germany
B United Kingdom
C France
D Netherlands
E Poland
F Czech Republic
G Romania
H Spain
I Belgium
J Lithuania
K Slovak Republic
L Single claims / no relationship

b) Claims in Germany only

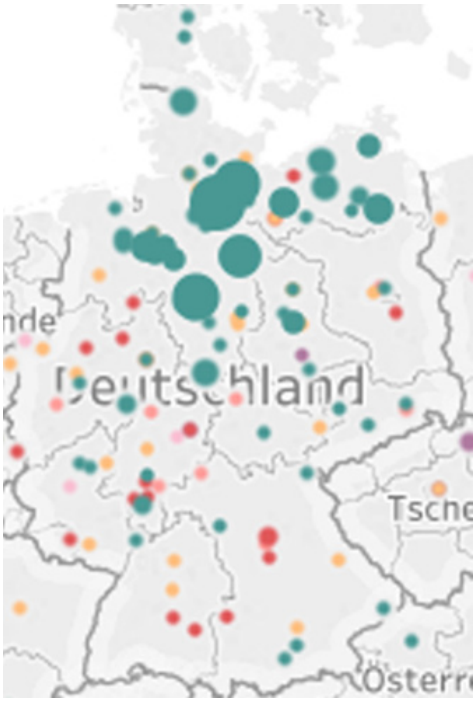
A Bremen
B Hamburg
C Braunschweig
D Hannover
E Rostock
F Kiel
G Lübeck
H Magdeburg
I Dresden
J Leipzig
K Single claims

Figure 1 — Injector complaints inner leakage OM 47x (Courtesy Daimler)

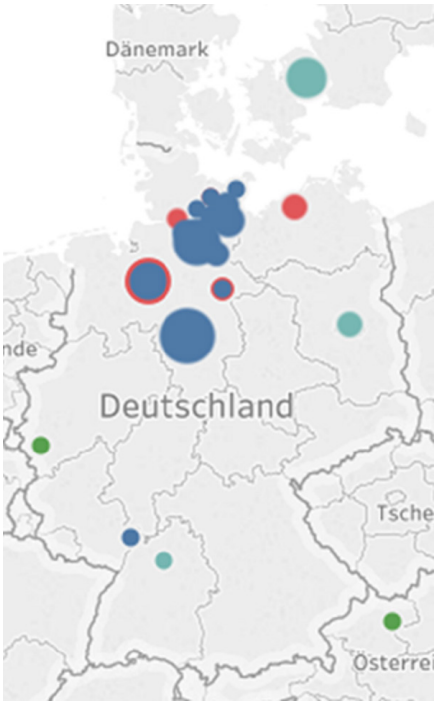
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a) Heavy duty engines



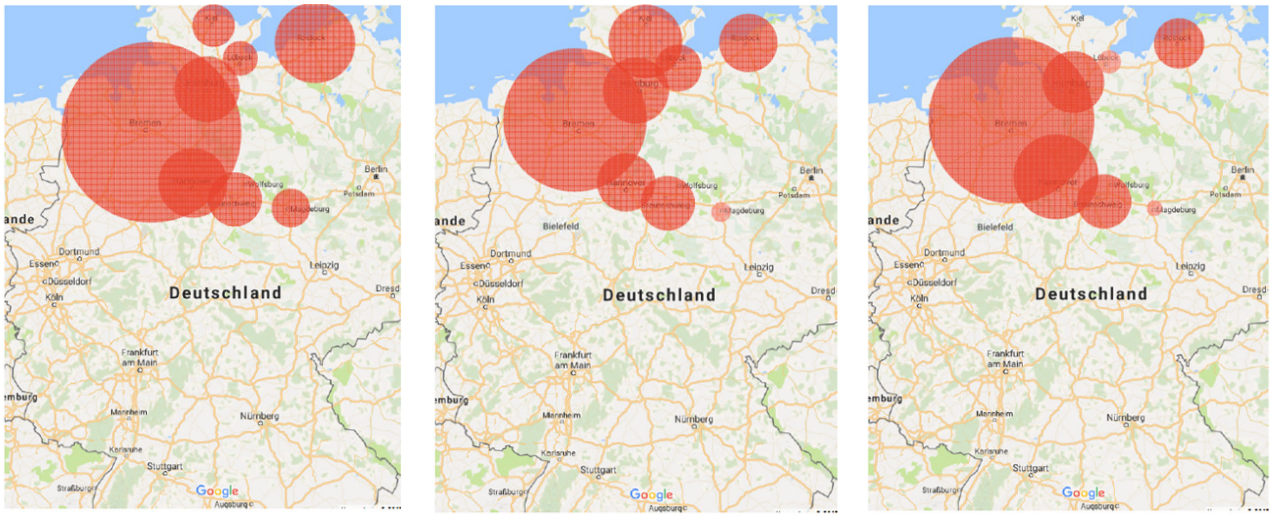
b) Vans



c) Personal vehicles

Figure 2 — Daimler reported incidents (Courtesy Daimler)

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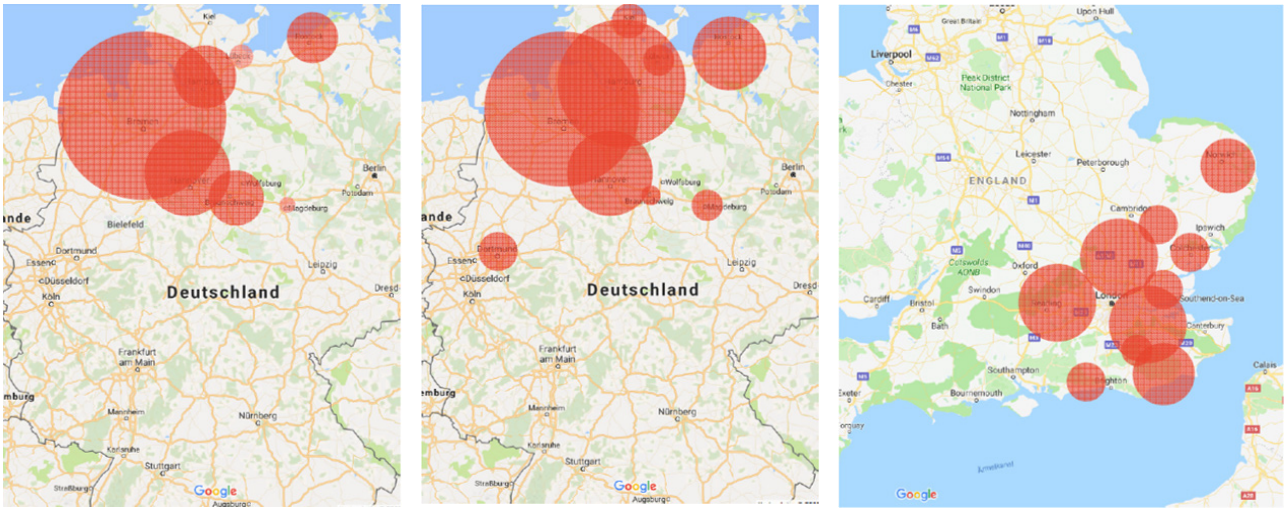


a) Inner leakage 1st half year 2017

b) Inner leakage 2nd half year 2017

c) Inner leakage 1st quarter 2018

Figure 3 — Distribution of injector failures HDEP in Germany (Courtesy Daimler)



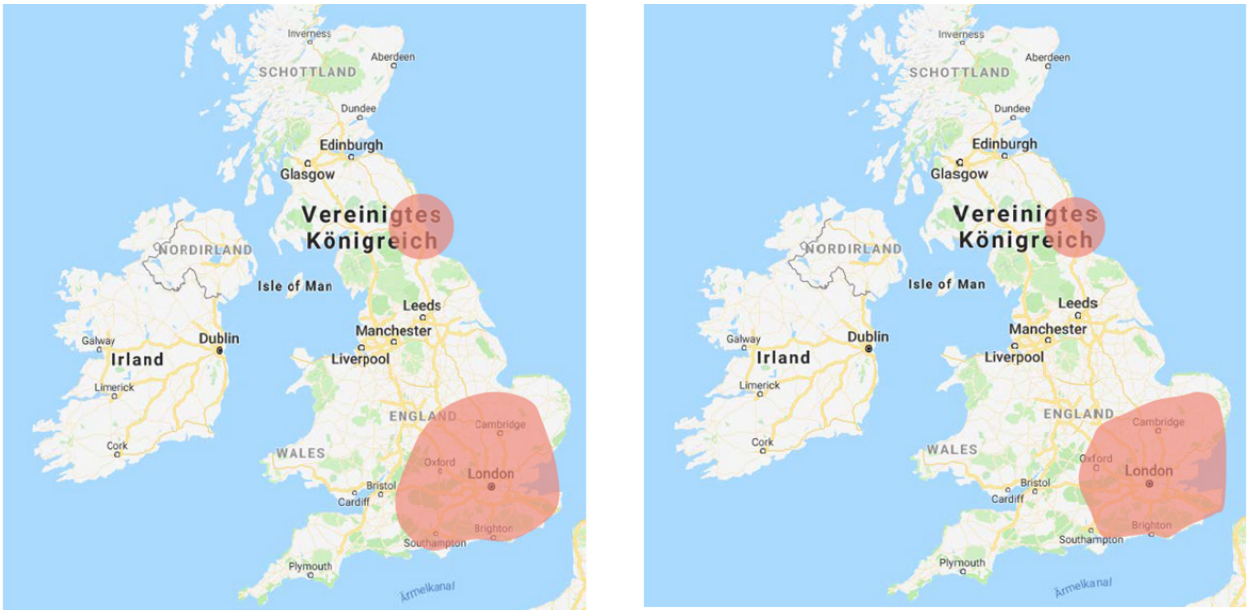
a) Inner leakage heavy duty engines 1st quarter 2018, Germany

b) Inner leakage middle duty engines 77% of all claims, Northern Germany

c) Inner leakage middle duty engines 80% of all claims, South-East England

Figure 4 — Distribution of injector failures HDEP/MDEG (Courtesy Daimler)

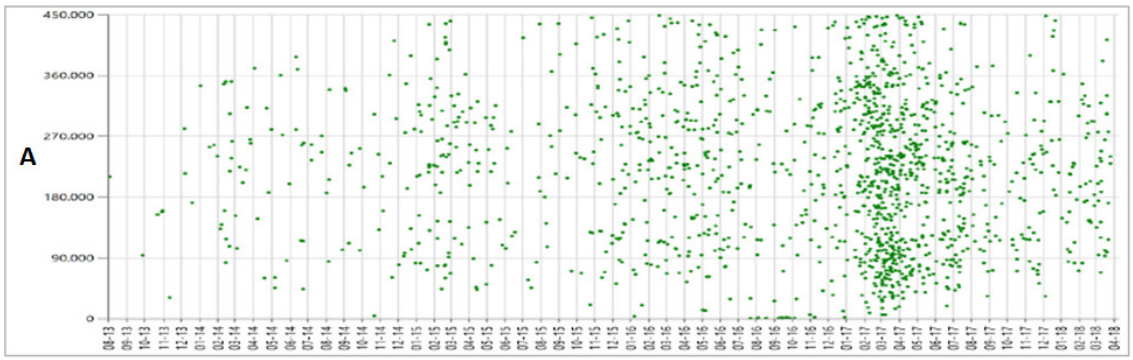
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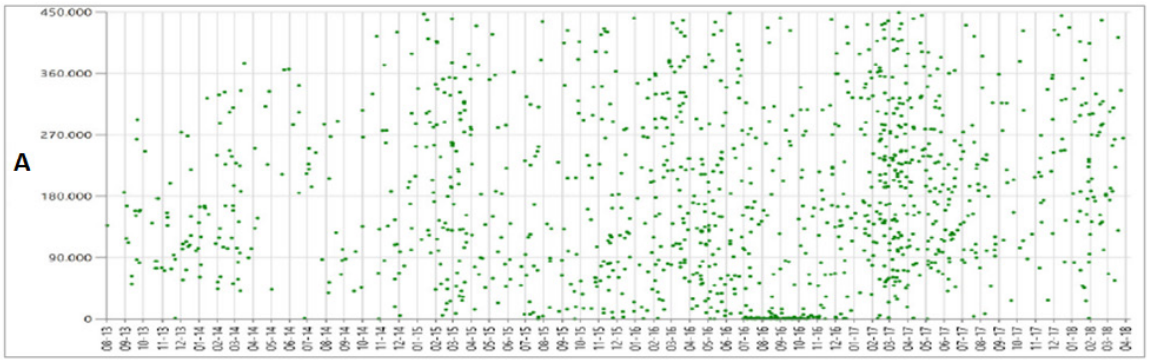
a) Heavy duty engines **b) Medium duty engines**

NOTE The claim rate in the marked areas is 13 times higher than in other parts of Great Britain.

Figure 5 — Injector claims "inner leakage" Great-Britain 2017/2018 (Courtesy Daimler)



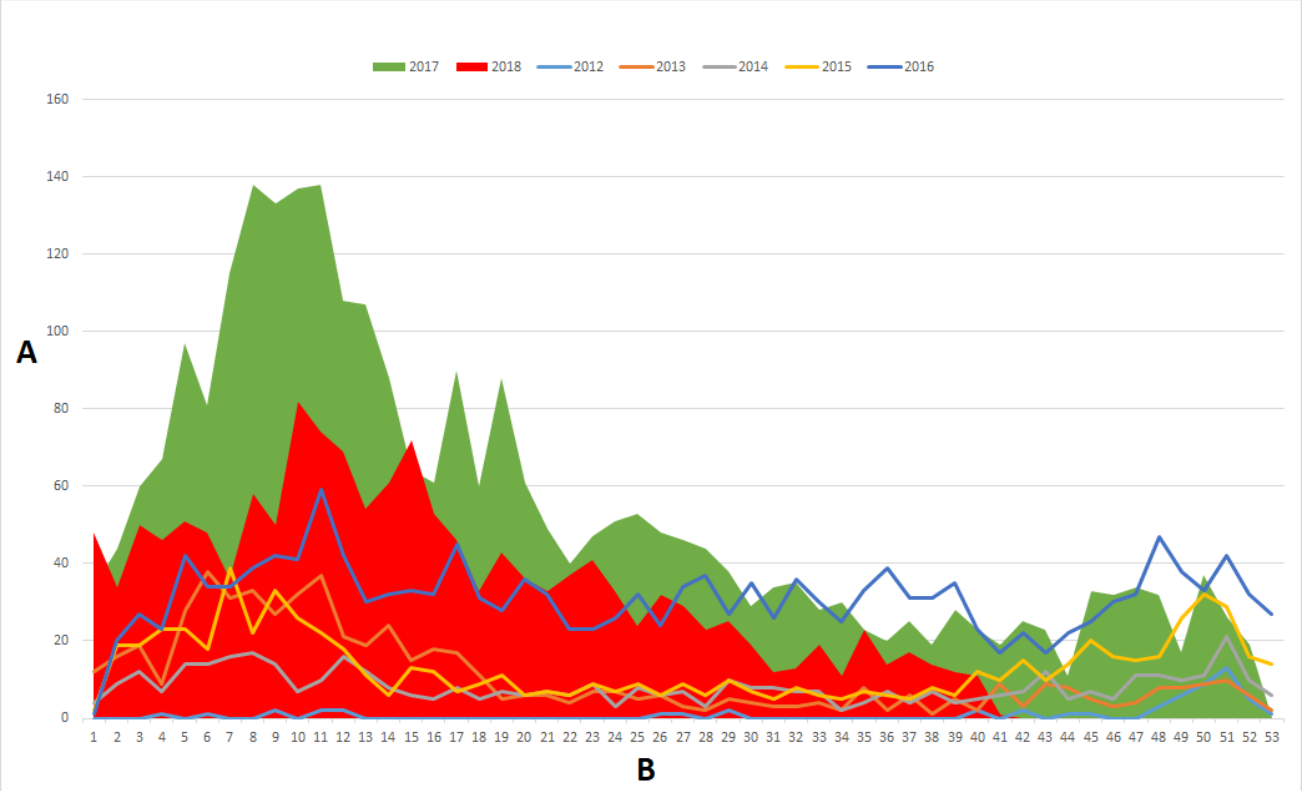
a) Starry sky by repair date of inner leakage heavy duty engines Northern Germany



b) Starry sky by repair date of inner leakage heavy duty engines Southern Germany

Figure 6 — Starry sky by repair date of inner leakage heavy duty engines fuel injector claims 2017/2018 (Courtesy Daimler)

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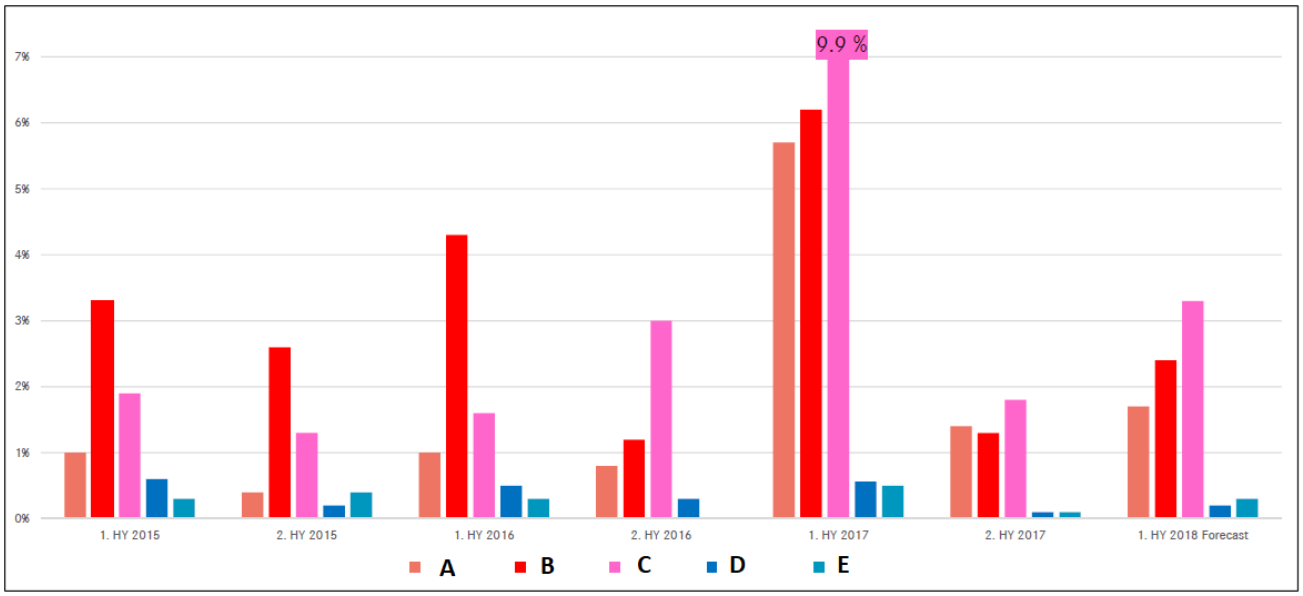
Key

A	amount of registered issues	B	calendar week
Light blue line	2012	Dark blue line	2016
Orange line	2013	Green block	2017
Grey line	2014	Red block	2018
yellow line	2015		

Figure 7 — Daimler heavy duty vehicle complaints (inner leakage) in Germany (Courtesy Daimler)

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Figure 8 illustrates the difference in injector failure rates between Northern and Southern Germany.



Key

Redish bars	Northern Germany	A	Hamburg
Blueish bars	Southern Germany	B	Bremen
		C	Rostock
		D	Frankfurt
		E	Stuttgart

Figure 8 — Injector failure rates HDEP in Germany (Courtesy Daimler)

DAF reported incidents are consistent with Daimler reported incidents in both Germany and the UK (Figure 9). It should be noted that 78,7 % of the failures in Germany occurred in Northern Germany. Their yearly trend since the start of the incidents is shown in Figure 11.

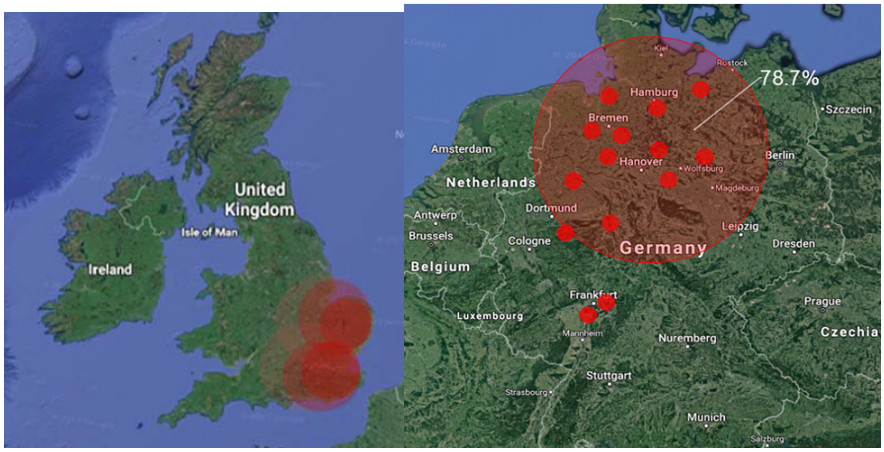


Figure 9 — DAF reported incidents (Courtesy DAF UK)

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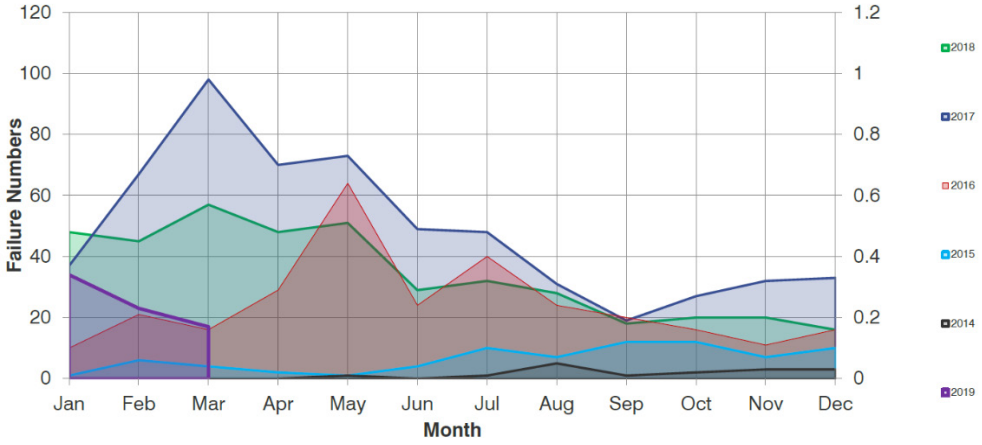


Figure 10 — Year comparison of failures per month for trucks over 16 ton (Courtesy DAF UK)

Figure 11 shows DAF (UK) comparative warranty rates for injectors and highlights the Southeast of the UK area with the highest number of returns. Note that actual numbers are not reported for Figures 11 and 12 due to commercial confidentiality requirements.



Figure 11 — UK warranty information - Injectors (Courtesy DAF UK)

Figure 12 shows comparative warranty information for the Fuel Rail Pressure Regulating Valve (PRV) and highlights that the highest number of failures are in the Southeast and East of England.

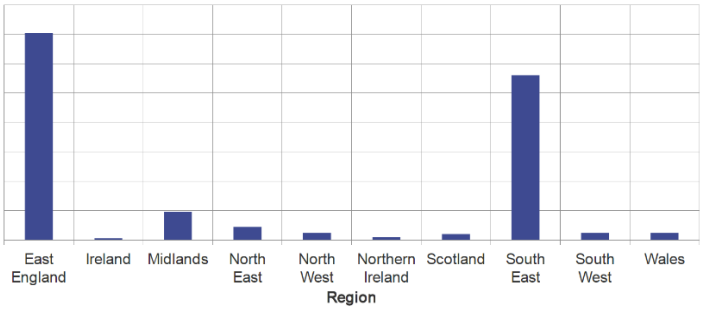


Figure 12 — UK warranty information – Rail and PRV (Courtesy DAF UK)

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Reported incidents (2014-2017) by CNH Industrial are plotted in Figure 13 and these again are clustered in Northern Germany (at least 25 % of claims are located in that area).



Figure 13 — CNH Industrial reported incidents on the German market (Courtesy CNH Industrial)

PSA reported incidents (Figure 14) are primarily in Northern Germany (41 %) and the UK (34 %) and to a lesser extent in France (19 %) and Spain (6 %), with none in Italy. Overall 90% of the repair occurred in February and March 2017, with fewer in May to July 2017.

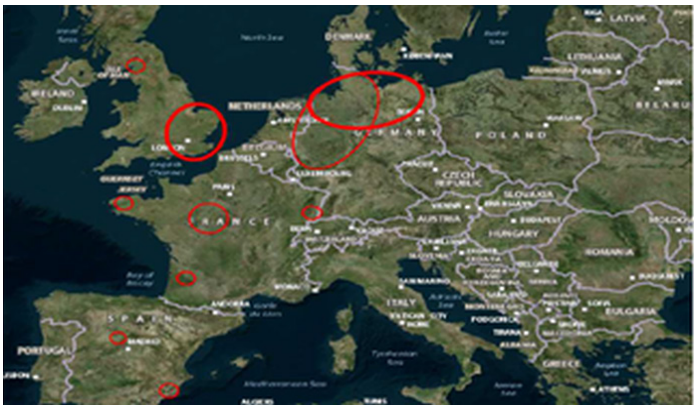
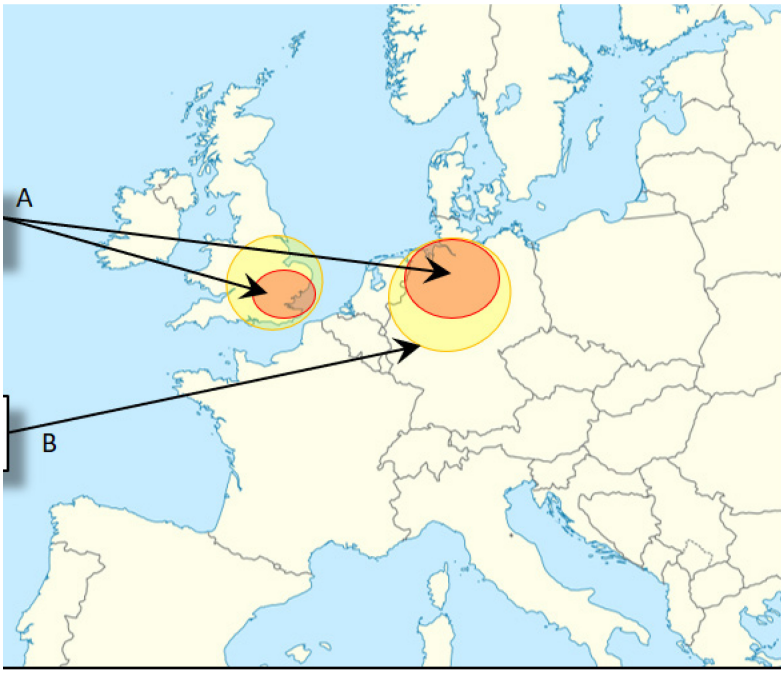


Figure 14 — PSA reported incidents (Courtesy PSA)

Delphi reported incidents (Figure 15) are clustered in Northern Germany and the Southeast of the UK. It is noted that a wide range of end users with issues had no obvious links. Also the issues in the areas indicated became apparent mid-2014 and accelerated mid-2016. There is circumstantial evidence that the affected areas predominantly see imported fuels.

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Key

A Orange areas show primary locations, but not linked to single fleet, fuel outlet or storage location

B Yellow areas show also observed occasions of issues

Figure 15 — Particle contamination issues reported in Northern-Germany/Southern UK (Courtesy Delphi)

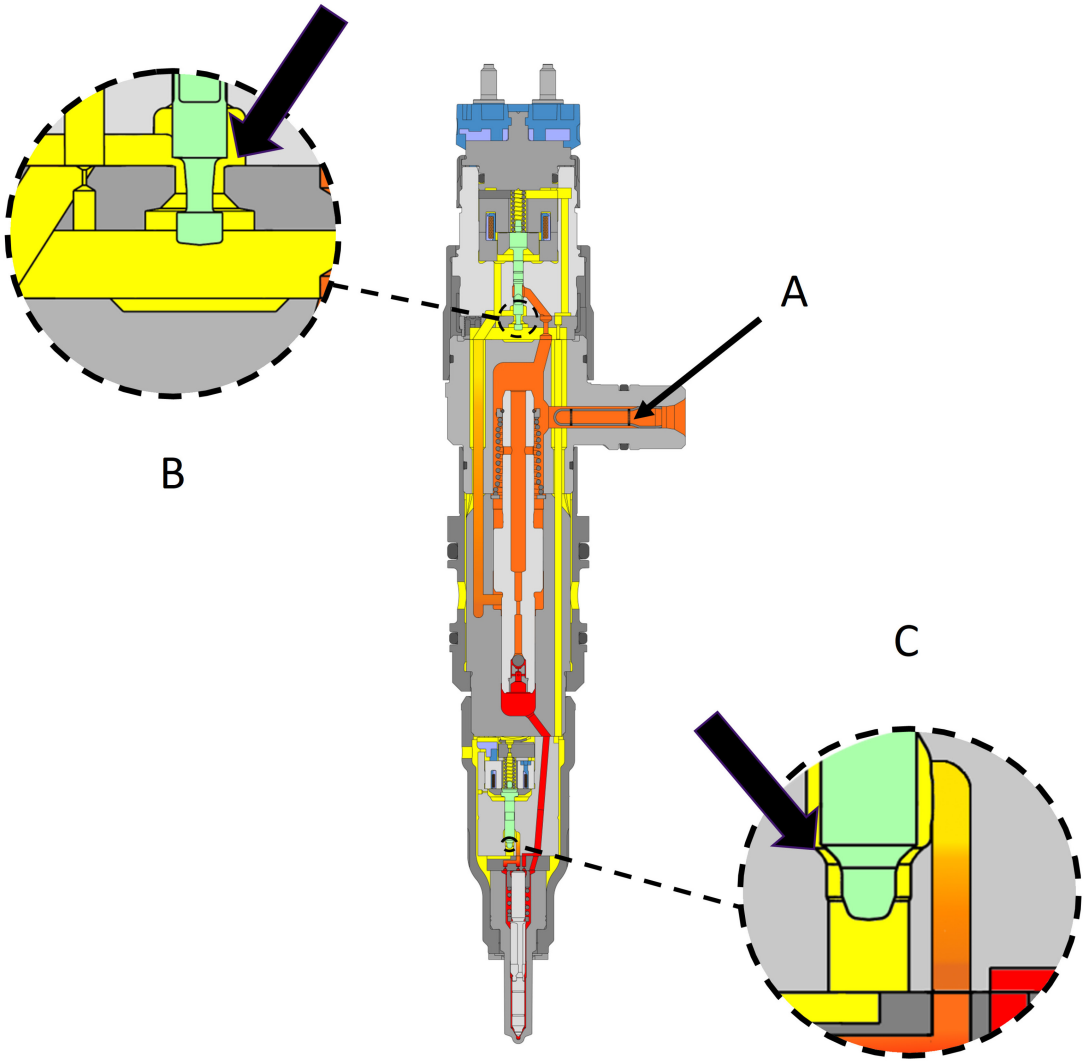
Warranty information from Volvo UK, regarding FIE claims in London, Southeast and South coast of the UK for the main engines used in Volvo trucks (D11, D13) show a significant increase in claims (FIE spare part kits) starting late 2016, continuing into all 2017 and still at the same (higher) level in 2018.

6 Fuel injection system damage investigations

Investigations by Daimler, DAF, CNH, PSA, Delphi and Bosch show similar damage to fuel injector moving parts, internal control valves and seats and pressure regulating valves. Figure 16 illustrates the internal locations in the fuel injectors where damage has been recorded. Due to the very high pressures, the working clearances between moving and sealing components in the fuel injection system are typically 1 – 4 µm, so only very small particles can pass between the moving parts and cause wear. Regardless of injection equipment manufacture the solenoid valve seats and moving components show signs of serious damage shown to be related to hard particulates < 4 µm in size.

NOTE On board vehicle filters are typically in the 4 – 5µm range and whilst they have some functionality below 4 microns they cannot protect against large numbers of < 1µm particles.

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Key

A Intake filter
B Lower valve seat
C Upper valve seat

Figure 16 — Locations inside injectors affected by particle erosion (Courtesy Bosch)

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Figure 17 shows the typical damage to solenoid valve seats caused by particle erosion and Figure 18 compares valve seat erosion from Northern Germany field failures with vehicle test components. Particle wear from the field failures is comparable with vehicle test results.

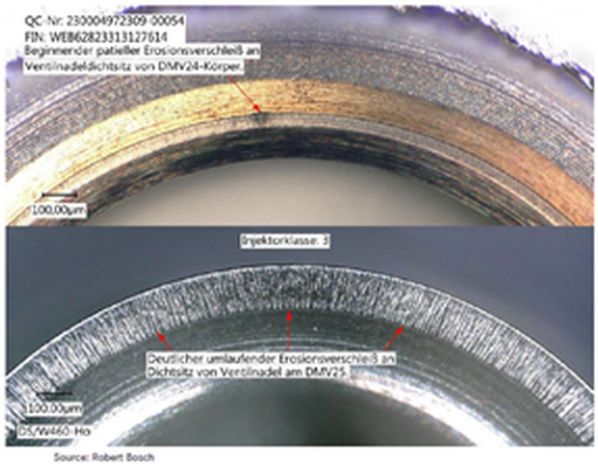
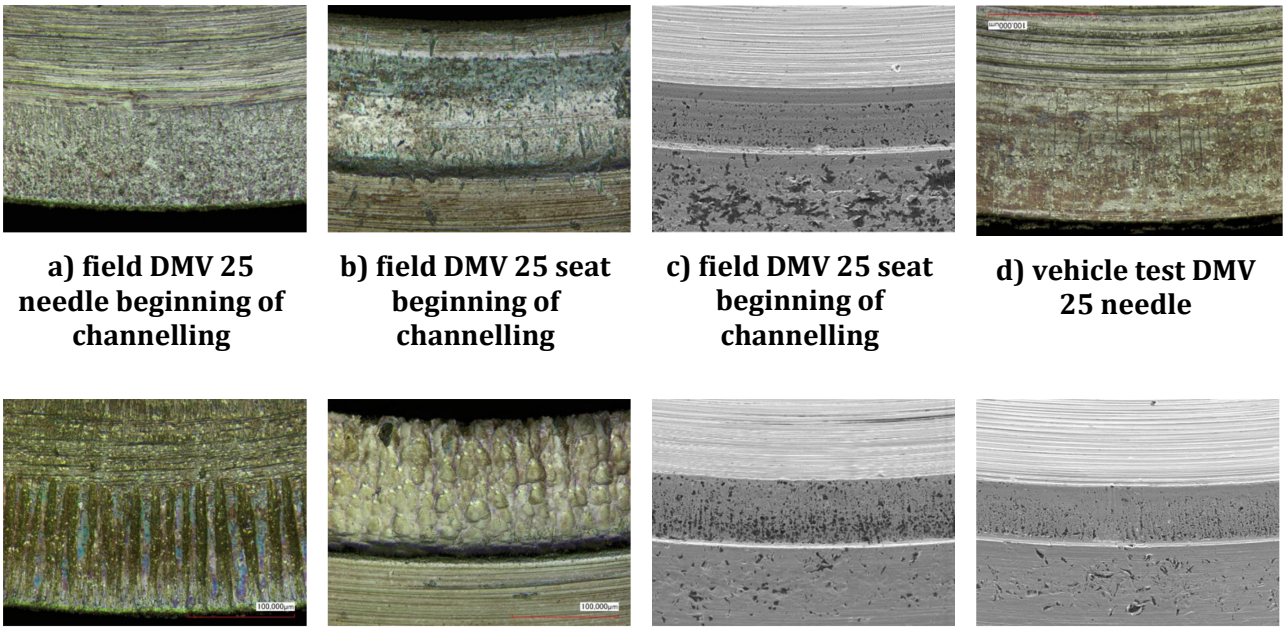


Figure 17 — Failure HDEP injectors – particle erosion on body seat (Courtesy Daimler)



a) field DMV 25 needle beginning of channelling

b) field DMV 25 seat beginning of channelling

c) field DMV 25 seat beginning of channelling

d) vehicle test DMV 25 needle

e) DMV 25 needle significant channelling

f) DMV 25 seat significant channelling

g) DMV 24 seat channelling

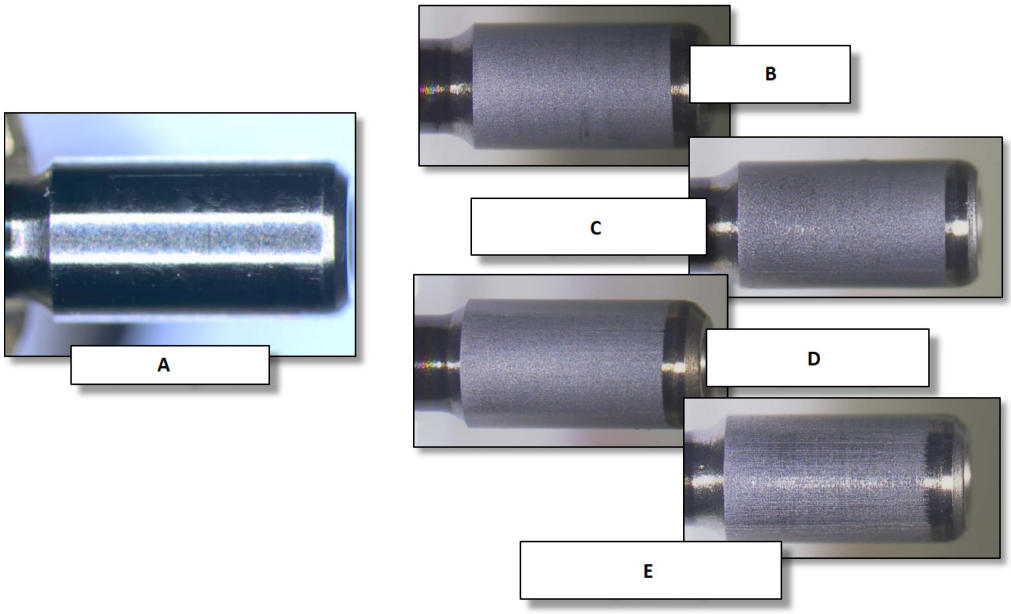
h) vehicle test DMV 24 seat

Figure 18 — FIE particle erosion at valve seat and valve needle (Courtesy Bosch)

The damage is not just limited to valve seats as the sliding components locating the valves are also affected as illustrated in Figures 19 and 20, where the severe erosion of light duty vehicle injector components has been observed following low mileage in the UK and Germany. In Figure 19 the observed rate of wear is many times higher than normally expected and there is clear evidence of particle erosion which is not lubricity related. Similar erosion wear mechanism is observed across multiple vehicles.

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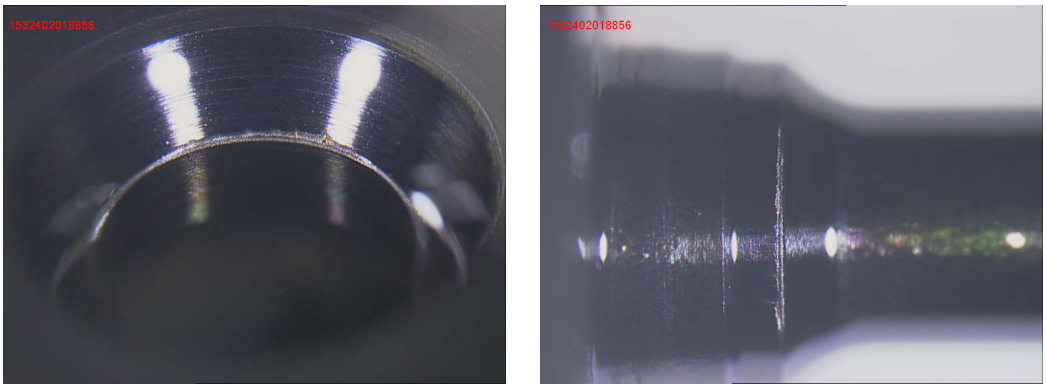


Key

A	New component	B	Maidstone (UK)	D	Wittenburg (Germany)
		C	Walton on Thames (UK)	E	Willemshaven (Germany)

Figure 19 — Severe erosion of light duty parts observed following low mileage in UK and Germany (Courtesy Delphi Technologies)

The analysis of roughly 200 cases of returns on the parts indicated in Figure 20 told us that the majority (180 cases) showed an NCV T3 change. Most cases came from Germany although they may be skewed by sampling location. Incidents per 1 000 vehicles at twelve months in service (IPTV) had been low and quite stable over time, but have dropped since the last quarter of 2015. There were no significant seasonal patterns observed.



Key

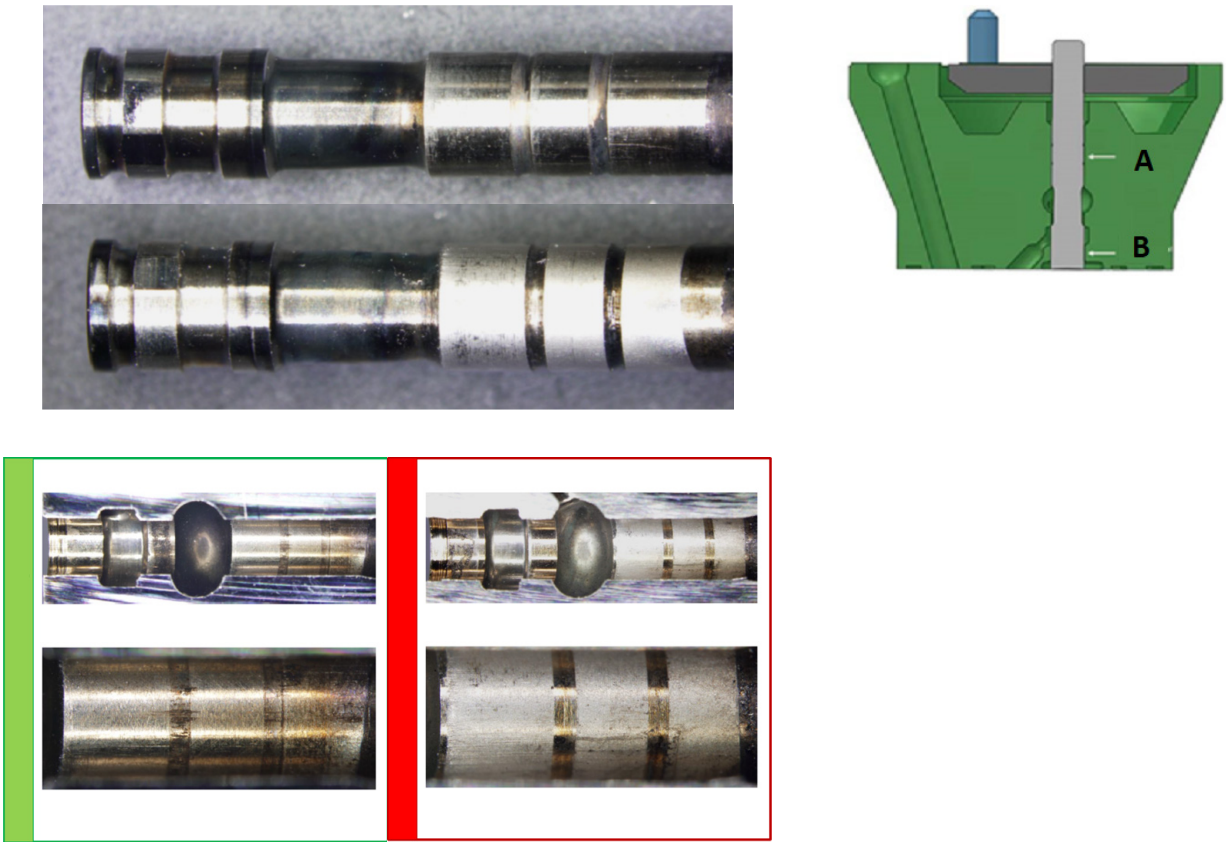
a Erosion on seat in guide

b Erosion on valve head

Figure 20 — Particle robustness, light-duty field experience (Courtesy Daimler)

Figure 21 compares MDEG sliding pin wear from a 300 000 km vehicle operating correctly with that of one removed from a vehicle with high leakage at 100 000 km. The damage to the surface can be seen clearly.

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Key

A Stem

B Collar

Figure 21 — MDEG sliding pin wear normal (top pin and green block) and failed (bottom and red block) (Courtesy Daimler)

In Figure 22 wear patterns are compared between the field failure returns and test pins evaluated using fuel artificially contaminated with so-called Arizona test dust. The wear patterns between the field failure component and the test dust component are very similar in nature. The resulting loss of hydraulic performance is also the same between field failure returned parts and the Arizona dust test.

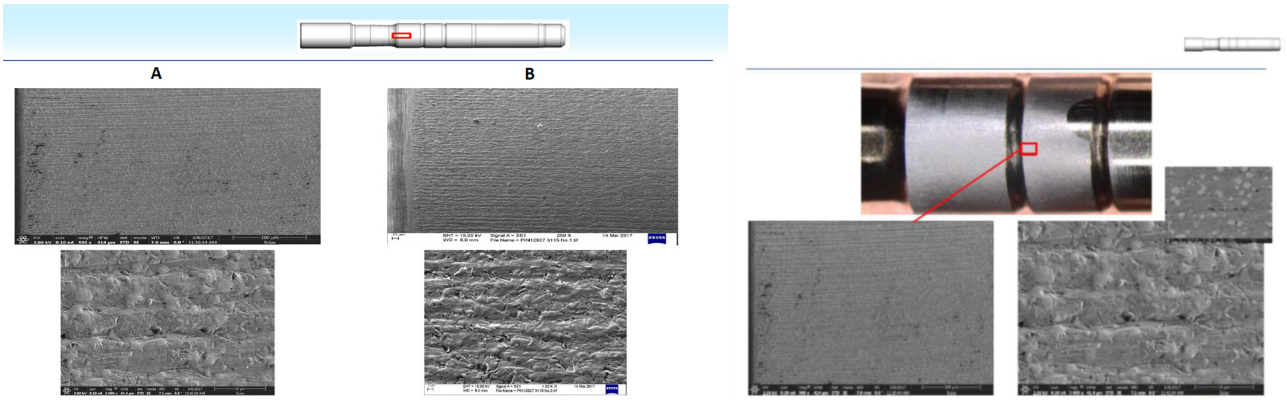


Figure 22 — Comparable wear pattern on field returns (A) and Arizona dust verification pattern (B) (Courtesy Daimler and Delphi)

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Similar valve damage has been reported by CNH (Figure 23) and PSA (Figure 24).



Figure 23 — Injector failure on F1A engine - (Courtesy CNH Industrial)



Figure 24 — Examples of high wearing due to "abrasion" (Courtesy PSA)

Figure 25 shows wear damage from a failed injector in the Southeast of the UK consistent with that reported by other manufacturers.

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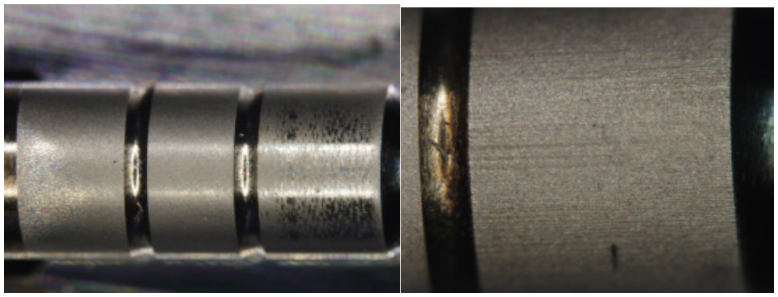
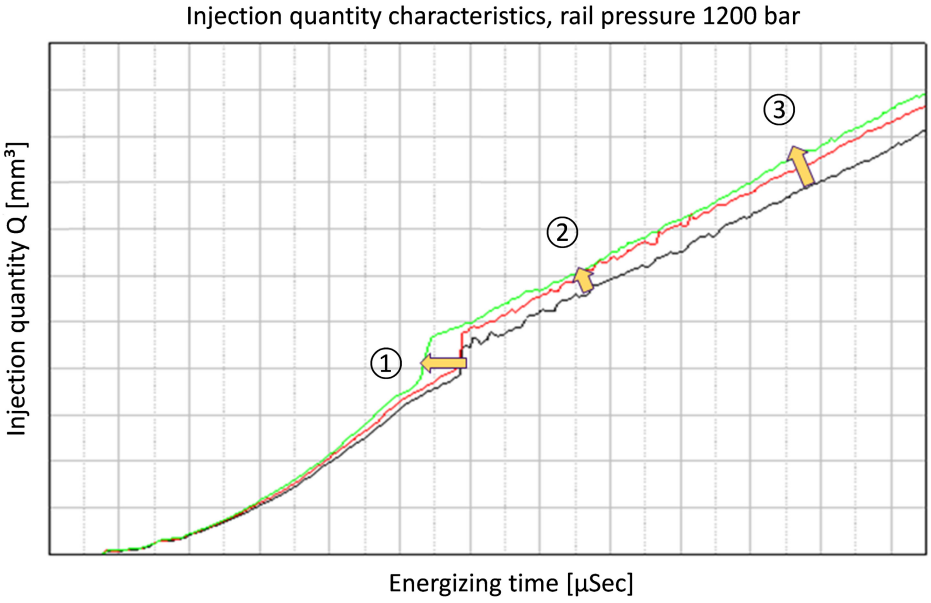


Figure 25 — Injector failure (Courtesy DAF (UK))

The damage to the valves, valve seats and sliding components in the fuel injectors increases internal leakage within the fuel injector which affects its performance. Figure 26 shows the typical hydraulic effects caused by particle erosion (injection quantity characteristics, Rail pressure 1 200 bar). This can result in pressure boosting ahead of time, increased internal leakage causing retarded needle closing and increased fuel throughout due to nozzle-widening by particle erosion.



Key

Black curve	Injection quantity, undamaged valves
Red curve	Injection quantity, seat/needle erosion at upper valve
Green curve	Injection quantity, seat/needle erosion at upper and lower valve
①	Lower valve, pressure boosting ahead of time caused by pressure influence via erosion channels
②	Upper valve, leakage results in quantity increased with the consequence of retarded valve closing
③	Nozzle, widening by particle erosion results in additional fuel throughput

Figure 26 — FIE particle erosion, hydraulic effects (Courtesy Bosch)

These hydraulic changes lead to the loss of the precise injector control required to deliver low diesel vehicle emissions and good vehicle operability and ultimately can stop the vehicle.

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Analysis by the fuel injection system manufacturers (Bosch and Delphi) summarized in this section of the report, has identified particle erosion as the root cause of the fuel injection system damage. The particles are shown to be hard and < 4 µm in size.

An official definition for hard and soft particles does not exist, however when considering their potential to damage fuel injection components made of steel, particles as hard as steel or even harder can therefore be classified as "hard" (reference value 300 HV30), particles with a lower hardness can be classified as 'soft'.

7 Fuel quality investigations

Fuel filter analysis has been carried out on failed vehicles to investigate filter loading and contaminants:

a) Analysis carried out by M+H and Mahle;

b) Fuel filters from complaint vehicles from Northern and reference filters from Southern Germany;

c) Common characteristics:

   i) High filter load for given runtime;

   ii) Brown discolouration to fuel filter when compared to normal fuel filter grey colour from Southern Germany (Figure 27);

   iii) High share of metallic particles, see Figures 28 and 29 and Tables 1 and 2.



Figure 27 — Fuel filter HDEP of complaint vehicle from Northern Germany (left) and a typical version from Southern Germany (right) (Courtesy Daimler)

Documents
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