EA11003EN-00108[0]

From: Non-responsive content removed
To:
CC:
Date: 03.26.2009, 5:28:00 PM
Subject: Re: CP4 pre-filling / first start-up at the belt in Non-responsive content removed

sorry; now the important part for you in **red**:

Process monitoring at [redacted] with respect to the initial filling at the engine and vehicle. (TT/A3) to avoid CP4 drivetrain damage.

Best regards

Non-responsive content removed

From: Non-responsive content removed
Sent: Thursday, March 26, 2009, 5:19 PM
To: Non-responsive content removed
Subject: Re: CP4 pre-filling / first start-up at the belt in Non-responsive content removed

I refuse to read chain mail

Best regards

Non-responsive content removed

From: Non-responsive content removed
Sent: Thursday, March 26, 2009, 3:24 PM
To: Non-responsive content removed
Cc:
Subject: Subject: CP4 pre-filling / first start-up at the belt in Neckarsulm

Hello Mr. [redacted]

that is, we can make it without Bosch in [redacted] (Facts are portrayed correctly).
Or try to convince Non-responsive content removed (however, RB-developers are required).

Best regards

[redacted]

From: Non-responsive content removed
Sent: Thursday, March 26, 2009, 3:13 PM
Non-responsive content removed
Subject: Re: CP4 pre-filling / first start-up at the belt in Non-responsive content removed

Dear Mr. [redacted]

Obviously, we support your request to test the commissioning procedure in the respective Audi plants
However, it does not appear to be necessary that we are all always personally present during the works inspection (especially at the [redacted] plant, that we have already visited very frequently), because it is adequate when the corresponding plant provides us with the commissioning procedure.

New features are as follows:

Engine plant:
- Engine speed-, rail pressure-, inlet pressure-, back pressure-, metering unit current, pressure control valve current progress via the entire testing and commissioning time, possibly in the form of a diagram with target and actual progress (measurement data record)

Vehicle plant:
- Duration of the low-pressure pre-ventilation (advance of the electric fuel pump for a stationary engine and pump, respectively)

Criteria:
Minimum pre-ventilation duration = [Duration "switch on electric fuel pump" until fuel line is at CP4"] + [10...20s]
Bosch recommendation: t_vent_min > 60 s In particular cases, e.g. Phaeton, it can be necessary to extend the minimum ventilation duration.
Proof can be given via a time measurement for a batch of vehicles,
whereby it is analyzed when a "milky" foam-like substance is no longer escaping at the pump return flow (individual bubbles permitted).

- Start time validation

Guide value of start time (in relation to starter contact) < 20 s

On the basis of this (written) information - and essentially only on this basis - we can confirm the commissioning according to specification.

That is why we request not to desist from the participation of the Bosch employee if nothing else based on the very tense economic situation and the enforced savings measures.
In the event that acute problems would make our visit to one of your plants necessary, we are obviously always at your disposal.

Best regards

Non-responsive content removed

Robert Bosch GmbH

Non-responsive content removed

CP4 FG xx-12-2008: Petrol in the diesel fuel

EDI 882022

Question

How much petrol does CP4 tolerate?

Action

Special endurance run with series pump CP4.1

Trial execution:

Diesel-petrol mixture 1:1 (50% petrol in diesel)
4500 rpm, 2050 bar, 50 hrs

Result

The components are in a good condition (Images page 2, 3).

Conclusion

Pump is resilient against petrol mixtures (wrong fueling). A statement on the long-term behavior is not possible. The setting parameters of viscosity and lubricity of the petrol-diesel mixture are decisive.

CP4 FG xx-12-2008: Petrol in the diesel fuel

EDI 882022

Special endurance run for petrol tolerability - series pump

Diesel systems

BOSCH

CP4 FG xx-12-2008: Petrol in the diesel fuel

EDI 882022

Special endurance run for petrol tolerability - series pump

RB - Audi Top Meeting on 10.28.2010

BOSCH
Invented for life

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

BOSCH

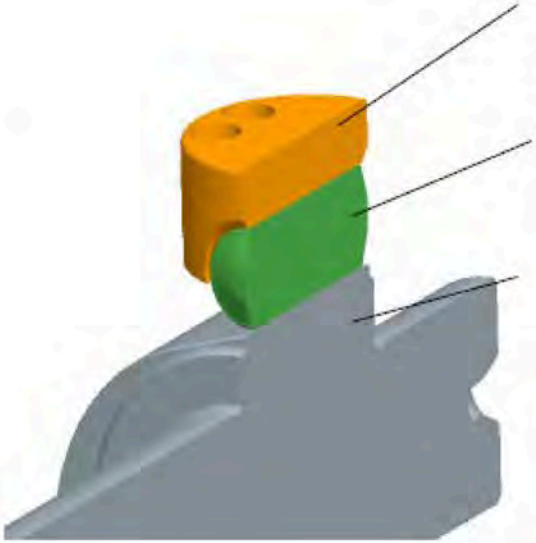
Agenda

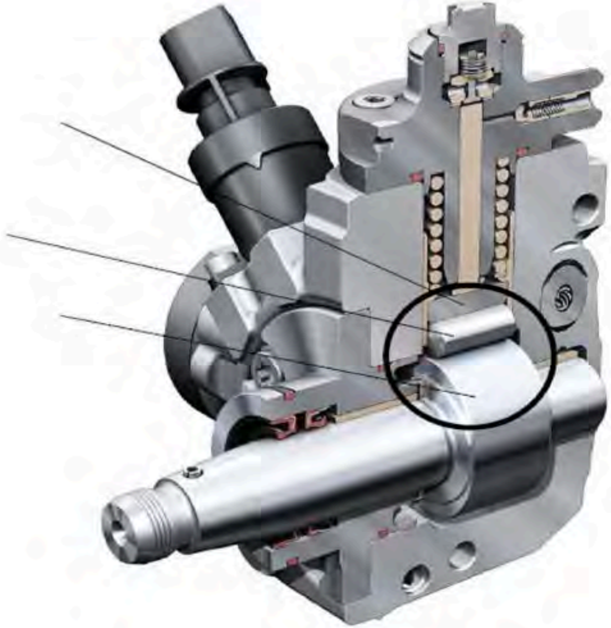
1. Hypothesis of damage profile of drivetrain	**RB**
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

BOSCH

1) Hypothesis of damage profile of drivetrain

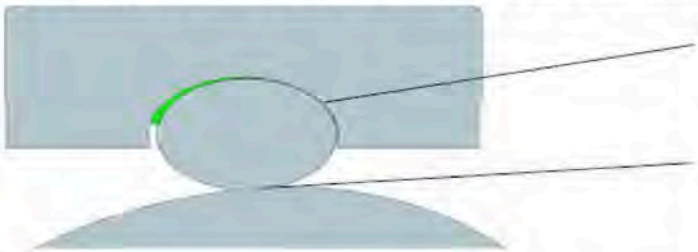
CP4-drivetrain





1) Hypothesis of damage profile of drivetrain

CP4 drivetrain function



	Coefficient of friction of roller / roller support
	Coefficient of friction of roller / cam

Function of the rollers of the roller on the cam is met when coefficient of friction of the roller cam is larger than the coefficient of friction of the roller / roller support.

Condition: μ_laufrolle-nocken > μ_laufrolle-rollenschuh

Typical values: μ_roller-cam: 0.11
μ_roller-roller support: 0.035

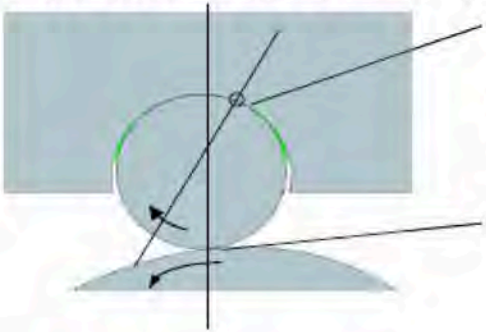
It can be concluded:

➔ Roller support surface is very smooth at every condition
Camshaft is rough at each condition

BOSCH

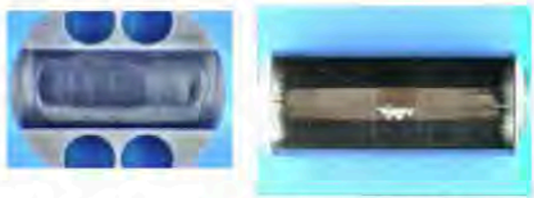
1) Hypothesis of damage profile of drivetrain

Flattening at the start, as the hydrodynamic lubricating wedge cannot set in when the roller rolls away



Deposits and / or vapor mixture prevent the buildup of a hydrodynamic pressure, thus no hydrodynamics and a stationary roller

Slip / wear



Boundary conditions for the non-buildup of hydrodynamic pressure:

- **Deposits** replace the fuel in the gap
- **Lack of lubrication,** too less fuel in the gap

Without fuel in the bearing gap, there is no build up of the hydrodynamics and thus no start-up of the roller

1) Hypothesis of damage profile of drivetrain

Damage sequence: Emergence of braking flats

Deposits in the roller support prevent the rocking of the roller in the roller support -> no buildup of hydrodynamics -> stationary / stiff roller -> Roller slides on the cam -> preliminary damage (braking flats on the roller).
Deposits are caused through deposition of biofuels / additives at temperatures > 140 °C.

Low-viscosity fuel at a low boiling temperature leads to evaporation of the fuel in the gap at high temperatures in the roller support (~ 200 °C) -> no buildup of hydrodynamics -> stationary / stiff roller -> roller slides on the cam -> preliminary damage (braking flats on the roller).

Low viscosity and low-boiling fuels with high proportion of additives (e.g. kerosene) combine both types.

BOSCH

1) Hypothesis of damage profile of drivetrain

Functional variables

Deposits in the roller support:

- ➔ Additives in the fuel
- ➔ aged biodiesel
- ➔ Temperatures > 140 °C between roller / roller support
  - Fuel with low viscosity
  - Air supply to the pump inlet / air in the pump interior
  - free water in the fuel
  - Cooling effect of the tappet body to the right CP4.2-RL is less (without AWP2)
  - reduced cooling quantity
  - Clogged filter through formation of deposits of aged biodiesel
  - Low-pressure supply in limit mode is not sufficient

Low-viscosity fuel at a low boiling temperature

- ➔ Temperatures > 140 °C between roller / roller support (see above)

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• **Overview of GQ**	**Audi**
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

BOSCH

Slides of Mr. [redacted]

BOSCH

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	**RB**
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

BOSCH

2) Findings Audi plants (engine / vehicle)

2) Findings Audi plants (engine / vehicle)

Summary

Analysis of 5 pumps from [redacted] vehicles after run-in distance (25 km)
Result: Roller with deposits and braking flats
Analysis of deposits: Iron hydroxide

Analysis of 5 pumps from incoming goods inspection [redacted] (engine from [redacted]) Result: No deposits

Analysis of 5 pumps from [redacted] vehicles (end of line).
Result: Deposits found on roller
Analysis of deposits D. 19.11.2010

Further work: Analysis of 5/25 pumps per vehicle plant (end of line)

ENTIRE PAGE CONFIDENTIAL

Overview of brown discoloration of components

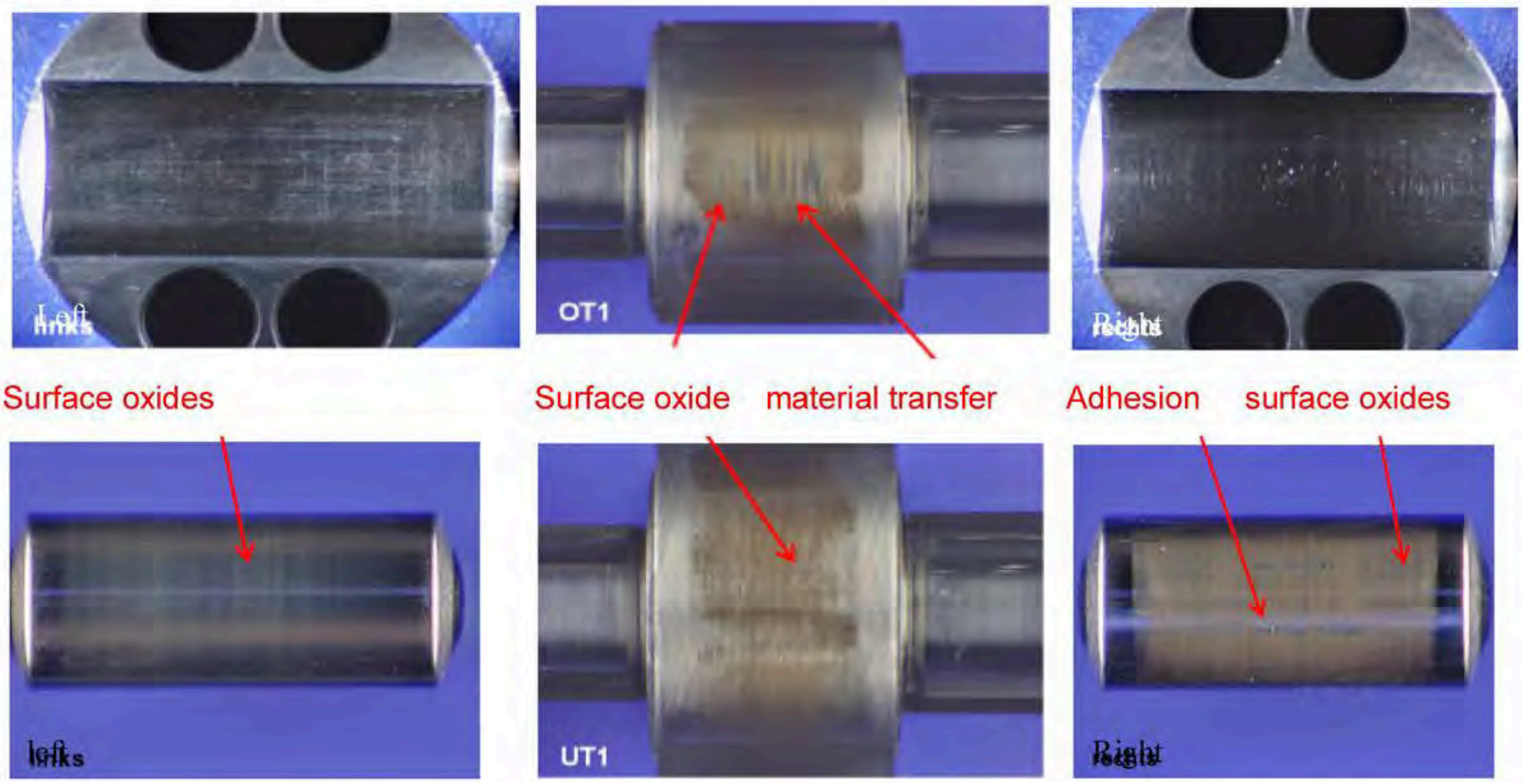
	Roller				Camshaft	Analysis of brown discoloration
	Coupling with brown discoloration	Brown ring	Brown bar	Material-transfer		
Feuerbach plant: DNA completion (Functioning OK)	0/900 Pump monthly	0/900 Pump monthly	0/900 Pump monthly	0/900 Pump monthly	0/900 Pump monthly	☺
[redacted] engine plant outgoing goods						(☺)
Vehicle plant [redacted] (End of line 0 km / pRail not OK)	3/4 Pump	2/4 Pump	0/4 Pump	0/4 Pump	0/4 Pump (brown)	☹
Vehicle plant in [redacted] (Parts receipt from [redacted]	0/5 Pump	0/5 Pump	0/5 Pump	0/5 Pump	2/5 Pump Corrosion	* ☺* *) Corrosion
Vehicle plant in Non-responsive content removed A6 2.7l local production	1/5 Pump	1/5 Pump	3/5 Pump	1/5 Pump	2/6 Pump (brown)	☹☹ 1 x : $Fe(OH)_2$
Vehicle plant in [redacted]						
Vehicle plant in [redacted]						
Vehicle plant in [redacted]						
Vehicle plant in [redacted]						

BOSCH

2) Findings Audi plants (engine / vehicle)

0 km pumps AUDI vehicle plant in [redacted] ([redacted])

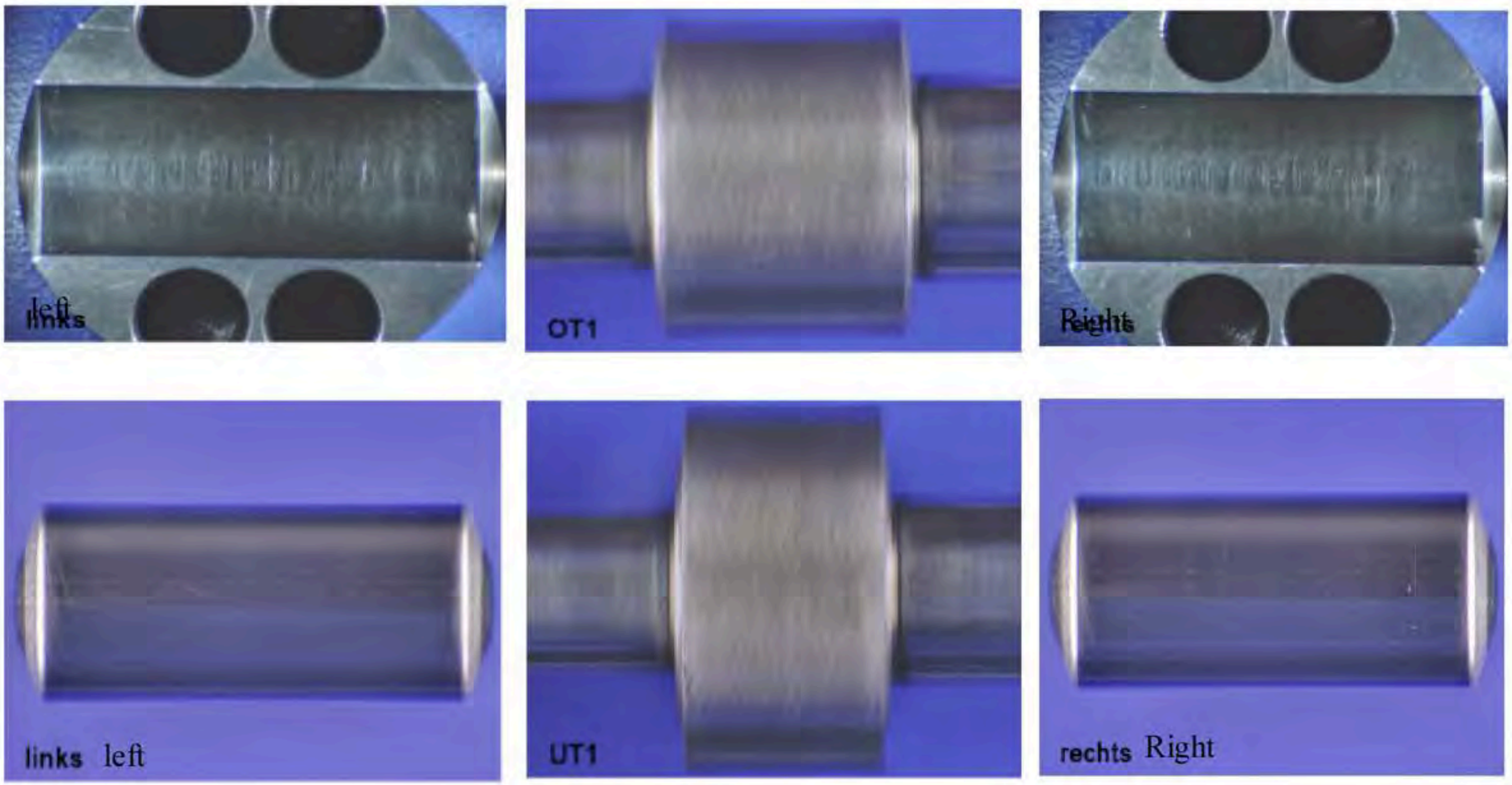
2010-CP4_0668 "good pump" with about 25 km (0445 010 611; DoM: 03.26.2010)



BOSCH

2) Findings Audi plants (engine / vehicle)

0 km pumps AUDI vehicle plant in [redacted] [redacted]
2010-CP4_0762 "good pump" goods receipt at [redacted] (0445 010 611; DoM: 04.26.2010)



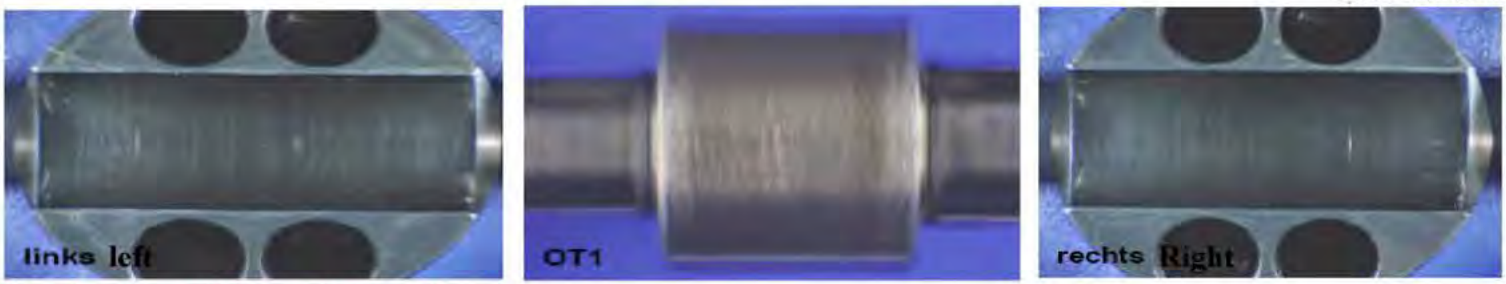
BOSCH

2) Findings Audi plants (engine / vehicle)

2010-CP4_0782 pump from the end of line at vehicle plant in Non-responsive content removed "0 km" pump without complaint

Veh. WAUZZZ8KXBA[redacted] Pump 0445010611, DoM: 9/29/2010

QTS: 3801075



Discolorations of fine stationary plates

Discolorations

BOSCH

Agenda 10.28.10

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	**Audi**
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

3) On-field measures

Slides of [redacted]

Agenda 10.28.10

Agenda

1. Hypothesis of damage profile of drivetrain — RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants
    - Overview of GQ — Audi
    - CP4 diagnosis of Volkswagen / Audi engine / vehicle plants — RB
3. On-field measures with AWP2 — Audi
4. **Low-pressure fuel system**
    - **Measures for low-pressure cycle** — **Audi**
    - Analyses on LPC (Q7 and Touareg) — RB
    - Analyses on individual low-pressure components — RB
    - Limit trial of start behavior with kerosene and biofuel — RB
5. Other possible robustness measures for world-wide usage — RB
6. Task Force Activity Recommendation — RB

4) Measures for low-pressure cycle

Slides of [redacted]

Agenda 10.28.10

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	**RB**
• Analyses on individual low-pressure components	**RB**
• Limit trial of start behavior with kerosene and biofuel	**RB**
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

BOSCH

Agenda 10.28.10

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• **Analyses on LPC (Q7 and Touareg)**	**RB**
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

4) Low-pressure cycle

Set of slides [redacted]

Agenda 10.28.10

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	**RB**
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

4) Analysis of low-pressure cycle components

Set of slides Non-responsive content removed

Agenda 10.28.10

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	**RB**
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

4) Limit trials with kerosene

BOSCH
Invented for life

4) Limit trials with kerosene

Summary

Objective: Formation of braking flats in the start case

Test bench

Start trials with kerosene @ 75 °C
Result after 80 cycles: Discolorations and flat spots on roller
Smoothing of camshaft, deposits on the rail system inlet

Further work

Provocation trials with intensification factors (start metering unit mode, without overrun, air supply) D. 11.30.2010

4) Limit trials with kerosene

Summary

Vehicle

1) Start trials with the filled system, kerosene
Result: No striking features

2) Start trials with the filled system, aged biodiesel
Result: Stationary plates

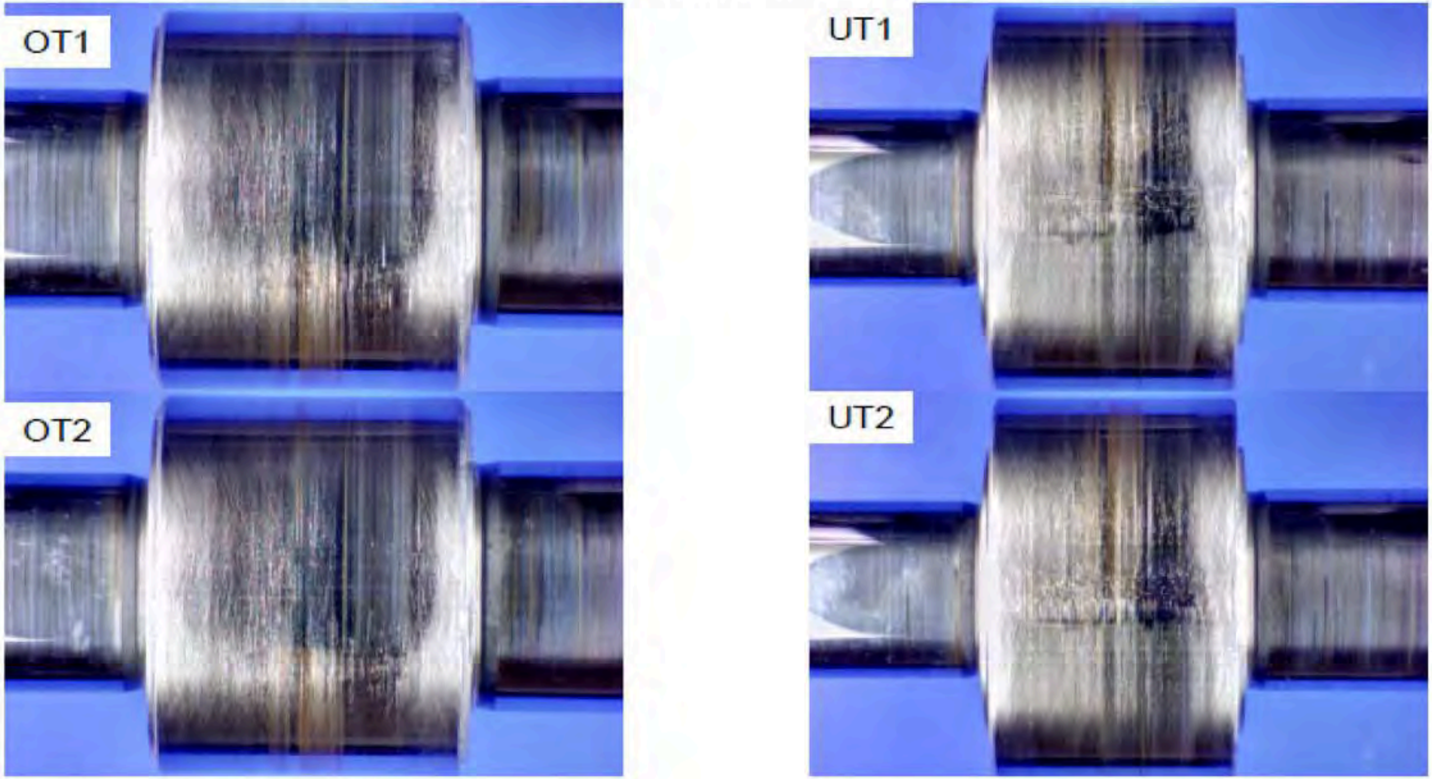
3) Start trial with the filled system, kerosene, "aged" tappet body with biodiesel
Result: Drivetrain damage due to flattening

Further work

Start trials with ventilated system	E.11.2011
Further start trials with differently "aged" tappet body	E.11.2011

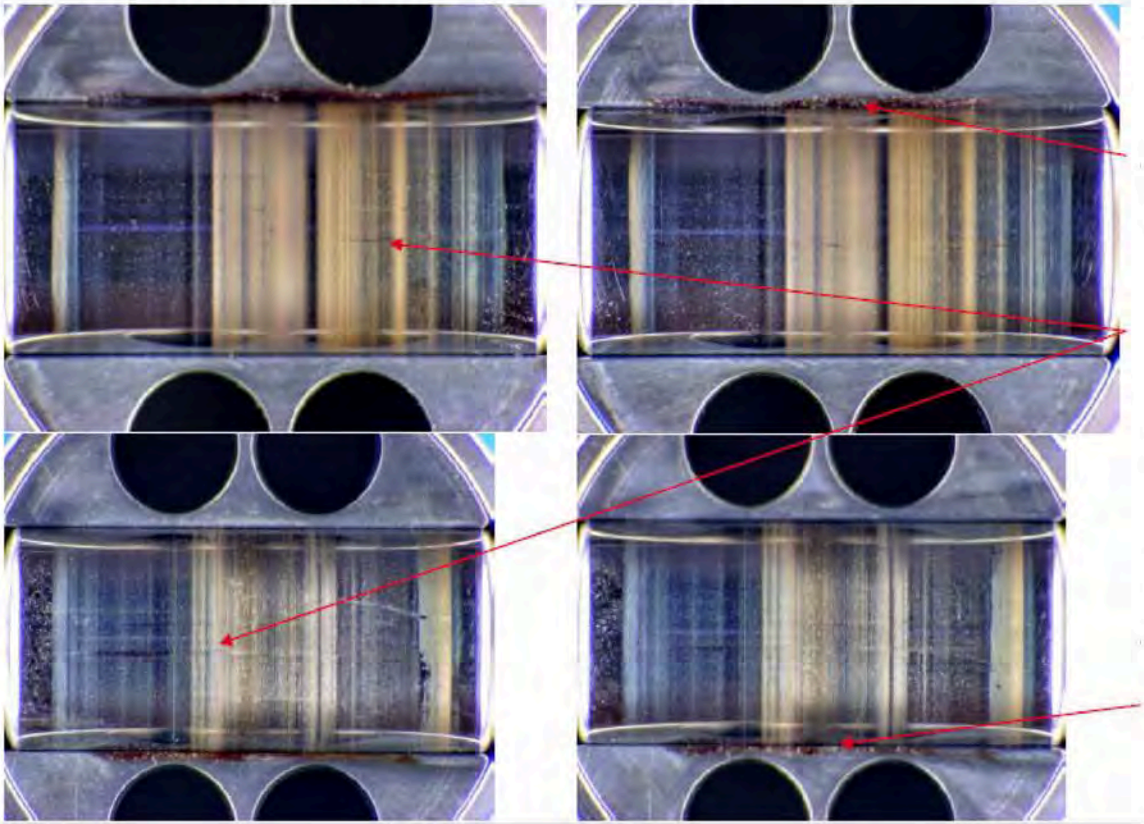
4) Limit trials with kerosene

Test bench: Images of camshaft after 80 cycles



4) Limit trials with kerosene

Test bench: Images after 80 cycles



left

Deposits on the rail system inlet

Stationary traces

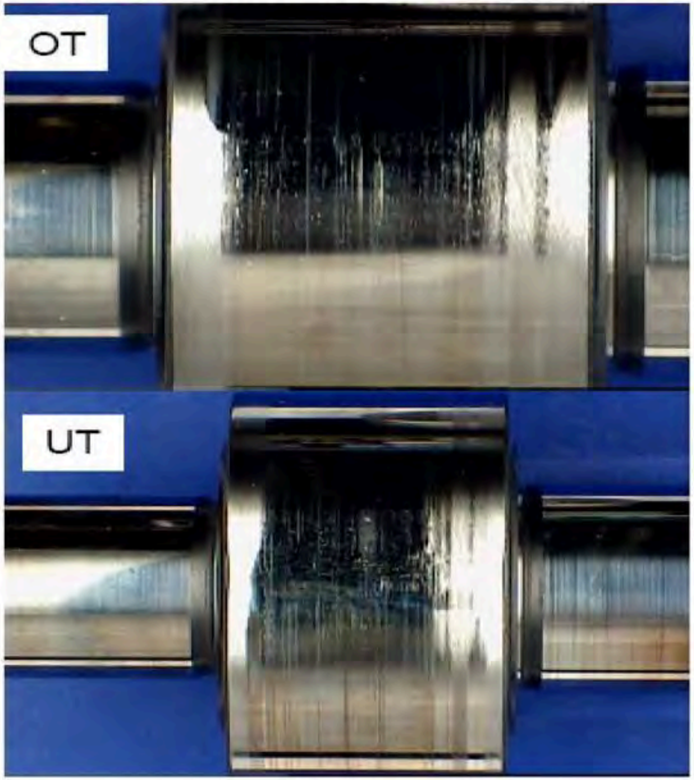
Right

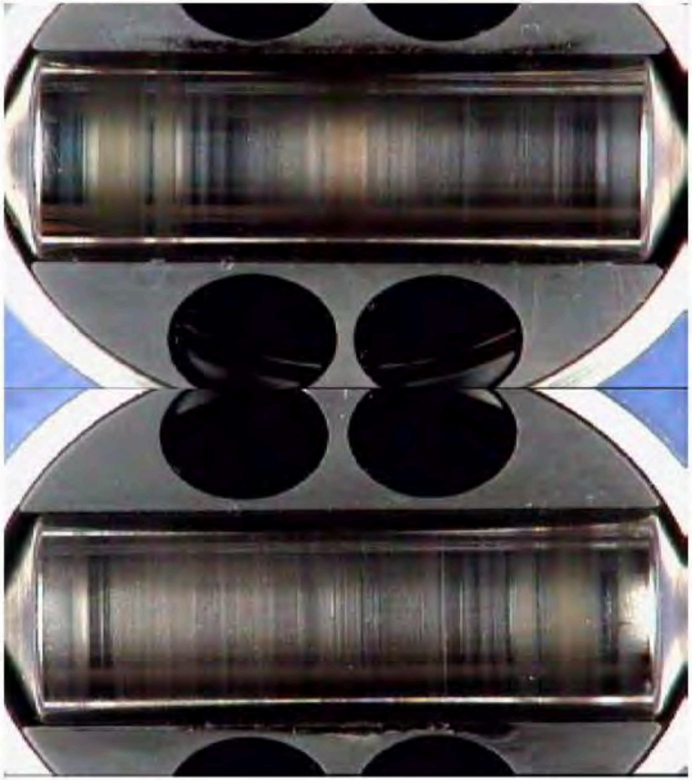
Deposits on

BOSCH

4) Limit trials with kerosene

Test bench: Smoothing of camshaft





Roller tappet left

Roller tappet the right

Agenda 10.28.10

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	RB

BOSCH

5) Other possible measures for worldwide usage

BOSCH
Invented for life

5) Other possible measures for worldwide usage

	package	Resp.	Platform measures	Prerequisite for customer delivery CP4.2	Result RB	RB possible Customer pattern deadline	Status as on 10.2010
1	**Transmission of force between roller / cam** finish direction camshaft Partly finished cam track	[redacted]	Start-up trials / roughness Temp. trials / QOLD Start-up trials / temp. trials MSS-T-HALT; GRV/Kerosene DL	QOLD MSS-T-HALT	12.2010 01.2011	02.2011 03.2011	
2	**reduced Drivetrain load** piston O 5.5+ stroke 7.5 3 uniform-acceleration cams	[redacted]	MBL2000bar; application influence on mapped determination of volumetric efficiency characteristic map Start-up trials for pressure dependence.	n-STOP 200 h	01.2011	03.2011	
3	**Hydrodynamic load-bearing behavior. Friction bearing** cylindrical roller lubricated friction bearing / roller crest spherical cam 3 uniform-acceleration cams	[redacted]	Design of drivetrain parts, production capability of drivetrain parts, endurance run kerosene / Global Robustness Validation [Fuel] Start-up trials (HSC / overload) constant endurance run 500h / product endurance run 2000h	Endurance run kerosene / Global Robustness Validation [Fuel] QOLD Product endurance run 1000h MSS-T-HALT	05.2011	09.2011	
4	**Hydrodynamic load-bearing behavior. Friction bearing** C3.1 +Unit layers development	[redacted]	QOLD Start-up trials (HSC / overload) Coefficient of friction model trials C-coating	MSS-T-HALT	03.2011	03.2011	
5	**Temperature inside the drivetrain** rail system at the tappet leveling hole interior pressure increase pö,üv	[redacted]	MBL volumetric efficiency Low-pressure pulsation / cavitation assessment of LP pulsation in the system QOLD MSS (Motor Start Stop) - T-stop	n-STOP - kerosene Fct. Trials for system assessment application	06.2011	08.2011	

BOSCH

Agenda

1. Hypothesis of damage profile of drivetrain	RB
2. Manufacturing processes in the VW / Audi engine / vehicle plants	
• Overview of GQ	Audi
• CP4 diagnosis of Volkswagen / Audi engine / vehicle plants	RB
3. On-field measures with AWP2	Audi
4. Low-pressure fuel system	
• Measures for low-pressure cycle	Audi
• Analyses on LPC (Q7 and Touareg)	RB
• Analyses on individual low-pressure components	RB
• Limit trial of start behavior with kerosene and biofuel	RB
5. Other possible robustness measures for world-wide usage	RB
6. Task Force Activity Recommendation	**RB**

BOSCH

6) Activity recommendation

6) Activity recommendation

Activity recommendation

1) Reduction in temperature and lack of lubrication

- ➔Introduction AWP2 RB-SOP WK43
- ➔Increase in flush volume in the start case
- ➔Checking leaks in the low-pressure cycle (wax stretching element, DBV)
- ➔EFPs reserve quantity verification
- ➔Improved switching-off process for EFP

2) Development of Reapaer test through provocation trials on the test bench and vehicle.

Activity recommendation

3) Intensive action in Non-responsive content removed to determine the cause of the deposits

4) Continuation of analysis of low-pressure cycle

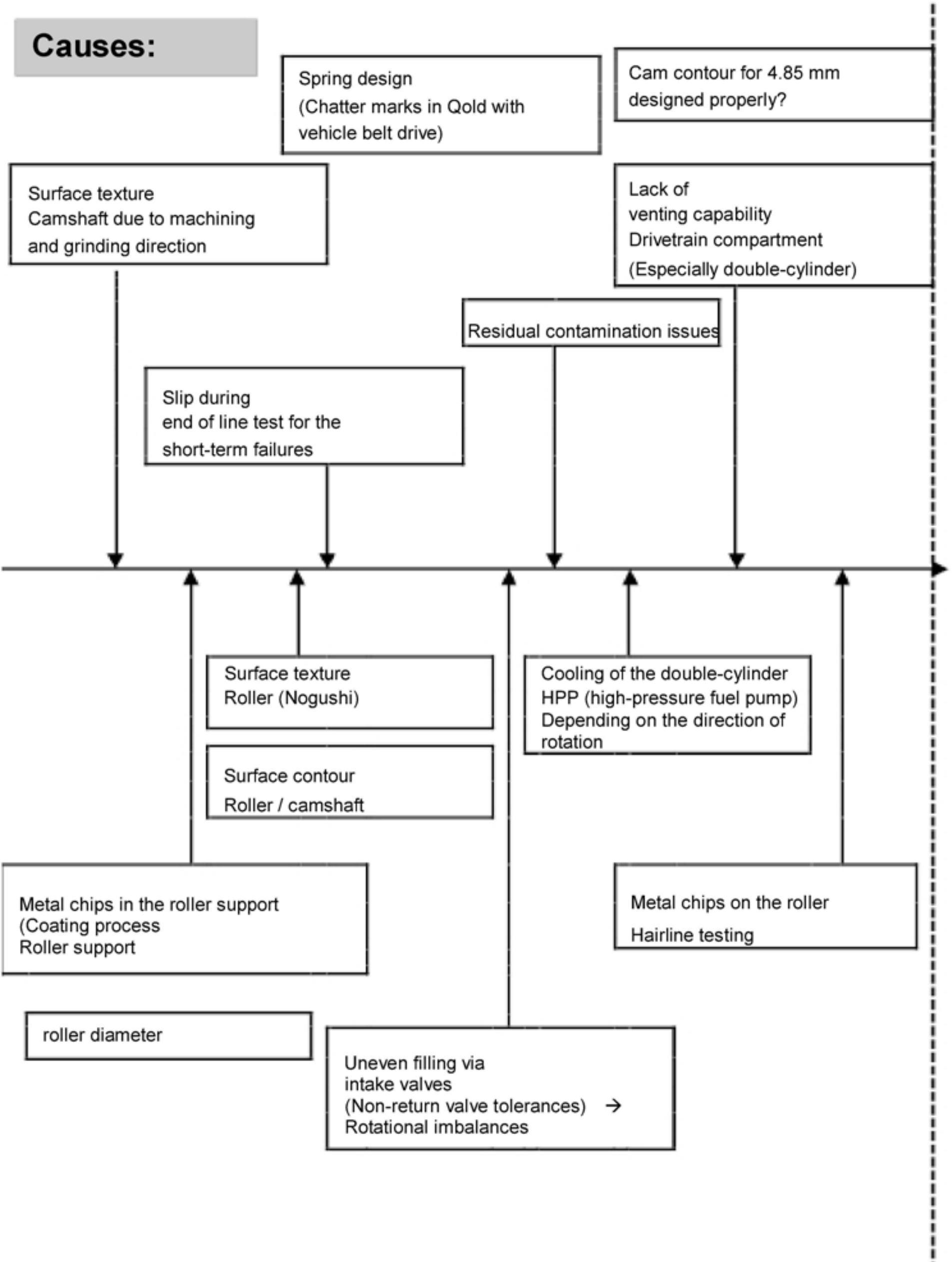
- 25 TI Inline EFP
- 25 LPF Systems [redacted]
- Vehicle trials with marginal low-pressure components

5) Launch of water separators for markets sensitive to fuel

BOSCH

EA11003EN-00166[0]

Outline of possible damage profile during drivetrain wear CP4.2 and the influencing variables



Non-responsive content removed

Notes on start-up of CRS3.2 with CP4.2 and presupply inline-EFP in the engine plant

this set of slides replaces set of slides [redacted] dated 03.08.2007 and set of slides [redacted] dated 07.19.2007

Status: 01.29.2008

BOSCH

Changes

➔ Current changes in the start-up regulations

date	Change	Slide no.
01.29.2008	→ Addition of a maximum negative pump rotation speed gradient for the cold test start-up (-1800 rpm/s)	Non-responsive content removed

BOSCH

To note during assembly

- Cleanliness requirements, particularly for supply lines to diesel fuel filter
- Assembly and service notes
- Assembly instructions (e.g. tightening torque), also see respective component TCDs and project drawings

Initial filling of injection system

- All TCD (Technical Customer Documentation) values must be followed!
- recommended filling fluid: Diesel fuel compliant DIN EN590, however, HFRR $\leq$ 400µm

Test to detect "gross leakage" from fuel system

- To detect gross leakage prior to start-up in the cold test, a pneumatic leakage test can be performed beforehand.

- Background: For safety, health, and cleanliness reasons, the fuel system should be checked for gross assembly defects (such as incorrect screwed connections) before it is filled with diesel fuel on the cold test bench.

Pneumatic leakage test of the injection system:

- The fuel system can be pneumatically tested with air* in the CP4-inlet with unpressurized total return flow with stationary high-pressure pump at 5 bar_{rel} for $t_{max} < 20$ s.

* see notes on slide 4

BOSCH

Notes on leakage test and cleaning, respectively, with gases or air

When using (compressed) air or gases for the leakage test and cleaning, there is risk of contamination caused by particles or water ingress.

The cleanliness requirements with regard to air must be followed:

- ➔ The air supply must be free of water and oil.
- ➔ The use of a filter of 0.3 mm is required to eliminate particulates contaminations from compressed air and gases.

[*RB recommendation: Series filter connection with 5µm [coarse] and 0.3 µm-Filter*]

Recommendation before venting, start-up, and cold test

→ Perform electrical check (e.g. CRI3.2: contacting, capacity measurement for low voltages, etc.
[Note: pay attention to line lengths and resistances of contact connectors])

→ Venting of Common-Rail system is performed for
- the low-pressure cycle through the CP4.2 return flow,
- The high-pressure section (CP4.2, rail) through intake or HP valve, through the PCV3.2 in total return flow.

→ For cold test start-up:
- Activation is not achieved by means of engine control unit → engine test rig controls are necessary
  - Activation of PCV3.2 and MU4
  - Injectors CRI3.2 do not inject

BOSCH

Venting high-pressure fuel pump CP4.2 (without gear pump) with presupply EFP (1)

Note the following conditions when venting the CP4:

→ Dry running of the high-pressure fuel pump is <u>not allowed</u>!

→ minimum loading/admission pressure of ≥ 4.5_{bar}abs must always be ensured through presupply EFP:

- Inlet pressure: $4.5 \leq p_{inlet}$ $[bar_{abs}] \leq 7$ *
- Volumetric flow > 80 l/h + HP fuel-quantity demand
- (Upper limit only restricted by max. inlet pressure).
- Differential pressure between inlet and return: $p_{inlet} - p_{return}$ flow ≳ 3.4 bar_{rel}

→ max. back pressure ≤ 2.0.bar_abs (continuous operation > 2.05 bar_abs can cause damage to the shaft seal).

→ At 0 bar rail pressure, the max. slip speed ** n_{CP} = 300 .. 1000 rpm [*RB-recommendation n_{CP} = 500 – 1000 rpm*]

* not a critical limit, but more is not advisable

BOSCH

Venting high-pressure fuel pump CP4.2 (without gear pump) with presupply EFP (2)

- → An important prerequisite for venting the C4 is that the rail pressure is near zero!

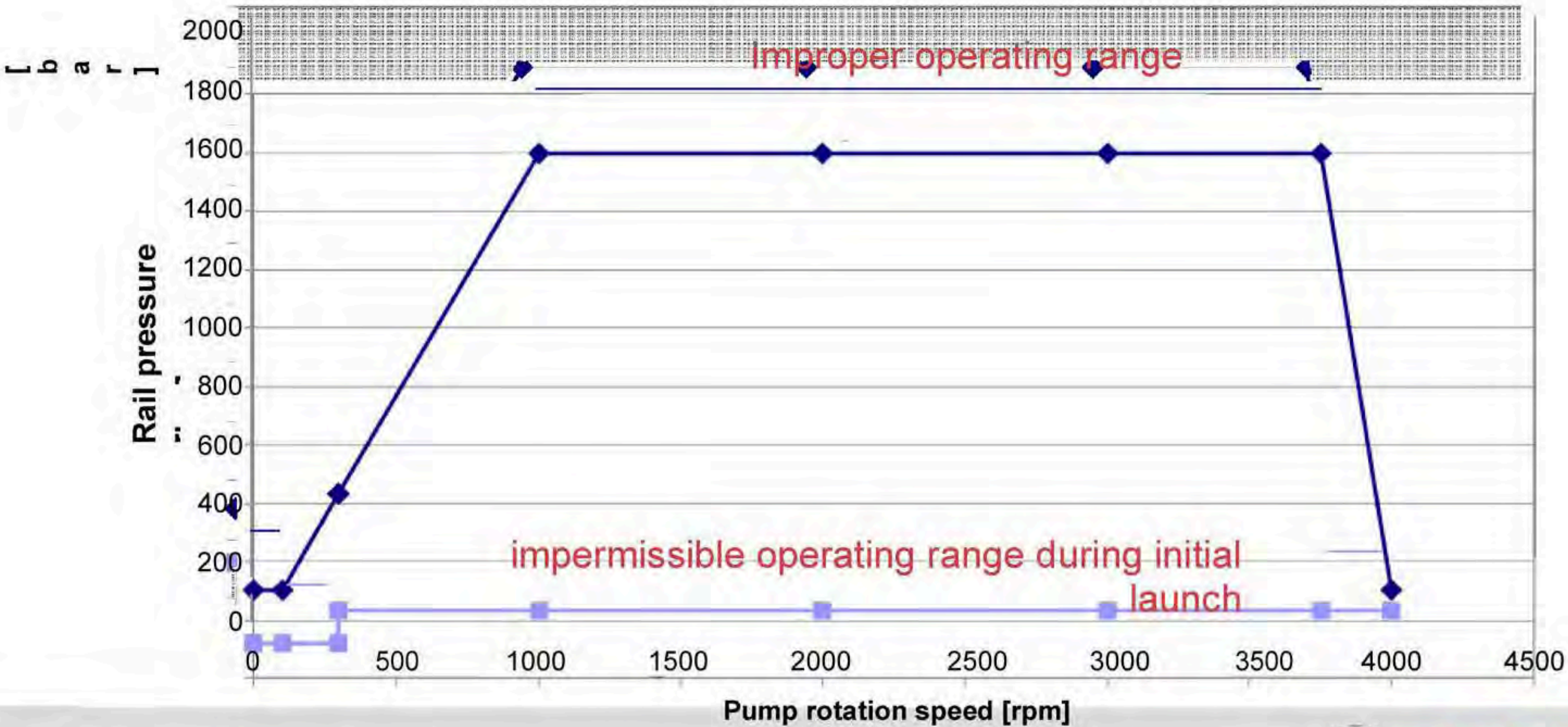
- → If there is static pressure in the rail, not even the compression ratio of the elements may be enough to deliver the air. In this case, the only venting path is through the HP piston guidance in the interior, which can take a long time.

- → If rail pressure is zero, a necessary pressure differential of **$3.1 \leq \Delta p\ [bar_{rel}] \leq 5.1$** over **intake and HP-valves is required.**

- → Since the **overflow valve** is set to approx**. $3.3\ bar_{rel}$** an EFP without rotating CP4 can only be vented if the tolerance values of the intake/HP valves are minimal.

Limit pressure curve CP4.2, cam 4.85 mm

Pump rotation speed [rpm]	0	100	300	300	1000	2000	3000	3750	4000
Engine speed [rpm]	0	133	400	400	1333	2667	4000	5000	5333
Max. rail pressure [bar]	300	300	633	633	1800	1800	1800	1800	300
Min. rail pressure [bar]	120	120	120	230	230	230	230	230	230



BOSCH

Overview procedure

Step 1LP/HP venting:

Continue filling the high-pressure fuel pump at a standstill until no further air bubbles are visible in the CP return flow or total return flow.
[*RB recommendation: Use of transparent inlet and return lines*] Notes: MU4 und PCV3.2 normally open; more efficient venting through back pressure-free total return flow bottom/top Presupply pressure > 4.5 bar_{abs}

Step 2 <u>Safe</u> venting of HP part:

Depending on the setting tolerance of intake/HP valve, possibly already completed in step 1 through EFP admission pressure.
Venting of intake/HP valve of CP4.2 by turning the high-pressure fuel pump with open (= normally) PCV3.2 until PCV-return flow is free of air bubbles.

→ System venting is complete; the system is ready for operation.

Detailed procedure

Step 1 LP/HP venting:

Venting time <u>without</u> speed: 10 (.. 20*) s
(this makes the low-pressure area safe; the high-pressure part is only conditionally vented, depending on the tolerance position of the intake/HP valves.)

Step 2 <u>Safe</u> **venting of HP part:**

Venting time <u>with</u> speed (300 ≤ n_{Slip} [rpm] ≤ 1000* after pre-venting of LP area: 5 to max. 10 s

→ max. allowed pos. CP4 speed gradient: **400 rpm/s**

→ **For Steps 1 and 2** applies: rail pressure p_{Rail} = 0 bar

<u>**Caution:**</u> **Step 2** is limited to max. 10 s! → **Risk of pump damage**

From **step 3** p_{Rail} ≥ 230 bar applies!

***RB recommendation**

Venting cold test start-up at engine plant

Step 1 Pre-venting of CP4.2 LP area

Q_{inlet} = 135 – 220 l/h (EFP or test rig supply)

alternative

p_{inlet} ≥ 4.5 bar_{abs} (≤ 7 bar_{abs}) [RB-recommendation: 5.0 bar_{abs}]

(static, leads to $Q_{return\ flow}$ ≈ 330 l/h@ p_{RL} = 1 bar_{abs}),

further increase p_{inlet} increases Q_{return} flow by 400 l/(h*bar)

p_{inlet} - $p_{return\ flow}$ ≥ 3.4 bar_{rel} [corresponds to $p_{Diff-CP}$ with $Q_{return\ flow}$ ≥ 80 l/h]

$p_{Return\ flow}$ ≤ 2.0 bar_{abs} (static)

$t_{Venting}$ ≥ 10 s

n_{Pump} = 0 min^{-1} | pump standstill [!]

p_{Rail} = 0 bar_{rel} (in relation to $p_{Return\ flow}$) | DRV3.2 open (non-energized)

Venting cold test start-up at engine plant

Step 2 complete venting CP4.2 HP area

Q_{inlet} = 135 – 220 l/h (EFP or test rig supply)

alternative

p_{inlet} ≥ 4.5 bar_{abs} (≤ 7 bar_{abs})

$p_{Return\ flow}$ ≤ 2.0 bar_{abs} (average pressure)

$t_{venting}$ t = 5 to max. 10 s [Caution: Risk of pump damage!]

n_{pump}[min.-1] = 1000 min-1 [max. allowed pos. CP4 speed gradient: 400 rpm/s]

p_{Rail} = 0 bar_{rel} (in relation to $p_{Return\ flow}$) | DRV3.2 open (non-energized)

→ System venting is complete; the system is ready for operation.

→ Further operation during start-up not under minimum rail pressure (p_{Rail} ≥ 230 bar), otherwise risk of pump damage!

→ When revving up the CP4 for the first time, the permissible **maximum positive CP4 engine speed gradient** is limited at 400 rpm/.

BOSCH

Further tests during cold test start-up

Step 3 Measurement of rail pressure fluctuation

testing whether venting occurred correctly or measuring the air that escapes during venting. [Caution: min. rail pressure pRail ≥ 230 bar]

Step 4 Test for high-pressure tightness → pRail ≥ 230 bar

with e.g. 1600 bar rail pressure and a pump rotation speed of 1500 rpm. Proposal: Duration* 30 sec.

After step 4 the system can be operated as in the vehicle. When shutting down the engine, **the permissible maximum negative CP4 engine speed gradient**: **-1800 rpm/s** (pay attention to the transmission ratio!)

*** depends on the program**

Further tests during cold test start-up

Proposal: Check HP tightness in purely pressure control valve operation (due to venting; better through PCV3.2)
Metering unit test: Function test through temporary closing of MU → Monitor drop in pressure (energization max. 1 s with 1.7±0.1A; not clocked)

At the end of the cold test, the fuel can remain in the system. It is possible to empty the counting point incl. inlet and return lines through blowing out (e.g. with air). [Pay attention to note on following slides!]
To transport the engine, seal the inlet and return connections of the injection system tightly with plugs, since HP and LP system are by-passed with deenergized PCV3.2. This is intended to prevent leakage of the system, particularly emptying of the rail.

Note: Filling of leakage oil seal is not supported in cold test; only in first start-up or hot test. Filling takes place through the control volume of the injectors during injection.

Emptying the LP-lines through blowing out (1)

To avoid entrainment of fuel, the LP area and thus the CP can be emptied by means of blowing out* (e.g. with clean air, nitrogen) in the connection at the EFT and the hot test, respectively.

However, the start-up behavior at the end of line in the vehicle plant deteriorates as a result of blowing the LP area empty. Hence, it must be ensured that a prior operation of the EFP is guaranteed in the line flow (this can be achieved via the intervention of a tester after the wet tank calibration).

This will avoid the CP from running without lubrication for an undefined period of time. Simultaneously, the CP cannot deliver air into the rail when the PCV is closed and rail is filled, so that a pressure build-up is not possible.

⋆ Observe the cleanliness requirement with respect to air on page 4!

BOSCH

Emptying the LP-lines through blowing out (2)

Only the LP-area is blown free to minimize the air-cleaned amount of fuel. This can happen in two ways.

1. Possibility (small inlet pressure, deenergized PCV):

   $p_{inlet} \leq 2.8$ bar_rel

   DRV deenergized

2. Possibility (high inlet pressure, PCV energized):

   $p_{inlet} \leq 5.0$ bar_rel DRV

   energized with 1.8 A

Otherwise, the following generally applies:

$-0.2 \leq p_{Return\ flow}[bar\_rel] \leq 1.0$

$t_{blow\ out} \leq 40$ sec.

$n_{Pump} = 0\ min.^{-1}$ (pump at standstill)

BOSCH

Overview of venting CP4.2 and further cold tests

No.	Speed CP4.2 [rpm]	CP4-return-flow pressure [bar_{abs}]	p_{Rail}	EFP [bar_{abs}]	DRV3.2	MU4	Min.-Duration [sec]	Max.-Duration [sec]	$Q_{erf,max}$ Inlet [l/h]	Remarks
1	0	1.0 - 1.2 max.2.0 Attention: pZU-pRü? 3.4bar_{rel}	0	min. 4.5 RB rec. 5.0	open I = 0 A	open I = 0 A Energization permitted (max. 1.7A ± 0.1A, not clocked; max 1s)	10 s	Unlimited Rb - Rec. 20 s	350l/h @ 4.0 bar_{rel}	Venting at standstill: CP-LP-Venting with EFP-admission pressure in the CP- inlet Securing the Fuel lubrication and venting of the Total system until (CP- bottom/top Pressure control valve-bottom/top Total-) return flow is free of air bubbles
2	(300...) 1000	1.0 - 1.2 max.2.0	0	min. 4.5	open I = 0 A	open I = 0 A	5 s	10 s	210l/h @ 3.5 bar_{rel}	For the secure ventilation of the HP-part(area after intake/HP-valves up tofor the PCV-return flow until free from air bubbles

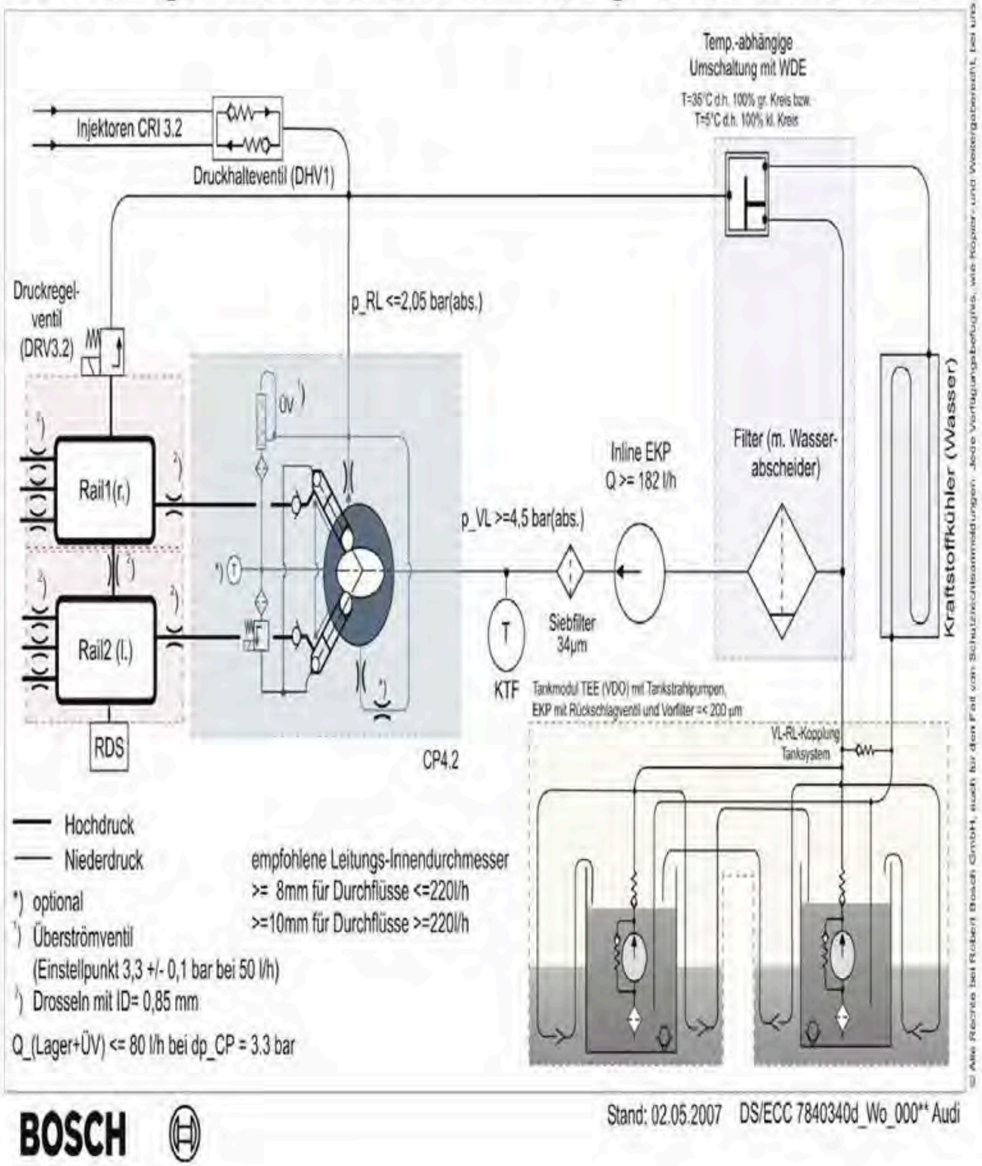
No.	Speed CP4.2 [rpm]	CP4-return-flow pressure [bar_{abs}]	p_{Rail}	EFP [barabs]	DRV3.2	MU4	Min.-Duration [sec]	Max.-Duration [sec]	Qerf,max Inlet [l/h]	Remarks
3	(300...) 1000	max.2.0	Start (?230)	min. 4.5	regulate	open I = 0 A	closed Determine	? 180 s	210l/h @ 3.5 bar_{rel}	Venting check through measurement of rail pressure fluctuation If, after 10 sec a stable starting pressure is not reached, cancel test
4	see limit-Pressure curve (Slide 7)	max.2.0	see limit - Pressure-curve (Slide 7) (?230)	min. 4.5	regulate	open I = 0 A	-	30 s	260l/h @ 3.5 bar_{rel}	Leakage check (temperature increase PCV-return flow), Attention: In the first hour of operation High speeds with subsequent fast drop in pressure are to be avoided

The following applies for steps 1-4: max allowed pos. of CP4 gradient: **400 rpm/s** and last max. negative CP4-gradient: **-1800 rpm/s**

Δp_{CP} > 3.4 bar_{rel} applies for all steps

BOSCH

Low-pressure layout for the Audi V6 TDI EU5 (Q7)



Injectors CRI 3.2

Pressure-holding valve (DHV1)

Temperature-dependent

switchover with WDE

T=35°C, that is 100% large cycle and T=5°C that is 100% small cycle, respectively

p_Return = 2.05 bar(abs.)

Pressure control valve (DRV3.2)

Flow-Return coupling tank system

CP4.2

High-pressure low-pressure

Recommended line inside diameter

Optional

Overflow valve

(Setpoint 3.3 +/- 011 bar at 50 1/11) throttle with 1l:) 0.85 mm

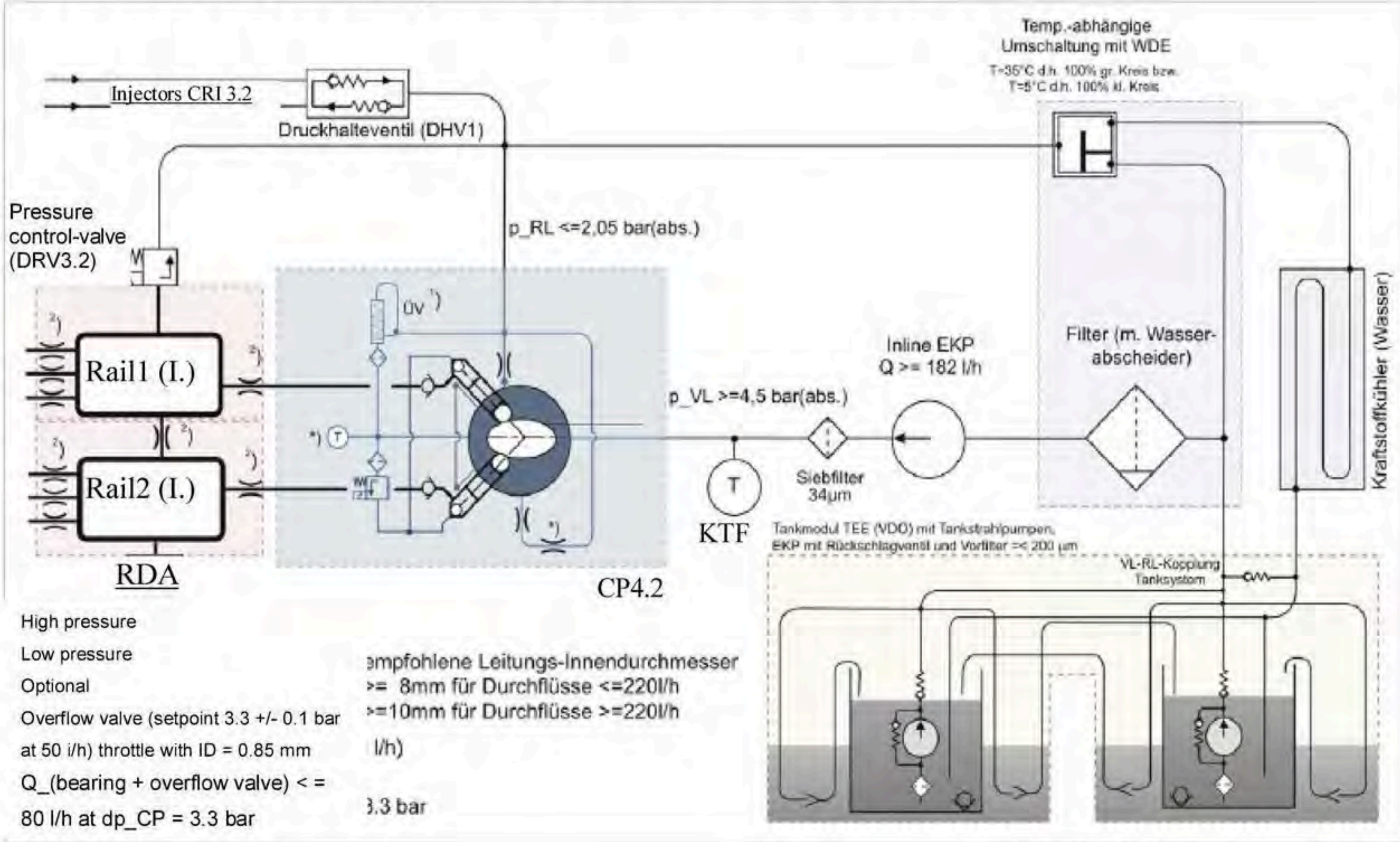
Q_(bearing+overflow valve) < = 80 Uh at db_CP = 3.3 bar

> = 8mm for flow rates < = 220l/h

> = 10mm for flow rates

Status 05.02.2007 DS/ECC 7840340d_Wo_000** Audi

Initial start-up Audi V6 TDI EU5



Status 05.02.2007 DS/ECC 7840340d_Wo_000** Audi

 Non-responsive content removed

ENTIRE PAGE CONFIDENTIAL

EA11003EN-00173[20]

Notes on start-up of CRS3.2 with CP4.2 and presupply inline-EFP in the engine plant

this set of slides replaces set of slides [redacted] dated 03.08.2007 and set of slides [redacted] dated 07.19.2007

Status: 01.29.2008

BOSCH

Changes

→ Current changes in the start-up regulations

Date	Change	Slide no.
01.29.2008	→ Addition of a maximum negative pump rotation speed gradient for the cold test start-up (-1800 rpm/s)	Non-responsive content removed

Audi V6 TDI EU5 and EU5 CO2: Notes on start-up in the engine plant

To note during assembly

- Cleanliness requirements, particularly for supply lines to diesel fuel filter
- Assembly and service notes
- Assembly instructions (e.g. tightening torque), also see respective component TCDs and project drawings

Initial filling of injection system

- All TCD values must be followed!
- recommended filling fluid: Diesel fuel compliant DIN EN590, however, HFRR ≤ 400µm

BOSCH

Test to detect "gross leakage" from fuel system

→ To detect gross leakage prior to start-up in the cold test, a pneumatic leakage test can be performed beforehand.

→ Background: For safety, health, and cleanliness reasons, the fuel system should be checked for gross assembly defects (such as incorrect screwed connections) before it is filled with diesel fuel on the cold test bench.

Pneumatic leakage test of the injection system:

→ The fuel system can be pneumatically tested with air* in the CP4-inlet with unpressurized total return flow with stationary high-pressure pump at **5** $\mathbf{bar_{rel}}$ for $\mathbf{t_{max}}$ < 20 s.

* see notes on slide 4

Notes on leakage test and cleaning, respectively, with gases or air

When using (compressed) air or gases for the leakage test and cleaning, there is risk of contamination caused by particles or water ingress.

The cleanliness requirements with regard to air must be followed:

→ The air supply must be free of water and oil.

→ The use of a filter of 0.3 mm is required to eliminate particulates contaminations from compressed air and gases.

[*RB recommendation: Series filter connection with 5µm [coarse] and 0.3 µm-Filter*]

BOSCH

Recommendation before venting, start-up, and cold test

→ Perform electrical check (e.g. CRI3.2: contacting, capacity measurement for low voltages, etc.
[Note: pay attention to line lengths and resistances of contact connectors])

→ Venting of Common-Rail system is performed for
- the low-pressure cycle through the CP4.2 return flow,
- the high-pressure section (CP4.2, rail) through intake or HP valves, through the PCV3.2 in total return flow.

→ For cold test start-up:
- Activation is not achieved by means of engine control unit → engine test rig controls are necessary
  - Activation of PCV3.2 and MU4
  - Injectors CRI3.2 do not inject

BOSCH

Venting high-pressure fuel pump CP4.2 (without gear pump) with presupply EFP (1)

Note the following conditions when venting the CP4:

→ Dry running of the high-pressure fuel pump is <u>not allowed</u>!

→ minimum loading/admission pressure of ≥ $4.5bar_{abs}$ must always be ensured through presupply EFP:

- Inlet pressure: $4.5 \leq p_{inlet}$ $[bar_{abs}] \leq 7$ *
- Volumetric flow > 80 l/h + HP fuel-quantity demand
- (Upper limit only restricted by max. inlet pressure).
- Differential pressure between inlet and return: $p_{inlet} - p_{return\ flow} \geq 3.4\ bar_{rel}$

→ max. back pressure ≤ 2.0.bar_abs (continuous operation > 2.05 bar_{abs} can cause damage to the shaft seal).

→ At 0 bar rail pressure, the max. slip speed ** n_{CP} = 300 .. 1000 rpm [*RB-recommendation n_{CP} = 500 – 1000 rpm*]

* not a critical limit, but more is not advisable

Venting high-pressure fuel pump CP4.2 (without gear pump) with presupply EFP (2)

- An important prerequisite for venting the CP4 is that the rail pressure is near zero!

- If there is static pressure in the rail, not even the compression ratio of the elements may be enough to deliver the air. In this case, the only venting path is through the HP piston guidance in the interior, which can take a long time.

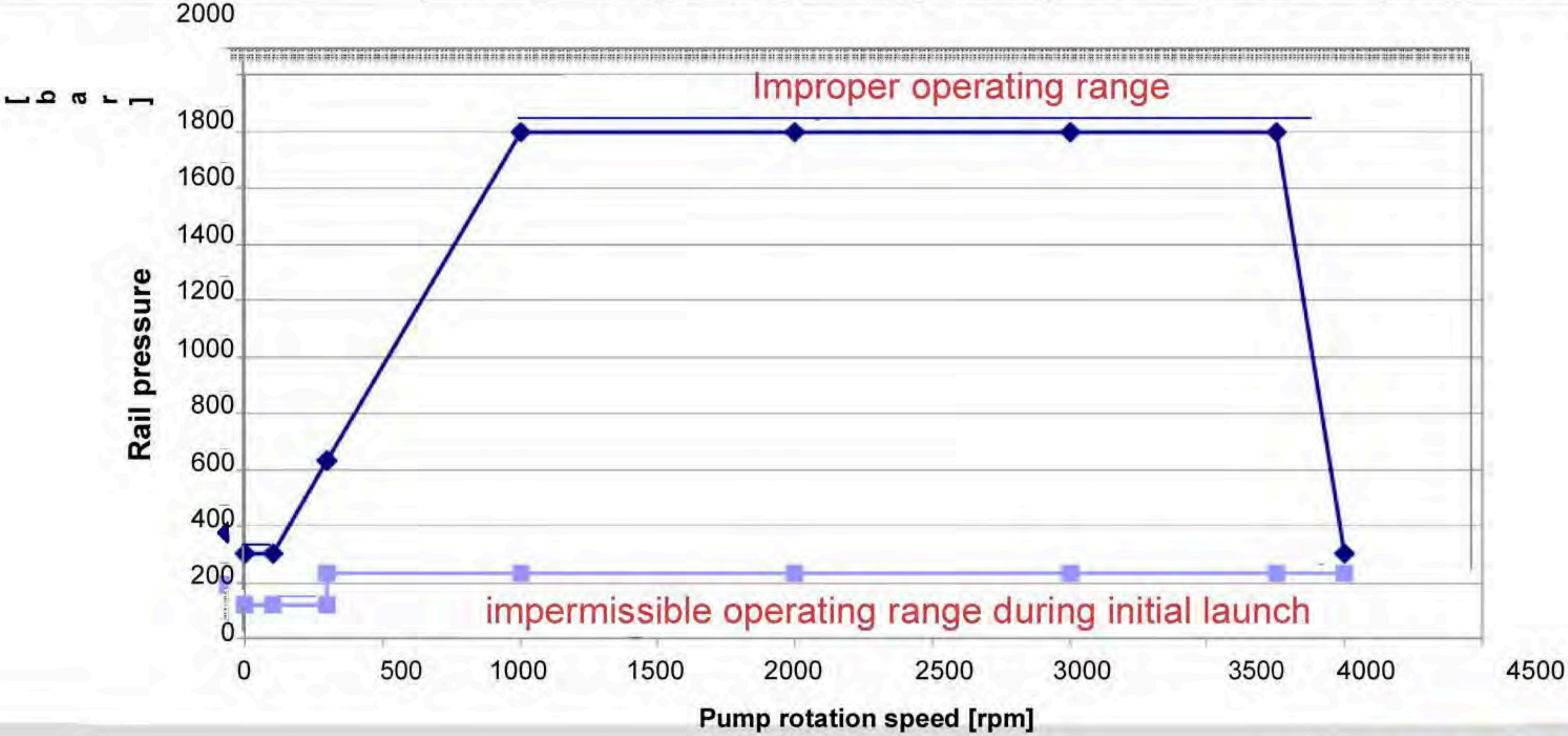
- If rail pressure is zero, a necessary pressure differential of **$3.1 \le \Delta p\ [bar_{rel}] \le 5.1$** over **intake and HP-valves is required.**

- Since the **overflow valve** is set to approx**. $3.3\ bar_{rel}$** an EFP without rotating CP4 can only be vented if the tolerance values of the intake/HP valves are minimal.

BOSCH

Limit pressure curve CP4.2, cam 4.85 mm

Pump rotation speed [rpm]	0	100	300	300	1000	2000	3000	3750	4000
Engine speed [rpm]	0	133	400	400	1333	2667	4000	5000	5333
Max. rail pressure [bar]	300	300	633	633	1800	1800	1800	1800	300
Min. rail pressure [bar]	120	120	120	230	230	230	230	230	230



BOSCH

Overview procedure

Step 1 LP/HP venting:

Continue filling the high-pressure fuel pump at a standstill until no further air bubbles are visible in the CP return flow or total return flow.
[*RB recommendation: Use of transparent inlet and return lines*]
Notes: MU4 und PCV3.2 normally open; more efficient venting through back pressure-free total return flow bottom/top Presupply pressure > 4.5 bar_{abs}

Step 2 <u>Safe</u> venting of HP part:

Depending on the setting tolerance of intake/HP valve, possibly already completed in step 1 through EFP admission pressure.
Venting of intake/HP valve of CP4.2 by turning the high-pressure fuel pump with open (= normally) PCV3.2 until PCV-return flow is free of air bubbles.
→ System venting is complete; the system is ready for operation.

BOSCH

Detailed procedure

Step 1 LP/HP venting:

Venting time <u>without</u> speed: 10 (.. 20*) s
(this makes the low-pressure area safe; the high-pressure part is only conditionally vented, depending on the tolerance position of the intake/HP valves.)

Step 2 <u>Safe</u> venting of HP part:

Venting time <u>with</u> speed (300 ≤ n_{Slip} [rpm] ≤ 1000* after pre-venting of LP area: 5 to max. 10 s

→ max. allowed pos. CP4 speed gradient:**400 rpm/s**

→ For **Steps 1 and 2** applies: Rail pressure p_{Rail} = 0 bar

<u>Caution</u>: **Step 2** is limited to max. 10 s! → **Risk of pump damage**

From **step 3** p_{Rail} ≥ 230 bar applies!

*RB recommendation

Venting cold test start-up at engine plant

Step 1 Pre-venting of CP4.2 LP area

Q_{inlet} = 135 – 220 l/h (EFP or test rig supply)

alternative

p_{inlet} ≥ 4.5 bar_{abs} (≤ 7 bar_{abs}) [RB-recommendation: 5.0 bar_{abs}]
(static, leads to $Q_{return\ flow}$ ≈ 330 l/h@ p_{RL} = 1 bar_{abs}),
further increase p_{inlet} increases $Q_{return\ flow}$ by 400 l/(h*bar)

p_{inlet} - $p_{return\ flow}$ ≥ 3.4 bar_{rel} [corresponds to $p_{Diff\text{-}CP}$ with $Q_{return\ flow}$ ≥ 80 l/h]

$p_{Return\ flow}$ ≤ 2.0 bar_{abs} (static)

$t_{Venting}$ ≥ 10 s

n_{Pump} = 0 min^{-1} | pump standstill [!]

p_{Rail} = 0 bar_{rel} (in relation to $p_{Return\ flow}$) | DRV3.2 open (non-energized)

Venting cold test start-up at engine plant

Step 2 complete venting CP4.2 HP area

Q_{inlet} = 135 – 220 l/h (EFP or test rig supply)

alternative

p_{inlet} ≥ 4.5 bar_{abs} (≤ 7 bar_{abs})

$p_{Return\ flow}$ ≤ 2.0 bar_{abs} (average pressure)

$t_{venting}$ t = 5 to max. 10 s [Caution: Risk of pump damage!]

n_{pump} [min.-1] = 1000 min-1 [max. allowed pos. CP4 speed gradient: 400 rpm/s]

p_{Rail} = 0 bar_{rel} (in relation to $p_{Return\ flow}$) | DRV3.2 open (non-energized)

→ System venting is complete; the system is ready for operation.

→ Further operation during start-up not under minimum rail pressure (pRail ≥ 230 bar), otherwise risk of pump damage!

→ When revving up the CP4 for the first time, the permissible **maximum positive CP4 engine speed gradient** is limited at 400 rpm/.

BOSCH

Further tests during cold test start-up

Step 3 Measurement of rail pressure fluctuation

Testing whether venting occurred correctly or measuring the air that escapes during venting. [Caution: min. rail pressure pRail ≥ 230 bar]

Step 4 Test for high-pressure tightness → pRail ≥ 230 bar

with e.g. 1600 bar rail pressure and a pump rotation speed of 1500 rpm. Proposal: Duration* 30 sec.

After step 4 the system can be operated as in the vehicle. When shutting down the engine, **the permissible maximum negative CP4 engine speed gradient**: **-1800 rpm/s** (pay attention to the transmission ratio!)

* depends on the program

Further tests during cold test start-up

Proposal: Check HP tightness in purely pressure control valve operation (due to venting; better through PCV3.2)
Metering unit test: Function test through temporary closing of MU→Monitor drop in pressure (energization max. 1 s with 1.7±0.1A; not clocked)

At the end of the cold test, the fuel can remain in the system. It is possible to empty the counting point incl. inlet and return lines through blowing out (e.g. with air). [Pay attention to note on following slides!]
To transport the engine, seal the inlet and return connections of the injection system tightly with plugs, since HP and LP system are by-passed with deenergized PCV3.2. This is intended to prevent leakage of the system, particularly emptying of the rail.

Note: Filling of leakage oil seal is not supported in cold test; only in first start-up or hot test. Filling takes place through the control volume of the injectors during injection.

Emptying the LP-lines through blowing out (1)

To avoid entrainment of fuel, the LP area and thus the CP can be emptied by means of blowing out* (e.g. with clean air, nitrogen) in the connection at the EFT and the hot test, respectively.

However, the start-up behavior at the end of line in the vehicle plant deteriorates as a result of blowing the LP area empty. Hence, it must be ensured that a prior operation of the EFP is guaranteed in the line flow (this can be achieved via the intervention of a tester after the wet tank calibration).

This will avoid the CP from running without lubrication for an undefined period of time. Simultaneously, the CP cannot deliver air into the rail when the PCV is closed and rail is filled, so that a pressure build-up is not possible.

* Observe the cleanliness requirement with respect to air on page 4!

BOSCH

Emptying the LP-lines through blowing out (2)

Only the LP-area is blown free to minimize the air-cleaned amount of fuel. This can happen in two ways.

1. Possibility (small inlet pressure, deenergized PCV):

   $p_{Inlet} \leq 2.8$ bar_rel

   DRV deenergized

2. Possibility (high inlet pressure, PCV energized):

   $p_{Inlet} \leq 5.0$ bar_rel DRV

   energized with 1.8 A

Otherwise, the following generally applies:

$-0.2 \leq p_{Return\ flow}$ [bar_rel] ≤ 1.0

$t_{blow\ out} \leq 40$ sec.

$n_{Pump} = 0$ min.$^{-1}$ (pump at standstill)

BOSCH

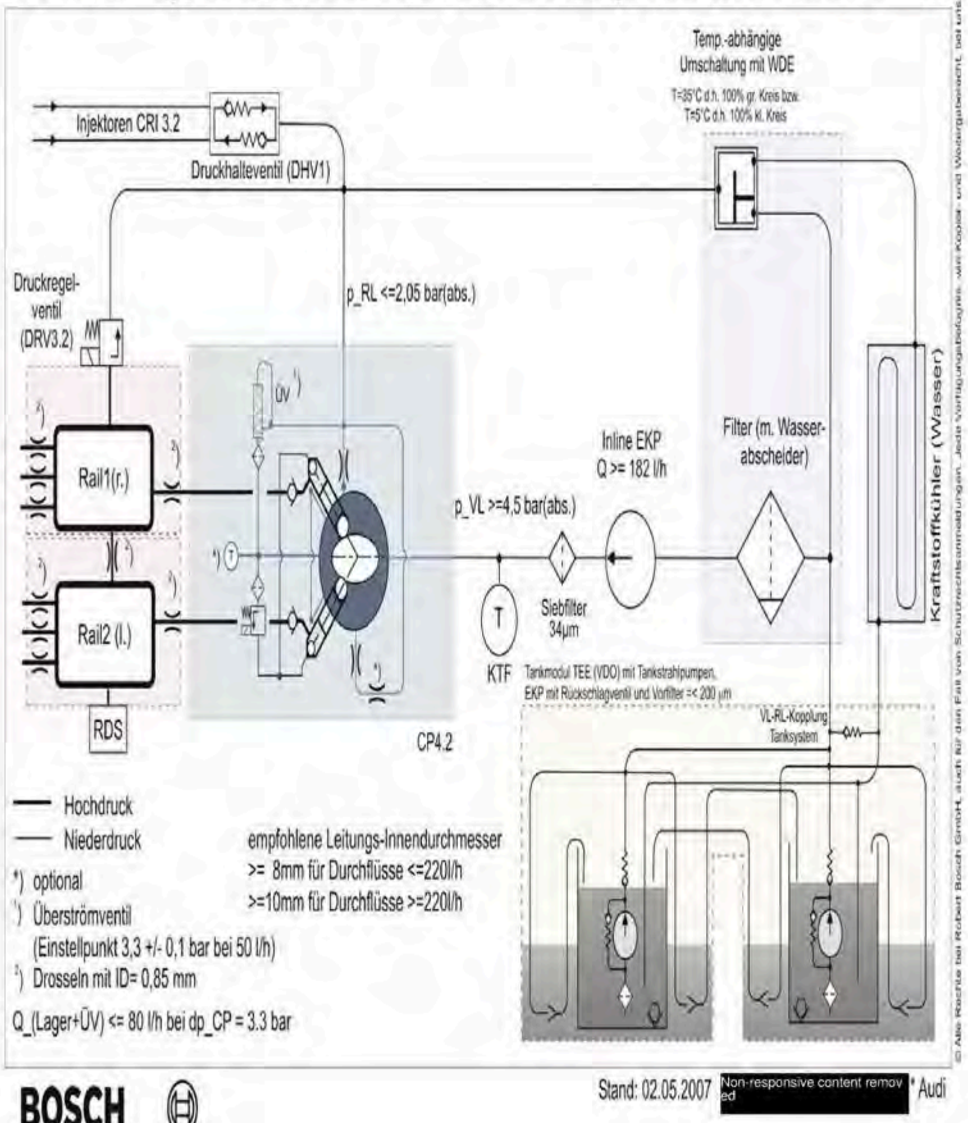
Overview of venting CP4.2 and further cold tests

No.	Speed CP4.2 [rpm]	CP4-return-flow pressure [bar_{abs}]	p_{Rail}	EFP [bar_{abs}]	DRV3.2	MU4	Min.-Duration [sec]	Max.-Duration [sec]	$Q_{erf,max}$ Inlet [l/h]	Remarks
1	0	1.0 - 1.2 max.2.0 Attention: pzu-pRü? 3.4bar_{rel}	0	min. 4.5 RB rec. 5.0	open I = 0 A	open I = 0 A Energization permitted (max. 1.7A ± 0.1A, not clocked; max 1s)	10 s	Unlimited Rb - Rec. 20 s	350l/h @ 4.0 bar_{rel}	Venting at standstill: CP-LP-Venting with EFP-admission pressure in the CP- inlet Securing the Fuel lubrication and venting of the Total system until (CP- bottom/top Pressure control valve-bottom/top Total-) return flow is free of air bubbles
2	(300...) 1000	1.0 - 1.2 max.2.0	0	min. 4.5	open I = 0 A	open I = 0 A	5 s	10 s	210l/h @ 3.5 bar_{rel}	For the secure ventilation of the HP-part(area after intake/HP-valves up to for the PCV-return flow until free from air bubbles
3	(300...) 1000	max.2.0	Start (?230)	min. 4.5	regulate	open I = 0 A	closed Determine	? 180 s	210l/h @ 3.5 bar_{rel}	Venting check through measurement of rail pressure fluctuation If, after 10 sec a stable starting pressure is not reached, cancel test
4	see limit-Pressure curve (Slide 7)	max.2.0	see limit - Pressure-curve (Slide 7) (?230)	min. 4.5	regulate	open I = 0 A	-	30 s	260l/h @ 3.5 bar_{rel}	Leakage check (temperature increase PCV-return flow), Attention: In the first hour of operation High speeds with subsequent fast drop in pressure are to be avoided

The following applies for steps 1-4: max allowed pos. of CP4 gradient: **400 rpm/s** and last max. negative CP4-gradient: **-1800 rpm/s**

■Δp_{CP} > 3.4 bar_{rel} applies for all steps

Low-pressure layout for the Audi V6 TDI EU5 (Q7)



Injectors CRI 3.2

Pressure retaining valve (DHV1)

Temperature-dependent

switchover with WDE

T=35°C, that is 100% large cycle and T=5°C that is 100% small cycle, respectively

p_Return = 2.05 bar(abs.)

Pressure control valve (DRV3.2)

Flow-Return-coupling tank system

CP4.2

High-pressure low-pressure

Recommended line inside diameter

Optional

Overflow valve

(Setpoint 3.3 +/- 011 bar at 50 1/11) throttle with 1I:) 0.85 mm

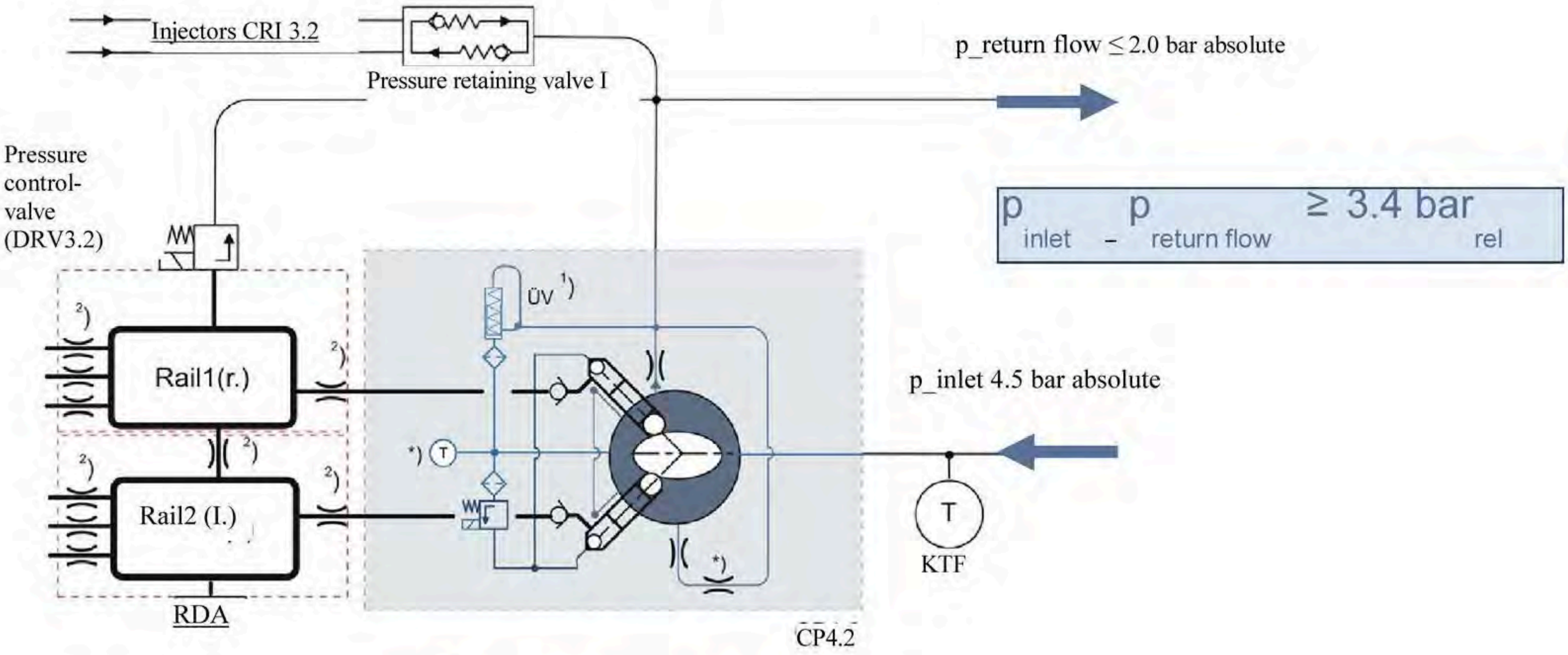
Q_(bearing+overflow valve) < = 80 Uh at db_CP = 3.3 bar

> = 8mm for flow rates < = 220l/h

> = 10mm for flow rates

Status 05.02.2007 DS/ECC 7840340d_Wo_000** Audi

Initial start-up Audi V6 TDI EU5



High pressure
Low pressure

*) Optional
1) Overflow valve
(setpoint 3.3 +/- 0.1 bar at 50 l/h)
2) throttle with ID = 0.85 mm
Q_(bearing + overflow valve) < = 80 l/h at dp_CP = 3.3 bar

ENTIRE PAGE CONFIDENTIAL

EA11003EN-00201[0]

Engine number:	QTS CP7, QTS [redacted]	Fault description	Note	Fault location	Customer	Fault logged	Engine construction data	Test sequences. KT Appendix	Hot test	
CAG 007960	2864884	HP Pump F. not OK	Not OK - no analysis available even at Bosch, up to 99% chips at the intake valve	CP7	Non-responsive content removed	07.01.2008 09:11				
CAG 016823	2901412	HP fuel pump not OK - was taken out of the statistics	Not OK	CP7		11.02.2008 12:37				
CAG 057763	3006768, 3016112	HP Pump F. not OK	Chip in the intake valve - avoidance of foreign particles / cleanliness / residual contamination	CP7		05.05.2008 16:17				
CAG 062587	3014970, 3023819	HP Pump F. not OK	Chip in the intake valve - avoidance of foreign particles / cleanliness / residual contamination	CP8		21.05.2008 00:00				
CAG 117188	31055567, 3114236	HP Pump F. not OK	Not OK - sent out on 08.26.08	CP7		11.08.2008 14:37				
CAG 130085	3123671, 3128323	Leaking at radial shaft seal. Radial shaft seal damaged	sent out, [redacted] had a look at the part at our place	CP7						
CAG 148374	3170517, 3167175	no pressure	Picked up from [redacted] by Bosch	CP7		09.10.2008	26.09.2008	ran 1x - appendix 4	no	no drivetrain damage: chip in intake valve
CAG 155306	3166777, 3167143	Chips in the high-pressure pump	Picked up from IN by [redacted]	CP7		14.10.2008	09.10.2008	ran 1x - appendix 1	no	**Drivetrain damage**
CAG 152161	3167368, 3167381	Chips in the high-pressure pump	Picked up from IN by [redacted]	CP7		14.10.2008	06.10.2008	ran 1x - appendix 3	no	**Drivetrain damage**
CAG 152161 same engine once again	3177710, 3181901	Engine noise, chip in the injection system	Should be picked up from [redacted] by Bosch	CP7		22.10.2008	06.10.2008	ran 1x - appendix 3	no	Same engine, consequential errors Which error?
CAG 157409	[illegible] [redacted]	no rail pressure, engine noises (HP pump?!)	Will be collected from [redacted] on 10.28.08 [redacted] [illegible] Bosch has picked up the part and delivered to Bosch.	CP7		22.10.2008	11.10.2008	ran 1x - appendix 3	no	**Drivetrain damage**
CAG [illegible]	still none, 3182328 [redacted] **2012, 15 levels**	No rail pressure	Will be collected from [redacted] on 10.28.08.	CP7		27.10.2008	16.10.2008	ran 1x - appendix 3	no	which fault?
CAG 160485	3187448, 3194123	HP pump noise Chips in the pump	Arrived at [redacted]	CP7		30.10.2008	11.10.2008	ran 1x - appendix 4	no	**Drivetrain damage**
CAG 162537	3186252, 3194115	Engine no longer starts, HP pump defect.	Arrived at [redacted] - dismantled along with [redacted] - roller abraded, no longer round. Cam surface is worn	CP7		30.10.2008	11.10.2008	ran 1x - appendix 4	no	**Drivetrain damage**
CAG [illegible]	3203922, 3182328	Chips in the HP fuel pump - engine was replaced [redacted]	Engine changed	CP7		08.11.2008	16.10.2008	ran 1x - appendix 3	no	Same engine, consequential errors Which error?
CBA 429395	3209634, 3217276	high-pressure fuel pump	Pump changed	CP7		20.11.2008	13.11.2008	ran 1x - appendix 4	no	High pressure fuel pump (HPFP) on 12.2


to Bosch

VW-R4 2.0l EU5
– CRS3.2 –

Notes on start-up of common rail system with CP4.1 and presupply inline-electric fuel pump in connection with cold test

1/14/2008

Notes:

This slide replaces the slides [redacted] {12.01.05} and [redacted] {12.09.05};

14911d_Zu **{03.14.06}** [Changes marked in "red"]

6860199d_Zu {06.27.06} **[Changes marked in "blue"]**

6870329d_Zu {08.02.06} **[Changes marked in "green"]**

6890468d_Zu {13.09.06} **[Changes marked in "pink"]**

6900721d_Zu {10.31.06} **[Changes marked in "light green"]**

7580457d_Zu {05.14.07} **[Changes marked in "light blue"]**

Values marked with **U** are defined; the "U" marking was deleted.

BOSCH

VW R4_2.0l: Notes on start-up of CRS3.2

To note during assembly:

→ Cleanliness requirements, particularly for supply lines to diesel fuel filter.

→ Assembly and service notes.

→ Assembly instructions (e.g. tightening torques), also see respective component TCDs and project drawings.

Initial filling of injection system

→ All TCD values must be followed!

→ recommended filling fluid: Diesel fuel compliant DIN EN590, however HFRR ≤ 400µm

VW-R4_2.0l: Notes on start-up of CRS3.2

Test to detect "gross leakage" from fuel system

To detect gross leakage prior to start-up in the cold test, a pneumatic leakage test can be performed beforehand.

Background: For safety, health, and cleanliness reasons, the fuel system should be checked for gross assembly defects (such as incorrect screwed connections) before it is filled with diesel fuel on the cold test bench.

Pneumatic leakage test of the injection system:

The fuel system can be pneumatically tested with air* in the CP4-inflow with depressurized
Total return flow for a **stationary** high-pressure fuel pump with **5bar_rel** for $t_{max.}$ **<30s** can be pneumatically tested with air*.
*Page 17

BOSCH

VW-R4_2.0l: Notes on start-up of CRS3.2

Recommendation before venting, start-up, and cold test:

→ Perform electrical check (e.g. CRI3.2: contacting, capacity measurement for low voltages, etc.
{Note: pay attention to line lengths and resistances of contact connectors})

Venting of Common-Rail system is performed for
- the low-pressure cycle through the CP4 return flow,
- the high-pressure section (CP4, rail) through intake or HP valves, through the PCVu in total return flow.

For cold test start-up:
→ Activation is not achieved by means of engine CU→, engine test bench controls are necessary
(Activation of PCVu, metering unit; CRI3.2 should not inject)

BOSCH

VW-R4_2.0l: Notes on start-up of CRS3.2

Venting high-pressure fuel pump CP4 (without GP) with presupply EFP

Note the following conditions when venting the CP4:

→ **Dry running** of the high-pressure fuel pump is **not allowed**!

→ minimum loading/admission pressure of ≥ 4.5bar_abs must always be ensured through presupply EFP:

- → **Inlet pressure: 4.5 ≤ p_inlet [bar_abs] ≤ 7***
  *(not a critical limit, but more is not sensible)
- → **Volumetric flow > 80 l/h + HP fuel-quantity demand**
  (Upper limit only restricted by max. inlet pressure)
- → **Differential pressure between CP inlet and return flow: $p_{Zu} - p_{Rü} \geq 3.4$bar_rel**

→ max. **back pressure** ≤ **2.0bar_abs** (continuous operation >2.0bar_abs can cause damage to the shaft seal).

BOSCH

VW R4_2.0l: Notes on start-up of CRS3.2

→ At **0bar rail pressure**, the **max. slip speed** is **n_{CP} = 300…1000 rpm.**

(RB recommendation n_{CP} = 500…1000rpm.)

→ An important prerequisite for venting the C4 is that the rail pressure is near zero.

→ If there is static pressure in the rail, not even the compression ratio of the elements may be enough to deliver the air.

→ In this case, the only venting path is through the HP piston guidance in the interior, which can take a long time.

→ If rail pressure is zero, a necessary pressure differential of **3.1 ≤ Δp [bar_rel] ≤ 5.1** over **intake and HP valve results.**

→ Since the **overflow valve** is set to **approx. 3.3 bar_rel,** an EFP without rotating CP4 can only be vented if the tolerance values of the intake/HP valves are minimal.

VW R4_2.0l: Notes on start-up of CRS3.2

→Operation of pump only permitted with **pressure limit curve CP4** (Tab.1, Diag.1).

Table 1: Transmission behavior [engine : pump] i = 1

Pump rotation speed [rpm]	0	100	300	300	1000	2000	3000	4000	4500	5000
Engine speed [rpm]	0	100	300	300	1000	2000	3000	4000	4500	5000
Max. rail pressure [bar]	300	300	633	633	1800	1800	1800	1800	1800	300
Min. rail pressure [bar]	120	120	120	230	230	230	230	230	230	230

Diagram 1:

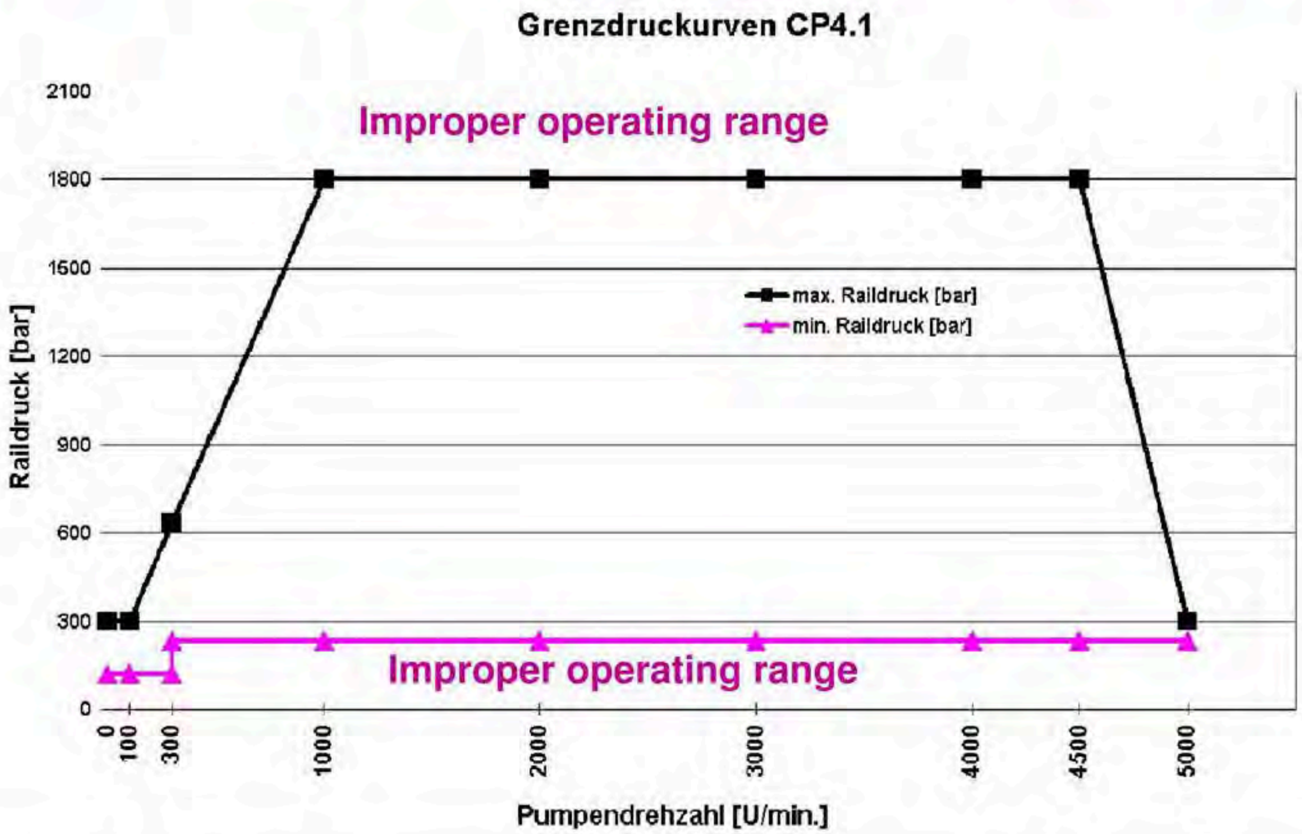
Pressure limit curves CP4.i

Max. rail pressure [bar]

Min. rail pressure [bar]

Pump rotation speed [rpm]

Rail pressure [bar]



BOSCH

VW R4_2.0l: Notes on start-up of CRS3.2

Step 1) LP/HP venting:
Continue filling the high-pressure fuel pump during standstill until no further air bubbles are visible in the CP return flow or total return flow. (transparent inlet and return lines recommended).
Notes: Metering unit normally open; PCVu normally open; more efficient venting through back pressure-free total return flow bottom/top Presupply pressure > 4.5bar_abs.

Step 2) Safe venting of HP part:
Depending on the setting tolerance of intake/HP valve, possibly already completed in step 1 through EFP admission pressure.
Venting of intake/HP valve of CP4 by turning the high-pressure fuel pump with open (=normally) PCVuuntil PCVu return flow is free of air bubbles.

→ System venting is complete; the system is ready for operation.

BOSCH

VW R4_2.0l: Notes on start-up of CRS3.2

Venting steps in detail:

Step 1) Venting time **without** speed: **10(…20*)s**

(this makes the low-pressure area safe; the high-pressure area is only conditionally vented, depending on the tolerance position of the intake/HP valves.)

and

Step 2) Venting time **with** speed (**300 ≤ n_{slip}[min.$^{-1}$] ≤ 1000***) after pre-venting the LP (low pressure) area: **= 5 to max. 10s**

→ max. allowed pos. CP4 speed gradient: **400rpm/s**

→ For **step 1) + 2)** applies: p_Rail = 0 bar

Caution: **Step 2)** with p_{Rail} = 0bar or deenergized pressure control valve is restricted to max.10s**!** → Danger of pump damage in new state!]
From **step 3)**,p_{Rail} ≥ 230bar applies!

*RB recommendation

VW-R4_2.0l: Notes on start-up of CRS3.2

Venting cold test start-up at engine plant

Step 1) Pre-venting of CP4.1 LP area

Q_{inlet} = 135 – 220 l/h (EFP or test bench supply)

alternative

p_{inlet} ≥ 4.5 bar_abs (≤ 7 bar_abs); RB recommendation: 5.0 bar_abs

further increase p_{inlet} increases Q_{return} by 400 l/(h*bar)

$p_{inlet} - p_{return} \geq 3.4$ bar_rel [= $p_{Diff.-CP}$ with $Q_{return} \geq 80$ l/h]

p_{Return} ≤ 1.8…2.0 bar_abs (static)

$t_{Venting}$ ≥ 10 sec. (pure CP venting time)

n_{Pump} = 0 min^{-1} (pump at standstill [!])

p_{Rail} = 0 bar_rel (rel. to $p_{Return\ flow}$), PCVu open, that is, deenergized [!]

VW-R4_2.0l: Notes on start-up of CRS3.2

Step 2) Final venting CP4.1 HP area

Q_{inlet}	= 135 – 220 l/h (EFP or test bench supply)
alternative	
p_{inlet}	≥ 4.5 bar_abs (≤ 7 bar_abs)
$p_{Return\ flow}$	≤ 1.8…2.0 bar_abs (mean pressure)
$t_{Venting}$	= 5 to max. 10 sec. [Attention: Danger of pump damage in new state!]
n_{Pump}	= 1000 min^{-1} (→ max allowed pos. of CP4 speed gradient: 400rpm/s)
p_{Rail}	= 0 bar_rel (rel. to $p_{Return\ flow}$), PCVu open, that is, deenergized [!]

Times must be determined directly in the final function test (FFT) through trials on the engine.

→ System venting is complete; the system is ready for operation.

→ Do not operate further without min. rail pressure [p_{Rail} ≥ 230 bar]

→ otherwise danger of pump damage in new state!

→ During the first revving up of the CP4, max. allowed pos. CP4 speed gradient: 400rpm/s

BOSCH

VW-R4_2.0l: Notes on start-up of CRS3.2

Tests for cold test start-up:

Step 3) Measurement of rail pressure fluctuation

i.e. testing whether venting occurred correctly or measuring the air that escapes during venting. [Attention: min. Rail pressure $p_{Rail} \geq 230$ bar]

Step 4) Test (e.g. test for high-pressure tightness) $\rightarrow p_{Rail} \geq 230$ bar with e.g. 1600 bar rail pressure and pump rotation speeds of 1500 rpm ($i=1 \rightarrow n_{CP} = n_{Motor}$). Proposal: Duration 30 sec.

After step 4), the system can be operated as in the vehicle. When shutting down the engine, the

max. allowed neg. CP4 speed gradient is: -1800rpm/s

(the transmission behavior [CP:Motor] must be observed.)

BOSCH

VW-R4_2.0l: Notes on start-up of CRS3.2

Proposal: Check HP tightness in purely pressure control valve operation (due to venting; better through PCVu)
Metering unit test: Function test through temporary closing of metering unit → Monitor drop in pressure (energization max. 1s with 1.7±0.1A; not clocked)
At the end of the cold test, the fuel can remain in the system. It is possible to empty the CP incl. inlet and return lines through blowing out* (e.g. air). [Description Page 15] To transport the engine, seal the inlet and return connections of the injection system tightly with plugs, since HP and LP system are by-passed with deenergized PCVu. This is intended to prevent leakage of the system, particularly emptying of the rail.

Note: Filling of leakage oil seal not supported in cold test; only in first start-up or hot test. Filling takes place through the control volume of the injectors during injection.

VW-R4_2.0l: Notes on start-up of CRS3.2

Venting steps in detail:

No.	EFP [bar_abs]	EFP [bar_rel]	CP4 Return flow counter-pressure [bar_abs]	CP4 speed [rpm]	Rail pressure [bar]	PCVu	MU (metering unit)	Remarks	min. Duration [sec.]	max. Duration [sec.]	QRec.max.[l/h] (inlet Test rig)
1	min. 4.5 RB rec. 5.0	min. 3.5 RB rec. 4.0	1.0 - 1.2 max.2.0 Attention: pinlet-preturn≥ 3.4bar_rel	0	0	open I = 0A	open *I = 0A* *(Energization permitted max.1.7A±0.1 A not air bubbles. max. 1 sec.)*	Venting at standstill: CP-LP-ventilation with EFP-admission pressure CP-inlet; Securing the fuel lubrication and Ventilation of the total system until CP- Return flow bottom/top PCVu and overall return flow without air bubbles	10	Unlimited RB rec. 20	4, 6, 8-cyl. 350l/h @ 4.0bar_rel
2	min. 4.5	min. 3.5	1.0 - 1.2 max.2.0	(300...) 1000	0	*open* *I = 0A*	*open* *I = 0A*	For secure ventilation after intake/HP-valve Ventilation of the HP-part until PCVu-return flow without air bubbles	5	10	4, 6, 8-cyl. 210l/h @ 3.5bar_rel
3	min. 4.5	min. 3.5	max.2.0	(300...) 1000	Start (≥230)	regulate	open *I = 0A*	• Venting check, i.e. measurement of rail pressure fluctuation • if, after 10sec. a stable starting pressure is not reached, cancel test	closed Determine	≤180	4, 6, 8-cyl. 210l/h @ 3.5bar_rel
4	min. 4.5	min. 3.5	max.2.0	Pressure/ Engine speed Table1	Pressure/ Engine speed Table1 (≥230)	regulate	open *I = 0... 0.7A*	Leakage check (temperature increase PCVu Return flow)	- - -	30	4-cyl. 245l/h, 6-cyl. 260l/h, 8-cyl. 300l/h 3.5bar_rel

Note: The following applies to steps 1through 4: Max. allowed pos. of CP4-speed-gradient: **400rp** max. allowed neg. CP4 speed gradient **-1800 rpm/s; $p_{permissible}$ - p_{Return} ≥ 3.4bar_rel**

<u>Proposal</u>: Customer coordination of start-up at vehicle plant with RB.

VW-R4_2.0l: Notes on start-up of CRS3.2

Optional:

Emptying of CP through blowing out* (e.g. air) after cold test start-up:

$p_{Inlet} \leq 2.8$ bar_rel

$-0.2 \leq p_{Return\ flow}$[bar_rel] ≤ 1.0

$t_{blow\ out} \leq 30$ sec.

$n_{Pump} = 0$ min.$^{-1}$ (pump at standstill)

Background: Avoid emptying rail volume through CP and pressure control valve.

$p_{Inlet} \leq 5.0$ bar_rel, when pressure control valve is closed, e.g., while energized during blowout process.

*Page 17

VW-R4_2.0l: Notes on start-up of CRS3.2

Note in case of air inclusion to the LP system before CP4:

If an air column is delivered to the CP4 (e.g. restart after emptying of tank, through cutting off CP inlet, after filter replacement) the CP4 cannot deliver the air column to the rail if the PCVu is closed; no pressure build-up is possible.
In this case, the PCVu must be deenergized, i.e. open; only then can the air column be routed through the CP piston to the rail, and then through the PCVu.
If CP4.1 is detectable → no pressure build-up is possible.

→ Software is available for this purpose in vehicle.

BOSCH

VW-R4_2.0l: Notes on start-up of CRS3.2

If **air or gases**, are used, there is a hazard of contamination and water ingress.

The cleanliness requirements with regard to air must be followed:

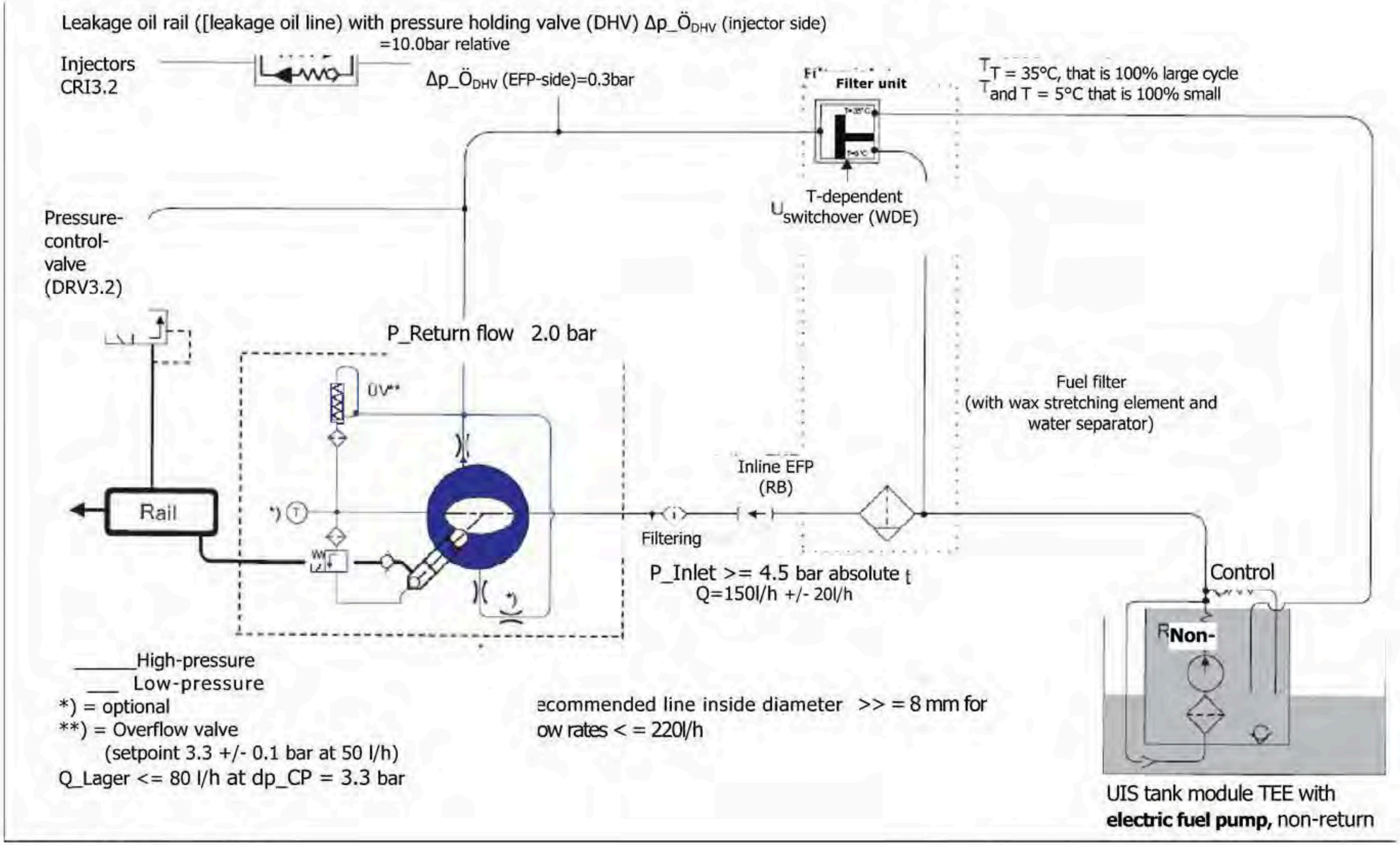
→The air supply must be free of water and oil.

→The use of a filter of 0.3µm is required to eliminate particulates contaminations from compressed air and gases.

RB recommendation: Series filter connection with 5µm [coarse] and 0.3µm filter.

VW-R4_2.0l: Notes for start-up

Common Rail System (CRS3.2 - 1800bar with CRI3.2, CP4.1 with tank- and Inline-EFP according to filter) low-pressure cycle VVV_R4_2.01_EU5/BIN5 in the K-SUV/Jetta

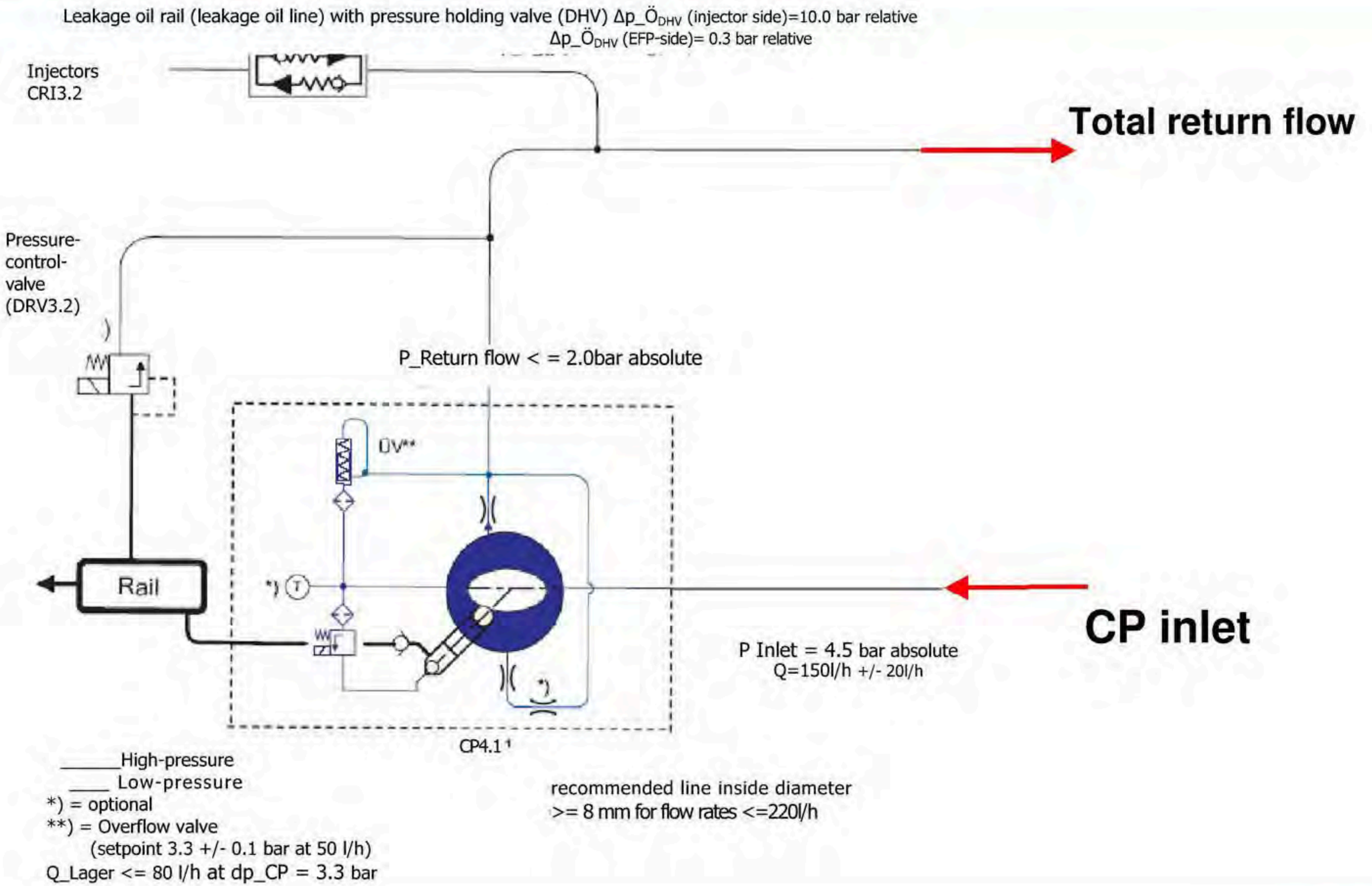


BOSCH

Non-responsive content removed VW

BOSCH

VW-R4_2.0l: Notes on start-up of CRS3.2



ENTIRE PAGE CONFIDENTIAL

EA11003EN-00209[0]

[redacted]

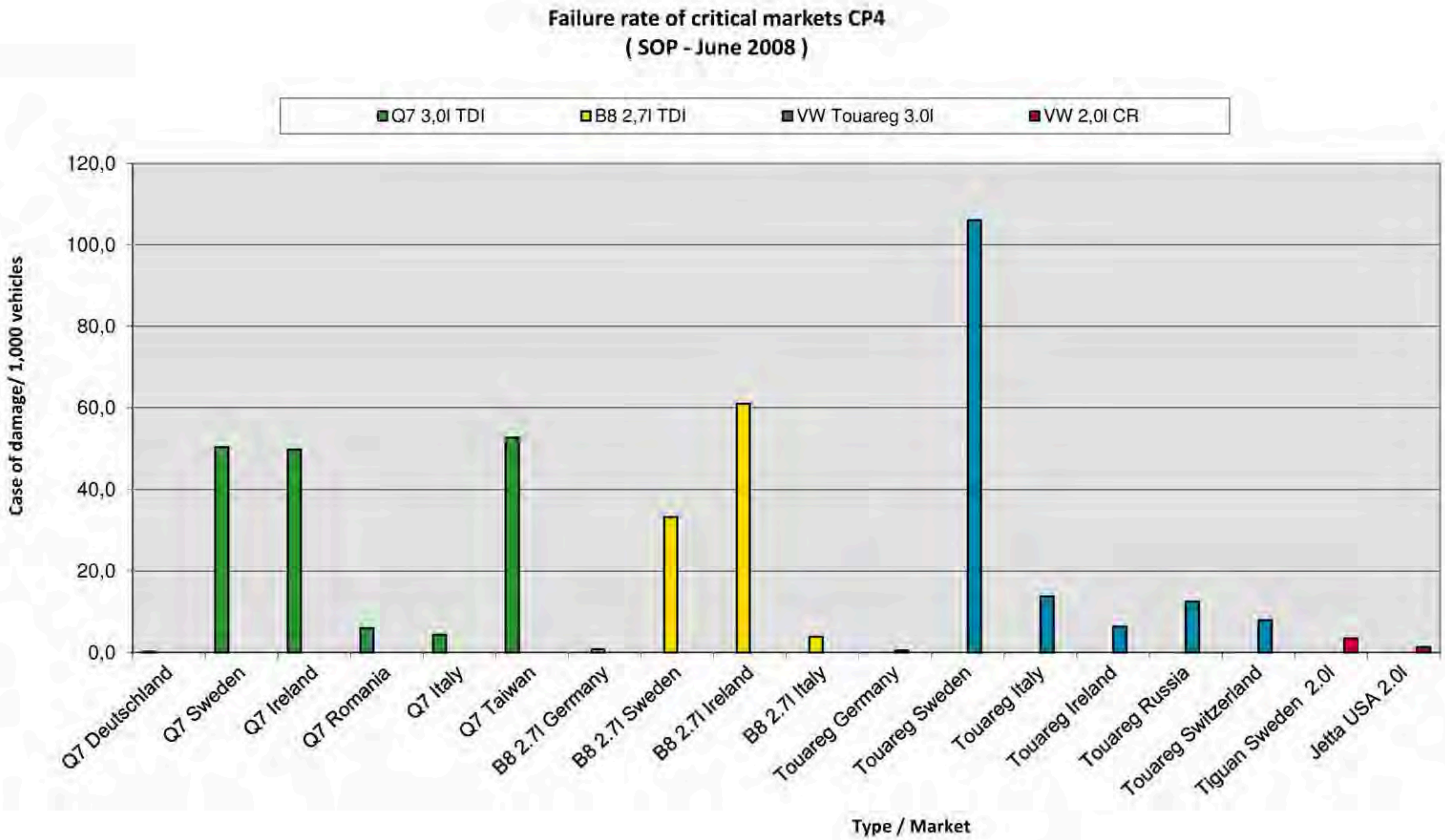
EA11003EN-00209[1]

Only clustered vehicle failures

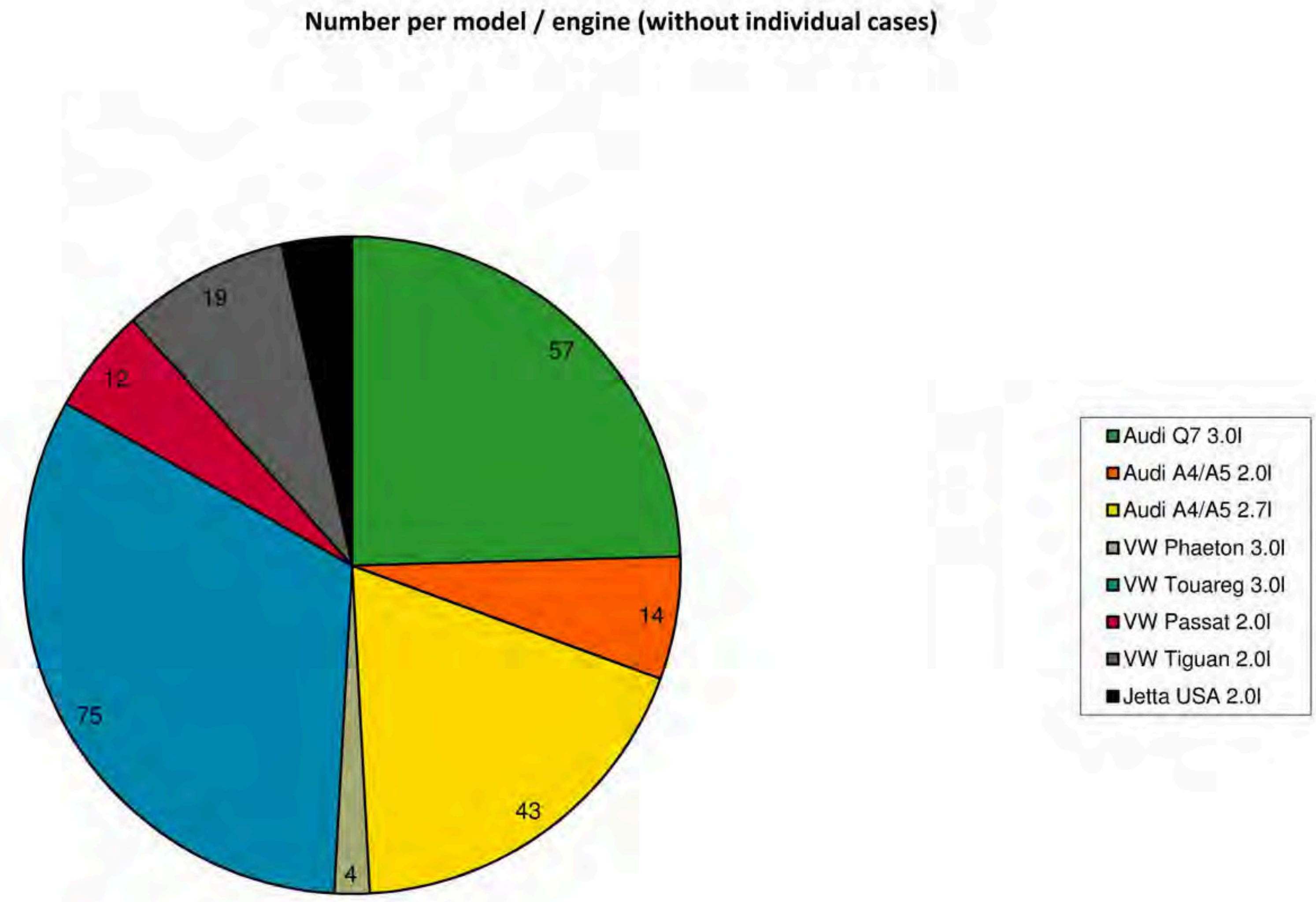
Model	Engine	Market	Failures	Total	Delivery volume Vehicles SOP - June 08	Delivery quantity Vehicle July - September 08	Delivery quantity Vehicle SOP - September 08	First vehicle delivery in the market	Failure rate in parts per thousand until June 08	Failure rate in parts per thousand until September 08	Factor above average in worldwide comparison	Factor above average in comparison Germany
Audi Q7 3.0l	**3.0l**	**Worldwide:**		**57**	**19.344**	4.537	**23.881**	Dez. 07	**2,9**	**2,4**	—	
		Q7 Deutschland	1		5.685	1.199	6.884	Dez. 07	0,2	0,1		
		Q7 Sweden	**13**		187	71	258	Dez. 07	**69,5**	**50,4**	21	347
		Q7 Ireland	**16**		317	4	321	Dez. 07	**50,5**	**49,8**	21	343
		Q7 Romania	**3**		477	24	501	Dez. 07	**6,3**	**6,0**	3	41
		Q7 Italy	**11**		1.954	583	2.537	Dez. 07	**5,6**	**4,3**	2	30
		Q7 Taiwan	**4**		76	???	76	Jan. 08	**52,6**	**52,6**	22	362
		Q7 GB	2		2.612	925	3.537	Dez. 07	0,8	0,6		
		Moldavia	2		no separate country code							
		Montenegro	1		no separate country code							
		Russia	1							#DIV/0!		
		Switzerland	1							#DIV/0!		
		Bulgaria	1		69	7	76	Dez. 07	14,5	13,2		
		France	1		1.712	368	2.080	Dez. 07	0,6	0,5		
Audi A4/A5 2.0l	**2.0 l**	**Worldwide:**		**14**	**87.660**	52.870	**140.530**	Okt. 07	**0,2**	**0,1**		
		Germany	7		24.813	15.545	40.358	Okt. 07	0,3	0,2		
		Spain	1		10.324	3.884	14.208	Nov. 07	0,1	0,1		
		Ireland	2		1.225	494	1.719	Dez. 07	1,6	1,2		
		Italy	1		8.733	7.393	16.126	Dez. 07	0,1	0,1		
		Sweden	2		1.724	1.070	2.794	Dez. 07	1,2	0,7	7	4
		Norway	1		1.225	634	1.859	Nov. 07	0,8	0,5	5	3
Audi A4/A5 2.7l	**2.7l**	**Worldwide:**		**43**	**18.516**	6.040	**24.556**	Sep. 07	**2,3**	**1,8**		
		B8 2.7l Germany	6		5.899	2.389	8.288	Sep. 07	1,0	0,7		
		B8 2.7l Sweden	**13**		243	148	391	Dez. 07	**53,5**	**33,2**	19	46
		B8 2.7l Ireland	**10**		161	3	164	Nov. 07	**62,1**	**61,0**	35	84
		B8 2.7l Italy	**10**		1.985	622	2.607	Sep. 07	**5,0**	**3,8**	2	5
		B8 2.7l Spain	2		1.777	318	2.095	Sep. 07	1,1	1,0		
		B8 2.7l Belgium	1							#DIV/0!		
		B8 2.7l GB	1		2.329	850	3.179	Sep. 07	0,4	0,3		
Audi A4/A5 3.0l	**3.0l**	**Worldwide:**		**2**	**40**	2.238	**2.278**	Sep. 08	**50,0**	**0,9**		
		Germany	0		40	970	1.010	Sep. 08		0,0		
		Italy	0		0	334	334	Sep. 08		0,0		
		Russia	1							#DIV/0!		
		Sweden	1		0	26	26	Sep. 08		38,5		
VW Phaeton 3.0l	**3.0l**	**approved markets**		**4**	**3.347**	431	**3.778**	Okt. 06	**1,2**	**1,1**		
		Germany	1		2.624	376	3.000	Okt. 06	0,4	0,3		
		Austria	1							#DIV/0!		
		Taiwan	**2**		not in QUASI-FI					#DIV/0!		
VW Touareg 3.0l	**3.0l**	**approved markets**		**75**	**10.825**	2.688	**13.513**	Mrz. 07	**6,9**	**5,6**		
		Touareg Germany	3		4.591	1.657	6.248	Mrz. 07	0,7	0,5		
		Touareg Sweden	14		120	12	132	Nov. 07	**116,7**	**106,1**	19	221
		Touareg Italy	17		1.009	227	1.236	Nov. 07	**16,8**	**13,8**	2	29
		Touareg Ireland	**5**		789	in QUASI-FI blo	789	in QUASI-FI bl	**6,3**	**6,3**	1	13
		Touareg Russia	23		1.562	278	1.840	Apr. 08	**14,7**	**12,5**	2	26
		Touareg Switzerland	4		433	72	505	Nov. 07	**9,2**	**7,9**	1	16
		Taiwan	**5**		not in QUASI-FI							
		Australia	1		not in QUASI-FI							
		Belgium	1							#DIV/0!		
		Spain	1							#DIV/0!		
		Montenegro	1		not in QUASI-FI							
VW Passat 2.0l	**2.0 l**	**approved markets**	---	**12**	**42.039**	25.039	**67.078**	Jul. 07	**0,3**	**0,2**		
		Germany	4		18.505	12.621	31.126	Jul. 07	0,2	0,1		
		UK / GB	3		6.250	3.995	10.245	Feb. 08	0,5	0,3		
		Russia	1		407	47	454	Feb. 08	2,5	2,2		
		Spain	2		5.111	1.636	6.747	Feb. 08	0,4	0,3		
		Italy	2		4.813	2.221	7.034	Feb. 08	0,4	0,3		
VW Tiguan 2.0l	**2.0 l**	**approved markets**	---	**19**	**44.962**	15.971	**60.933**	Feb. 07	**0,4**	**0,3**		
		Germany	5		17.928	7.002	24.930	Feb. 07	0,3	0,2		
		UK / GB	2		4.163	1.479	5.642	Okt. 07	0,5	0,4		
		Austria	1		2.073	856	2.929	Sep. 07		0,3		
		Spain	2							#DIV/0!		
		South Africa	1							#DIV/0!		
		Australia	1							#DIV/0!		
1 x Golf		France	4		6.299	2.166	8.465	Sep. 07		0,5		
		Tiguan Sweden 2.0l	**3**		579	294	873	Sep. 07	5,2	**3,4**	11	17
Jetta USA 2.0l	**2.0 l**	**Jetta USA 2.0l**	8		**1.379**	4.779	**6.158**	Okt. 07	**5,8**	**1,3**	4	6
Skoda Superb 2	**2.0l 125 kW**	CZECH REPUBLIC	1									
Total of field			234									

	Qty.	Deliveries	Failure (parts per thousand)
Sweden	46	4474	10,3
Ireland	33	2993	11,0
Italy	41	29874	1,4
Russia	26	2294	11,3
Germany	27	41759	0,6

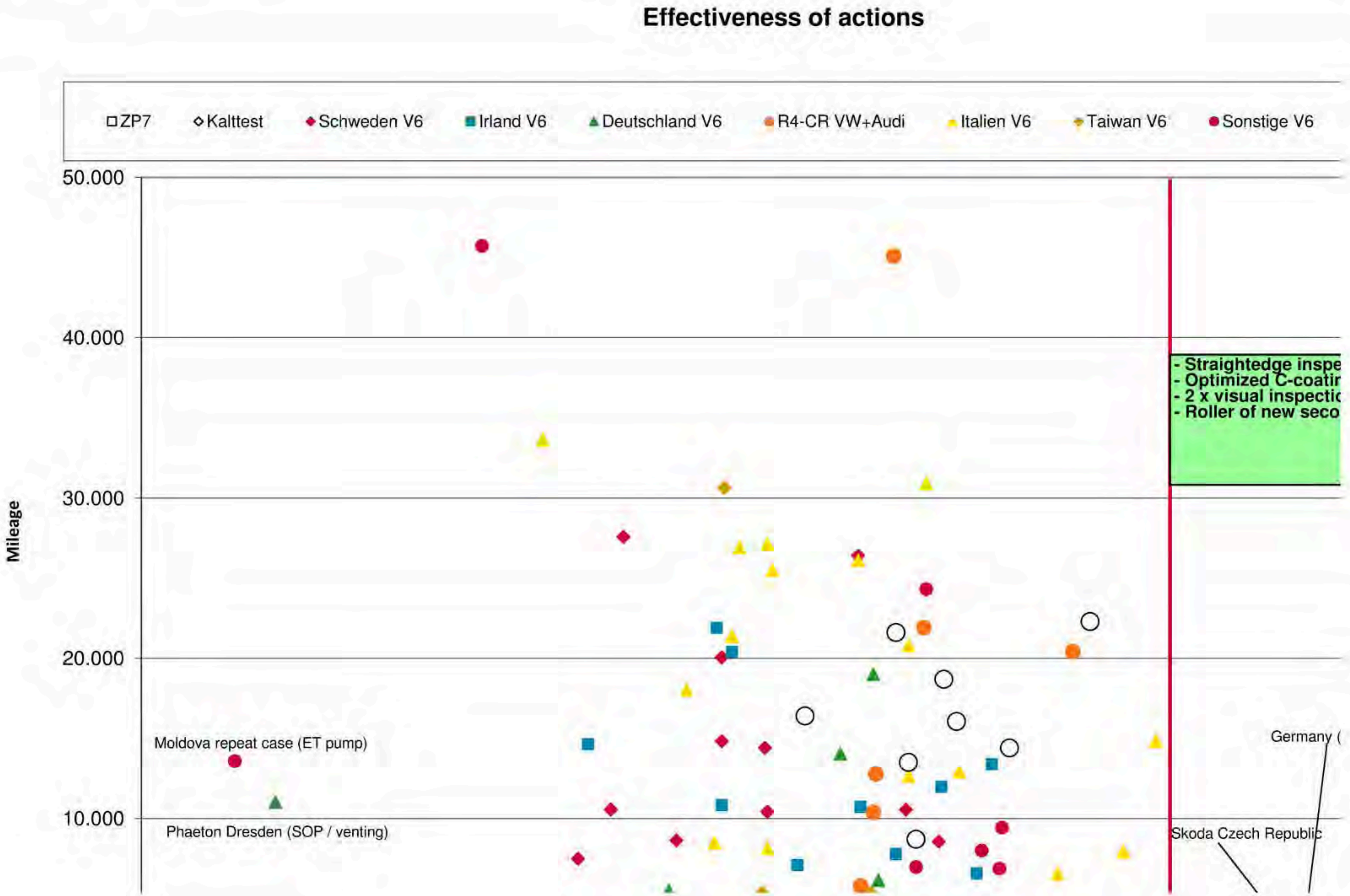
EA11003EN-00209[2]



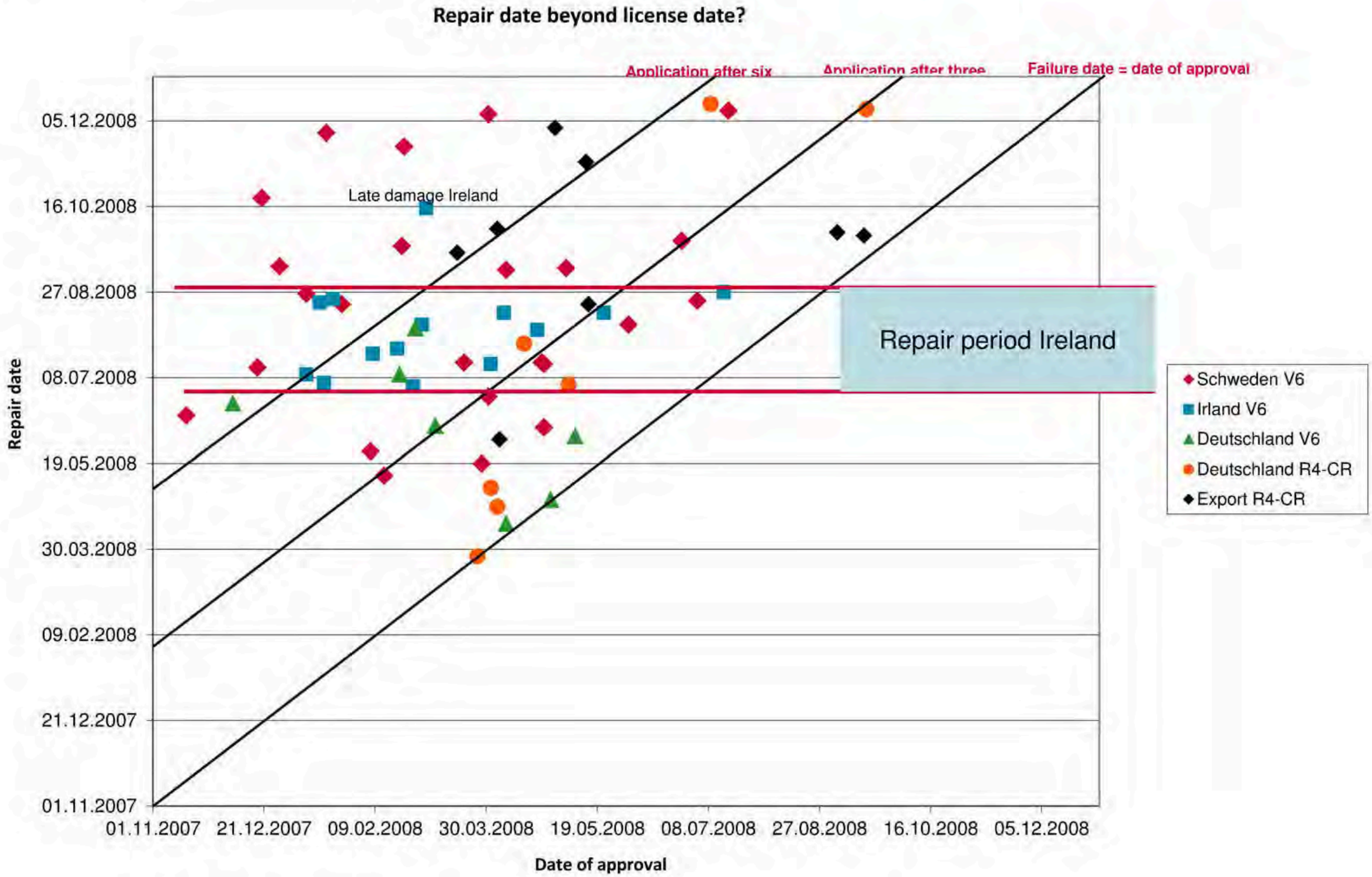
EA11003EN-00209[3]

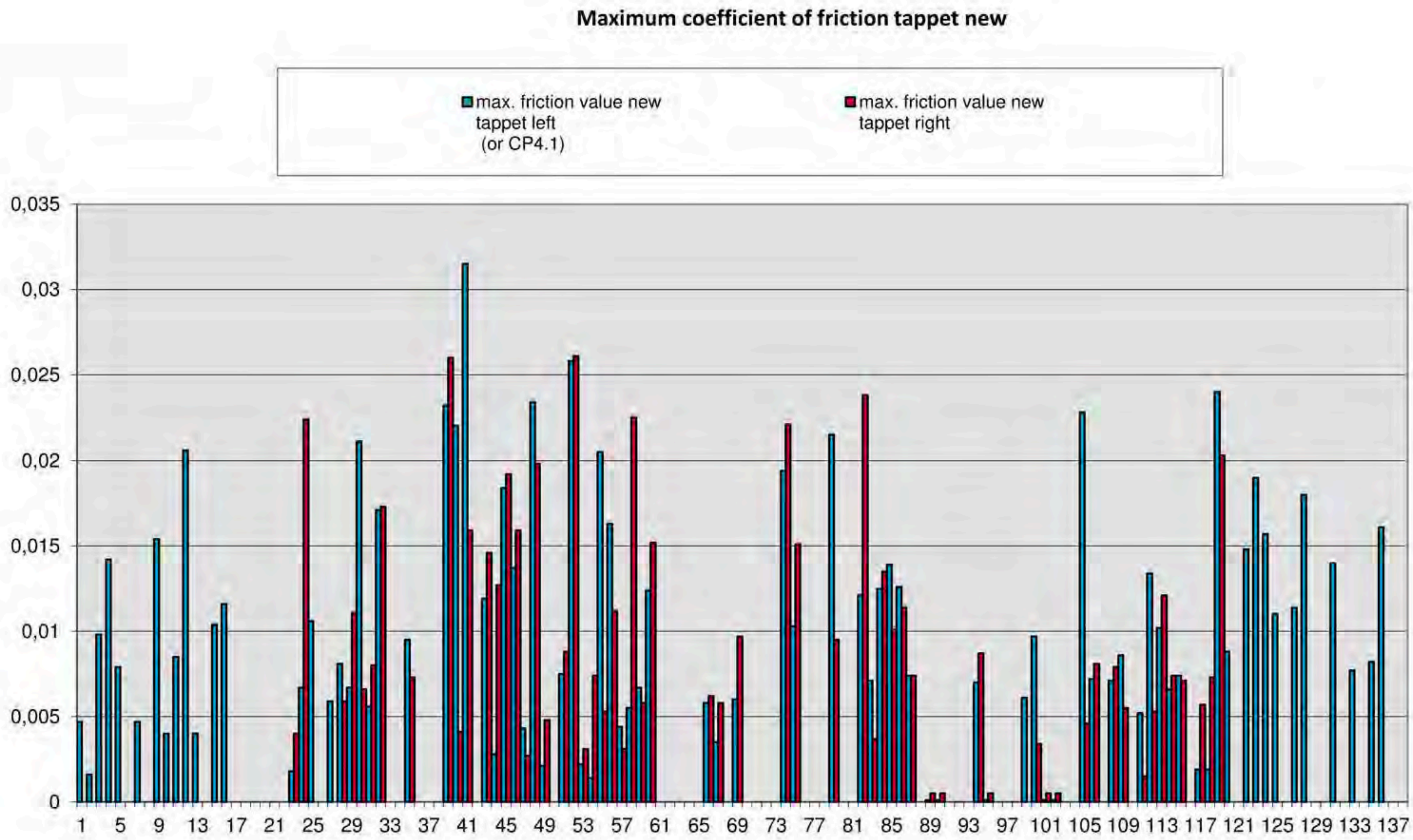


EA11003EN-00209[4]



EA11003EN-00209[5]




Maximum coefficient of friction tappet new
max. friction value new tappet left (or CP4.1)
max. friction value new tappet right
0,035
0,03
0,025
0,02
0,015
0,01
0,005
0
1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61 65 69 73 77 81 85 89 93 97 101 105 109 113 117 121 125 129 133 137

		EFP pre-filling time [in seconds, at least clock 82					
Serial no.	Technical discussion no.	Clock 82	Clock CP7 (functional test)	External energization	First start-up (in seconds)	Engine running time (in seconds)	Second start-up (in seconds)
1	A3070472	61s		N	9.9s	3s	
2	A3070473	59s		N	9.6s	3.1s	
3	A3070474	61s	60s/115s	N			
4	A3070475	60s		N			
5	A3070479	60s		N			
6	A3070480	60s		N			
7	A3070488	60s		N			
8	A3070812	60s	59s/107s	N	8.5s	2s	
9	A3070813	60s	60s/109s	N	7.4s	4s	
10	A3070814	60s	60s/109s	N	8.5s	5.4s	
11	A3070815	60s	60s/110s	N	9s	3s	
12	A3070816	60s	60s/110s	N	8s	3.1s	
13	A3070817	60s	60s/109s	N	8.3s	3s	

[redacted]

Minutes 08.11.2010:

Checklist (created by [redacted]):

1. Check EFP function between clock 68 and 82 (Note: Pay attention to the fuel hose at the engine)
   OK - vehicle does not get any power, that's why the pump cannot operate. Battery is included only on the clock 82
2. Do not operate the electric fuel pump (EFP) before first fueling
   OK - battery not included. (see slide 1)
3. Electric fuel pump operation not allowed before completion of wet calibration of fuel tank
   OK - wet calibration of fuel tank occurs automatically at clock 82 through test device. The sequence cannot be modified by employees.
4. Where does the wet calibration of fuel tank take place?
   Clock 82, OK
5. Measure pre-filling time
   Pre-filling times are between 235 and 240 s (default: at least 240 s)
   Pre-filling comprises the following:
   - Clock 82: first electric test ~ 60 Sec.
   - >Clock 83 External energization **EFP runs, but the high-pressure fuel pump does not get any fuel (currently there is no expansion)**
     There were two vehicles, wherein the EFP does not function even with external energization. The vehicles got a block note with the text: EFP function not OK
     Later, it became clear during rework that no oil was filled in the power steering.
     Rework process: Engine may not be started, vehicle is moved to the NA place and repaired. After repair, the vehicle is returned to the ECOS test and the standard procedure is applied.
     (Information from [redacted])
     Reworking of the defective engines will be done today.
   - First start-up: Approx. 60 + 115 Sec.

   Pre-filling occurs besides other work steps and depends on the duration of the other tests; → no automatic monitoring. **The times reached the limits in the measured vehicles. Please note and check the processes!**
6. Ensure external energization
   Where is the ignition change (ignition on / off)?
   Point of external energization: Clock 83
   Ignition change on the line:
   - Clock 82 1×
   - Clock 83 1×
   - First start-up 2× testing; 2× starting
7. Measure first start-up
   First start-up times are approx. at 9 s. In the vehicles tested → OK
   Second start: ~ 10 s.
8. How many seconds does the engine run afterwards? (The worker may not turn off the engine immediately, but let it run for at least 10 s).
   Not OK

The staff does not maintain the specified engine running time. After the first start-up, the employee stops the engine immediately (approx. 2 s).
Please raise the awareness of staff and check the processes!
→ New specification as per protocol TELCO 10.08.2010: 20 s. Engine running time

9. <u>there are problems in connecting the fuel lines (fuel leakage)</u>
   It is OK for the tested vehicles, according to statement by [redacted]
10. <u>How can wrong fueling with petrol be prevented?</u>
    It is not automatically verified. The employee must look at the fuel type on the accompanying sheet and refuel the tank accordingly. Tank guns are marked with different colors: diesel (filling capacity: 14 l); red: petrol (filling capacity: 8 l). **Please check the automation option!**
    - It was communicated to Planning: Machine is capable for the task, but currently out of service. **Deadline: open**
11. <u>If the tank is run empty, there is also a risk for the HPP! (Discuss the process with CP1)</u>
    Process monitoring: Tank level test is integrated in the test at the clock 82
    According to [redacted] statement: Vehicle does not start when the tank is empty. One of the defective vehicles was checked, fuel in the vehicle
12. <u>Refueling quantity</u>
    OK
    was automatically monitored and integrated into the line at the clock 82.
    In the defective vehicle, there was more fuel than in the vehicle which was built on the day of analysis.
    When the Test machine is pulled out, this implies that the tank check has not passed. After the reconnect the error message will disappear.

Analysis of the defective vehicle:

- Approach:
  - First start-up OK
  - Roller test OK
  - The vehicle failed during internal test drive
- Fuel pump seized, solid run mark and adhesive wear on the surface of the shaft (we believe that the pump has not run with sufficient or high-quality fuel - Bosch, Audi as on 08.10.2010)

- HP pump filled with chips
- We could not inspect the roller towing levers that were in the laboratory
  Analysis results are provided as hard copy, it is distributed on 08.16.2010. (by [redacted]
[redacted]

- Fuel quantity in vehicle OK
- Fuel quality according to internal laboratory analysis OK
  Analysis report must be distributed by Non-responsive content removed

Analysis of an OK vehicle:
An OK vehicle was dismantled at the request of Non-responsive content removed for analysis.
Analysis results are provided as hard copy, it is distributed on 08.16.2010. (by [redacted]

- There is brown discoloration on the surface (overheating or deposition) and coaxial running marks that originate most likely from machining
- Likewise, the surface of the shaft shows brown discoloration (overheating or deposition)

Points of teleconference 10.08.2010:

1. Return damaged pumps to Bosch
   After the standard process, some parts should not be dismantled from the engine and returned separately, but the whole engine should be dismantled.
   Special method should be approved by Non-responsive content removed **(or representative)**.
   (Statement by [redacted]
   Result of the meetings: On-the-spot repair is possible, but the work must be carried out by Győr or German colleagues. Second option: An outside company performs the repairs, however a colleague must be present here on site and check the repairs. (According to the discussion with Non-responsive content removed Non-responsive content removed
2. After transporting, allow the pump to be removed without prior installation; due to the bio-diesel sample
   Special method should be approved by Non-responsive content removed **(or representative)**.
   (Statement by [redacted])
   Result of the meetings: Prompt trial is possible if the pump is replaced by [redacted] If the spare parts arrive by 08.12.2010, we can do it. → Currently, there is no information about the calibration parts
3. Tank calibration - Check whether the tests can be carried out without ignition?
   Personally checked: The error message continues to be displayed until the ignition is switched off. Measurement not OK. The only work steps are secured by the program, they cannot be overridden. This statement was also confirmed by Non-responsive content removed (manufacturing process)
4. Trial with extended engine running time (20 sec) after first start-up.

Trial in WK32 not possible, because there are no additional vehicles built in this week. [redacted] shall carry out the test in WK 34.

5. Trial with transparent hose
   It was also rejected on the part of production and reworking. Such a trial must be discussed with TE (Technical Development) and TE must confirm it in writing.
6. Start time measurements:
   The Chinese colleagues have misunderstood me and wrong files were sent during the teleconference. (The files can be checked in the attachment)
   Second start-up was not measured. **According to** [redacted] **statement**: Each engine starts the second time very quickly (about 3 seconds).
   On 08.09.2010, I had a different experience. The start-up times then were almost the same as the first time, but in any case too slow. If the engines had already been run for a few seconds, then they immediately start-up.

No further TDI vehicles shall be built until WK34.

Conclusion based on the analyses and information to date:

Presently, I cannot determine clearly the cause of the fault, but the risk factors are:

1. pre-filling times are at the border.
   Specification: Approx. 240 seconds
   Actual value: Approx. 235 seconds – Time depends on other tests
   Low – Based on the statement by and vehicle Plants ([redacted])

2. Engine running time at first start-up
   Specification: Approx. 10 seconds → Telco 08.10.2010: min. 20 Sec.
   Actual value: Approx. 3 seconds (Statement from [redacted]), Personal opinion:
   Approx. 1-2 seconds and second start-up times were on 08.09.2010 roughly the same as the first start-up.
   Second start-up time had clearly improved the next day on 08.10.2010, when the colleagues waited a little longer.
   Probability: high – If the engine is not correctly ventilated, the pump can produce the same fault pattern.

3. Deposition over the transport path from the bio-diesel section
   Engine build data: 03.29 – 04.21
   Day of complaints: 07.27
   Period: 3-4 months
   Probability: I cannot assess – One pump in the delivery condition must be removed and analyzed.

EA11003EN-00222[0]

From: Non-responsive content removed
To:
CC:
Date: 9/23/2011, 11:51:06 AM
Subject: FW:
Attachments: Treibwerkschaden an HDP-Bosch 2011 ([redacted]).pdf

Hello Non-responsive content removed

Could you tell me what is [redacted]'s position on the implementation of an immediate measure, 10 s minimum running time after first start-up? Is this measure already in use?

Regards

Non-responsive content removed

AUDI HUNGARIA MOTOR Kft.
9027 Gyor, Kardán u. 1.
Non-responsive content removed

From: Non-responsive content removed
Sent: Wednesday, September 14, 2011 10:55 AM
To: Non-responsive content removed
Subject: FW: HPP drivetrain damage

Hello Non-responsive content removed

As requested, my presentation from yesterday.

Kind regards,

Non-responsive content removed

AUDI HUNGARIA MOTOR Kft.
9027 Gyor, Kardán u. 1.
Non-responsive content removed

From: Non-responsive content removed
Sent: Tuesday, September 21, 2010 3:01 AM
To: Non-responsive content removed
Subject: HPP drivetrain damage

What I presented about this topic on the Customer Day.

Non-responsive content removed

AUDI HUNGARIA MOTOR Kft.
9027 Gyor, Kardán u. 1.
Non-responsive content removed

EA11003EN-00223[0]

Audi

Non-responsive content removed

Bosch HPP 0km drivetrain damage

2011

Bosch HPP 0km Drivetrain damage 2011

Problem:

Fault location: Audi IN 4x, Neckarsulm4x

Date of notification: 03.02.11-07.06.11

Engine family: 2.0 Common-Rail Gen I(4x), and Gen II(4x) **always longitudinal** no failure in the transverse installation, neither Audi nor VW !

Part number: 03L 130 755, …755 AC

	Division of the fault			
	Gen I	Gen II		
2.0 CR Generation	4	4		
	Non-responsive content removed	Non-responsive content removed		
Manufacturer location of the pumps	4	4		
	Longitudinal engine	Transverse engine		
Vehicles	8.	0.		
	Non-responsive content removed	Non-responsive content removed		
Vehicle plants	4	4		
	Coating A	Coating B	Coating C	
Coating at CT	0	6	2	
	CT1	CT2	CT3	CT4
CT cabin at CT	3	2	2	1
	First start-up	Roller	Driving on road	Loading
Failure location	1	5	1	1

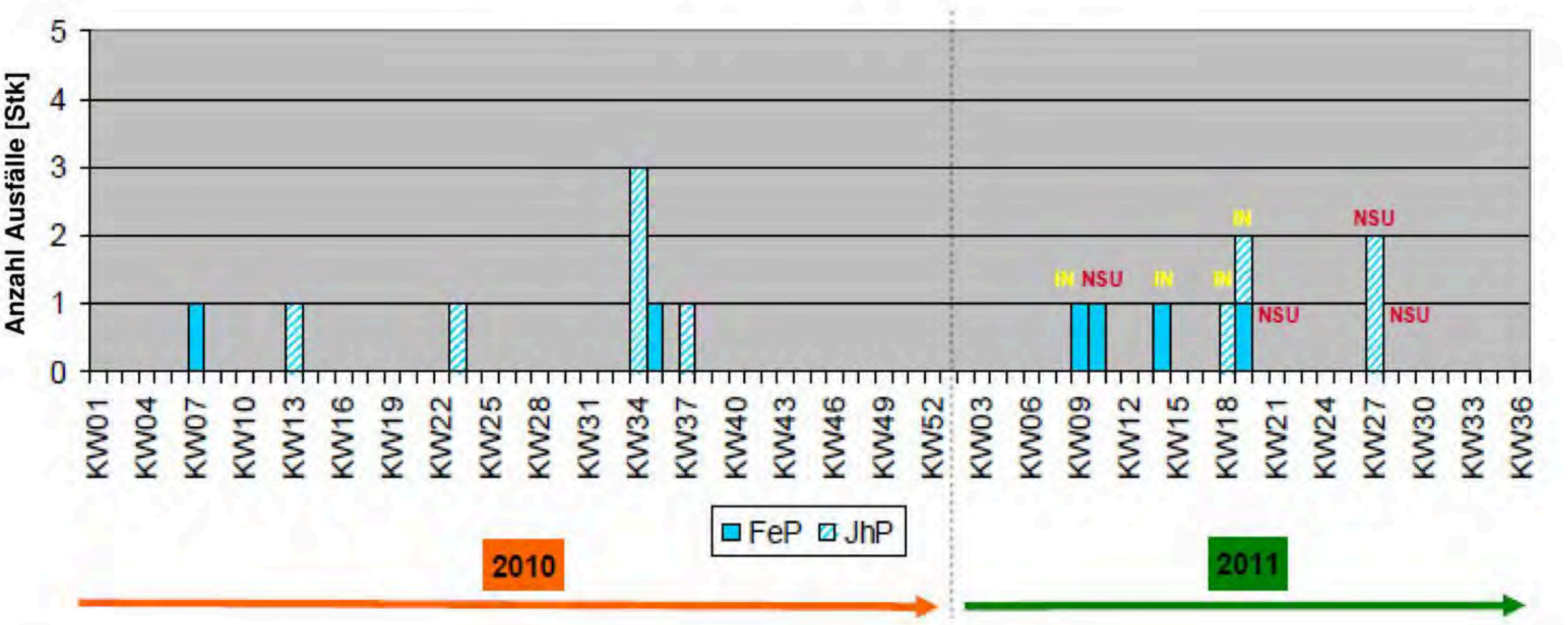
Non-responsive content removed

Status as on: 12.09.2011

EA11003EN-00223[2]

Failures 2010 2011

CP7 Drivetrain damage HPP in 2010...2011



Non-responsive content removed

Status as on:12.09.2011

Bosch HPP 0km Drivetrain damage 2011

Analysis by Bosch:

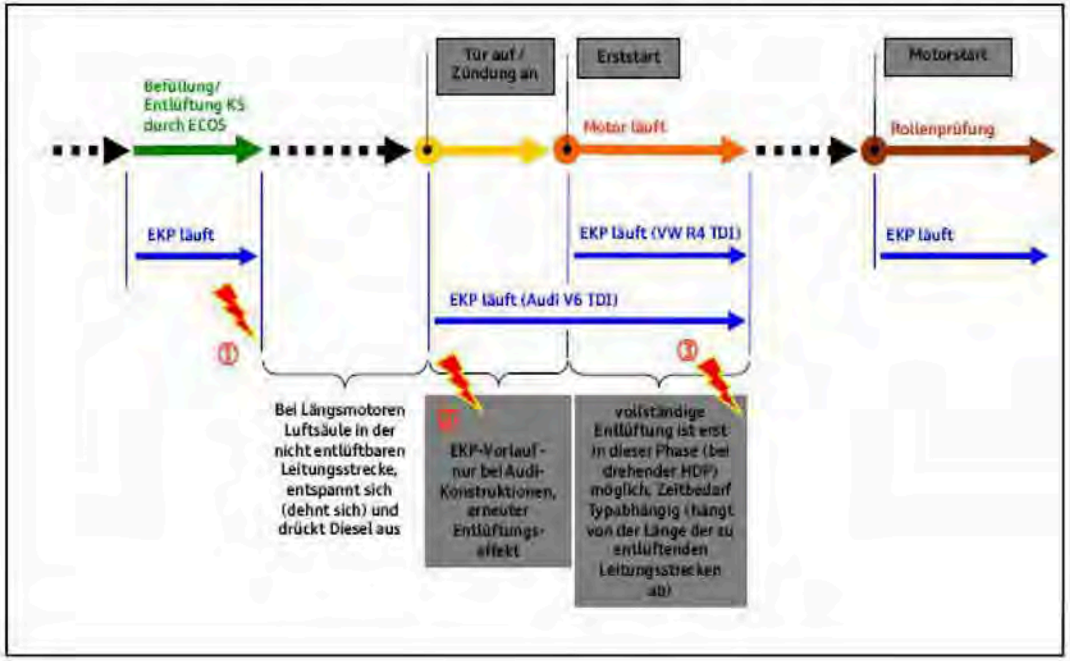
In 2011, Bosch rejected all complaints with drivetrain damage!

Analysis by AHM:

Engine build data: 02.22.11-06.27.11	No striking feature		finished
Hot test runs:	None affected. Engine was hot-tested		finished
Change of type at CT: No change of type affected within 1 hour prior to the check Engines			finished
Pressure cycle of the fuel system at CT: Absolutely OK in the middle of scattering			finished
Noise level at CT: OK			finished
Change of parameters at CT emptying Fuel system: none.			finished
At CT all engines are run directly			finished
Cleanliness analysis of fuel lines: is OK,: 0.0026-0.0046 mg/cm2, should be OK up to 0.05 mg/cm2			finished
Inspection process for mounting and CT OK			finished
Cleanliness analysis of fuel samples from CT1-CT4- Engine connection OK			finished
Investigation of lubricity of fuel from Neckarsulm – OK close to limit			
Audit of CT, LT, HT conditions in [redacted] with the participation of Bosch, QS Audi [redacted], JW happy, AHM assembly, start-up, emptying, blowing LT, HT OK		WK21	finished
Audit of start-up of the engine in the vehicle plant in [redacted] with Bosch and Non-responsive content removed [redacted]		WK26	finished
Audit of start-up of the engine in the vehicle plant in Non-responsive content removed with Bosch and Non-responsive content removed with Bosch and Non-responsive content removed		WK29	finished

Non-responsive content removed Status as on:12.09.2011

Ventilation / first start-up TDI engines in the vehicle plants



Filling / ventilation KS by ECOS
Door open / Ignition on
First start-up
Engine start
Engine running
Roller test
Electric fuel pump is running
Electric fuel pump is running (VW R4 TDI)
Electric fuel pump is F running
Electric fuel pump is running (Audi V6 TDI)
In case of longitudinal engines, air column eases (stretches) in the line area which cannot be ventilated and ejects diesel
EFP supply - only at Audi constructions, new ventilation effect
Complete ventilation is possible only in this phase (with turning HPP), time required depends on the type (depends on the length of the line area to be ventilated)

Differences / striking points in the process.

① Complete LPC ventilation (static, by EFP) during the filling only with the transverse engines. There are no line areas which require ventilation for longitudinal engines.

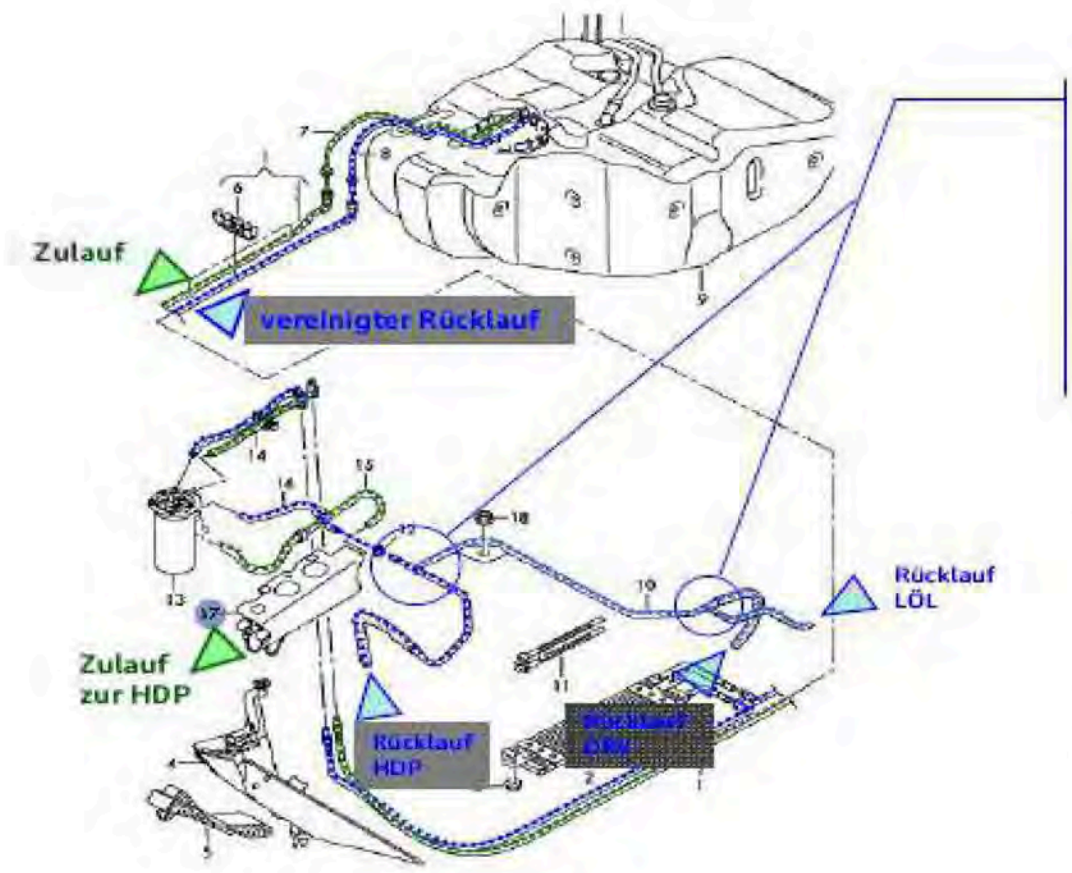
② EFP supply and its ventilation effect is missing only with the Audi constructions (V6 TDI), with VW engines (R4 TDI)

③ Initial run time ④ Process weakness

Non-responsive content removed

Status as on:09.12.2011

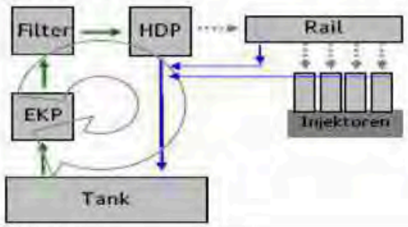
LP fuel system of the 2.0 L R4 TDI engines in the vehicle, transverse-installed engine, A3



All three return lines together flow back to the tank. Inflow and return lines create a simple flow circuit, which itself ventilates by the operation of the EFP.

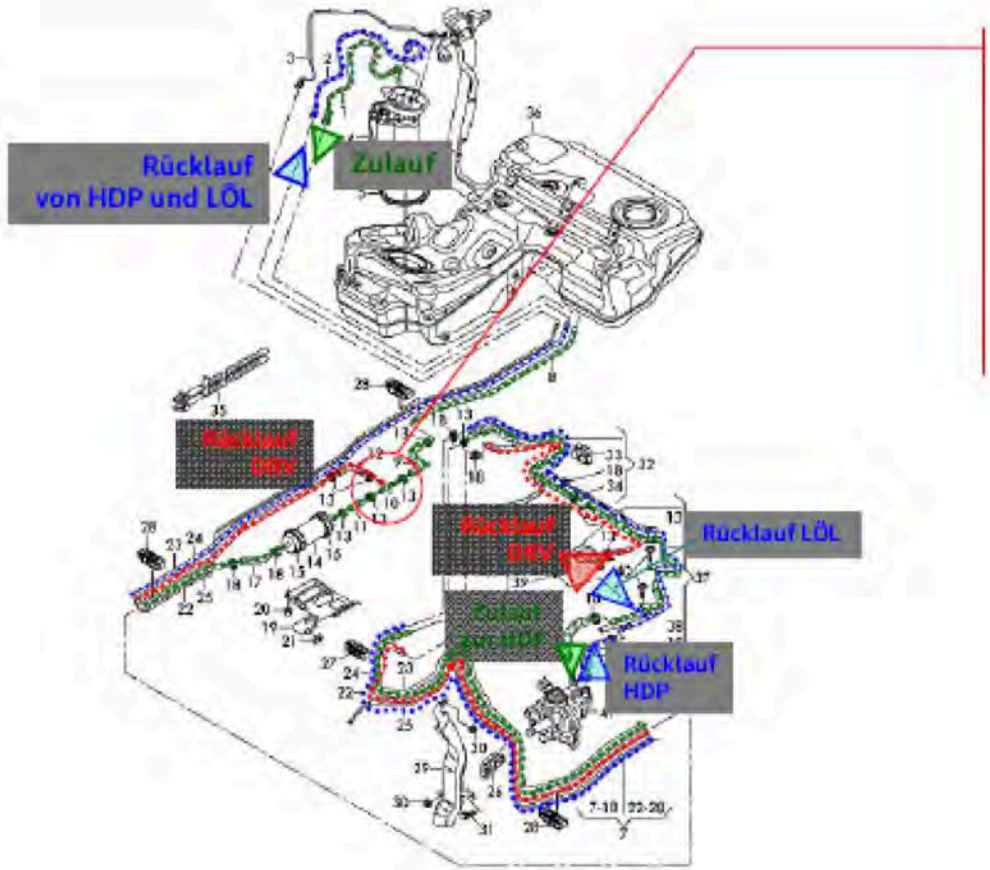
inlet
Cleaned return line
Return leakage oil line
Inflow line for the HPP
Return line for HPP
Return line for pressure control valve

Bubble-free inflow to the HPP at first start-up is ensured.



Injectors
Filter
Tank

LP fuel system of the 2.0 L R4 TDI engines in the vehicle, longitudinal engine GEN2



Pressure control valve return flow does not go back to the tank, line is connected to the inflow line. **This area (about 2m in length) cannot be ventilated by the EFP.** The air remains inside, and can be removed only after engine start by the turning HPP with open pressure control valve.

inlet

Return line from high pressure fuel pump (HPP) and leakage oil line

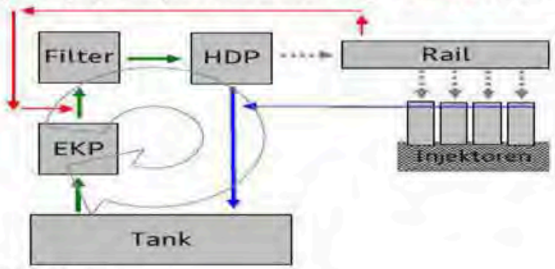
Return leakage oil line

Inflow line for the HPP

Return line for HPP

Return line for pressure control valve

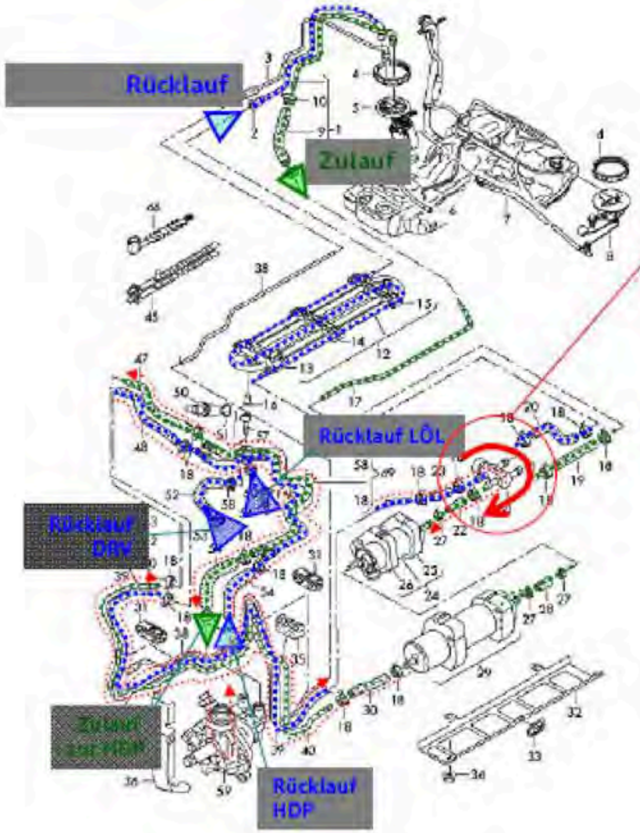
Bubble-free inflow to the high pressure fuel pump (HPP) at first start-up is not ensured.



Injectors
Filter
Tank

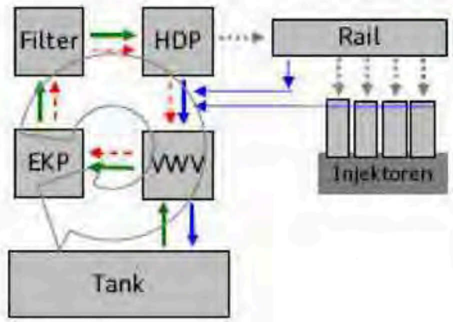
Non-responsive content removed

LP fuel system of the 2.0 L R4 TDI engines in the vehicle, longitudinal engine GEN1



Preheating valve in the LP circuit returns a part of the return flow to the inflow (Quantity depends on the temperature of the diesel). It cannot completely ventilate the LP circuit.
inlet
Return line from high pressure fuel pump (HPP) and leakage oil line
Return leakage oil line
Inflow line for the HPP
Return line for HPP
Return line for pressure control valve

Bubble-free inflow to the high pressure fuel pump (HPP) at first start-up is not ensured.



Injectors
Filter
Tank

Non-responsive content removed

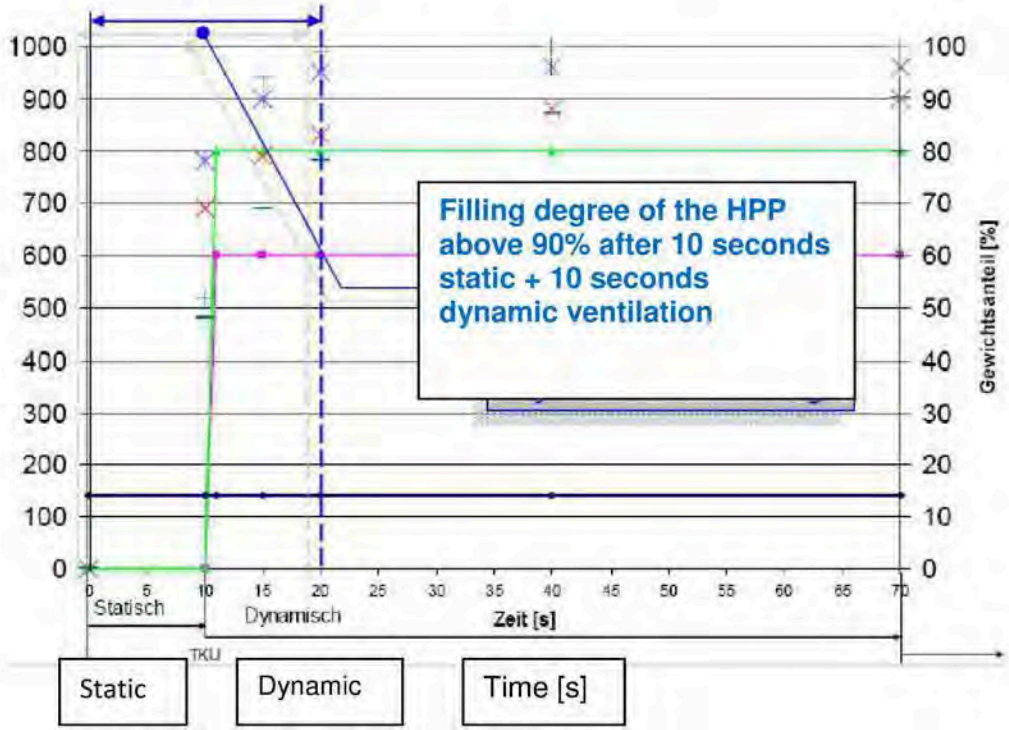
Status as on:09.12.2011

Filling time of the HPP on the test bench at Bosch

Filling of CP4 under similar vehicle boundary conditions VN-6507

Comparison of the ventilation of the different CP4 variants.

CP4 ventilation with similar vehicle boundary conditions



-ZrvE is always open
- Inflow quantity 140l/h
-Position CP4 2 same as W19 (top right cylinder head)
- Position CP4.1 same as EA189 (top metering unit)

- Inflow quantity [l/h]
- Engine speed CP4.2 [rpm]
- CP4 1 Filling [rpm]
- CP4 2 Filling [% weight]
- CP4.2 RP2 Filling [% weight]
- CP4 2 int overflow valve filling [% weight]
- CP4. 1 Filling [% weight]

No further ventilation

BOSCH

Record for verification of the start-up A6 with R4, 2.0l longitudinal engines (Gen2) on 07.21.2011 in the vehicle plant at Non-responsive content removed, Non-responsive content removed, Bosch

Striking points:

"*During the EFP pre-filling time investigations, the initial start-up process was* ***unintentionally started*** *on the adjacent A6 vehicle with R4, 2.0l engine due to connection of the vehicle voltage in the trunk for 15-20* ***seconds****. Start-up process could be switched-off only by removing the locking clamps in the trunk.*
Therefore, the CP4 high-pressure fuel pump was started dry without pre-filling, ***which is not permitted according to Bosch start-up regulation."***

A vehicle could not be refueled. Identification with label_ on the vehicle.
Has it been ensured that such a vehicle does not undergo engine start? „

"The first start-up with vehicle 2 already on the assembly line was accidental. ***First start-up time: not known****."*

Non-responsive content removed

Status as on: 09.12.2011

Breakdown in the roller test, vehicle plant [redacted] on 08.28.2011, KPM 5457062, "Engine no longer starts"

Detailed analysis by I/GQ-455, Pressure in high pressure fuel pump too low: No improvement after replacing HPP and rail → The functional problem of the EFP was only later detected, through additional troubleshooting.

"Does the pump have <u>drivetrain damage (Dry run consequential fault)</u>?
Why was the EFP fault not noticed with during the pre-filling of the CP4 on the assembly line at ECOS?

"We do not observe any defect in the EFP with Generation 1.
Test sequence was OK except for engine start, which could be due to faulty EFP.
However, it is implausible that the vehicle started despite that (The EFP may have temporarily delivered)
Detailed result of the analysis of the pump would certainly be interesting.
However, the test sequence records do not provide any clue of rework on the fuel system, <u>the pump replacement is also not recorded</u>.

Bosch HPP 0km Drivetrain damage 2011

Decisions:

- 1. Clarification for activation of terminal 15 for Audi / VW vehicles with R4 engines (similar to V6), Schedule clarification for duration to activate terminal 15 and terminal 50 (activation of starter)
  Objective: Activate EFP supply with ignition on in order to compress the air still present in the HPP after the EFP supply prior to the engine first start-up and thus ensure the lubrication of the HPP drivetrain parts to a 100% Non-responsive content removed **D: 09.30.2011**
  Note: For R4 vehicle with MDB engine, VW implemented an engine start-up delay and EFP supply time of max. 500 ms.
- 2. Determine correlation of engine first start-up times / residual air in high-pressure fuel pump using Henkel pump and transparent hose for vehicles with R4 and V6 engine.
  1. Clustering of R4, V6 LP cycles for correlation investigations Non-responsive content removed **D: 09.23.2011**
  2. Correlation investigation on min. two V6 development vehicles **D: 10.21.2011**
  3. Correlation investigation on min. two R4 development vehicles **D: 10.21.2011**
  4. Statistical confirmation of the analyses from point 2 and 3 in the vehicle plant on R4 and V6 vehicles Non-responsive content removed **D: 11.18.2011**
- 3. Send engine speed profile of insertion roller for vehicles with R4 or V6 engine (manual gear, automatic, DGS, Vario) for vehicle plants in Non-responsive content removed / Non-responsive content removed D: 09.16.2011
  Bosch evaluates whether the various engine speed profiles suffice for ventilation of the HPP Non-responsive content removed **D: after access to profiles**
- 4. Creation / Implementation of preliminary inspection specification for Audi vehicle plants Non-responsive content removed for R4 and V6 TDI vehicles of at least 10 seconds engine running time after vehicle first start-up (series, rework).
  [redacted] **D: 9/16/2011**

CP4.x - VW customer complaints
[redacted] plant

Cylinder head of piston seized

Fault scope
- 0-km 1x Pump [redacted]
- DoM: 09.30.2009 (SN: 01-0211)
- customer ref. No.: [redacted] (WE: 11.25.2009)
- QC no. .: [redacted]

Problem description of customer
- Pump does not function

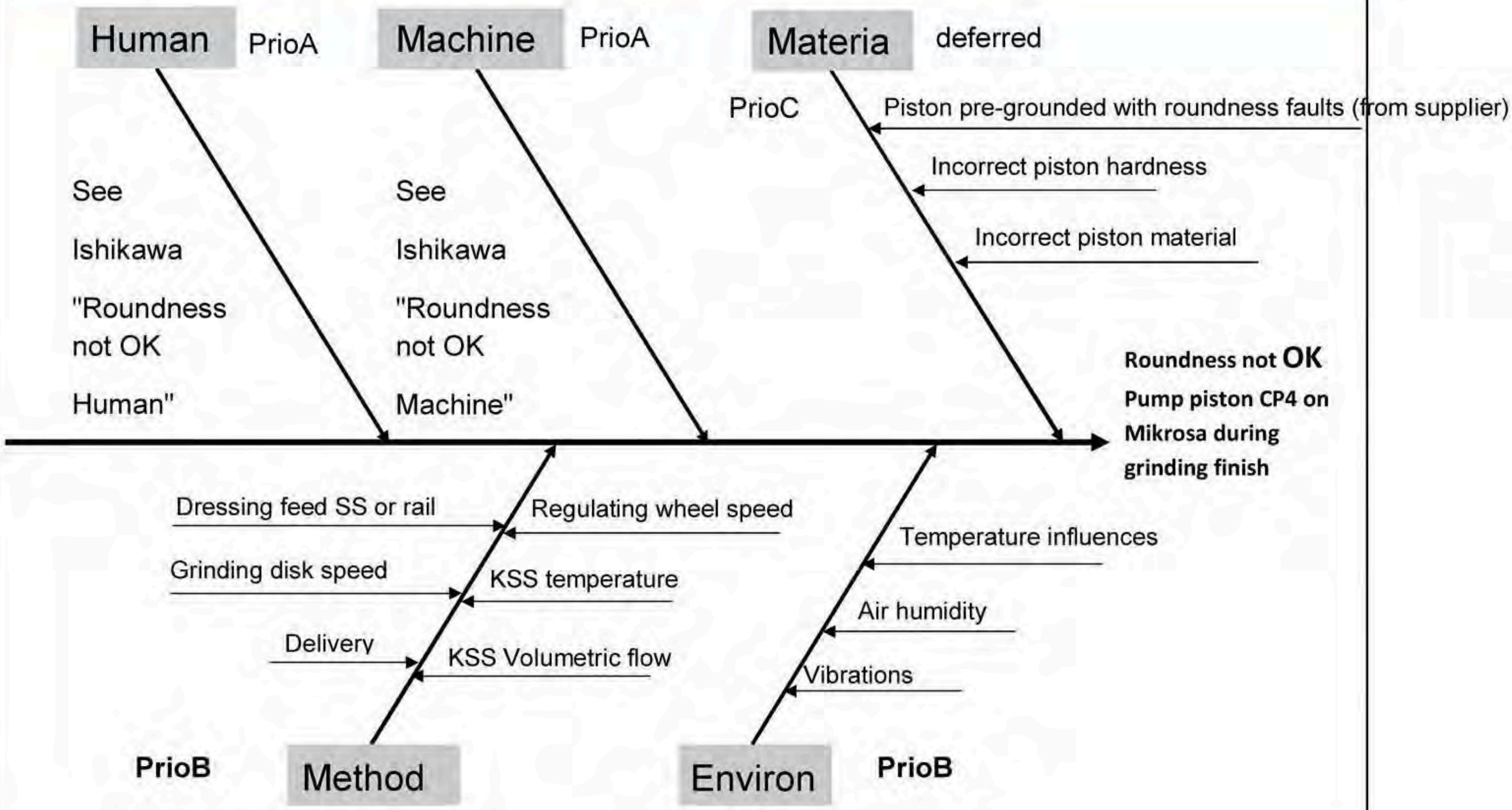
Root Cause Analysis
- Camshaft rotation test not OK (does not allow rotation)
- Cylinder head HP-piston stationary - seized
- Assembly procedure of the pump was checked
    - Pump was installed without breakdown
- Cylinder head separated
    - No roundness fault

Further analysis
- Analysis of the cylinder head or piston

Fig. 1: Type plate

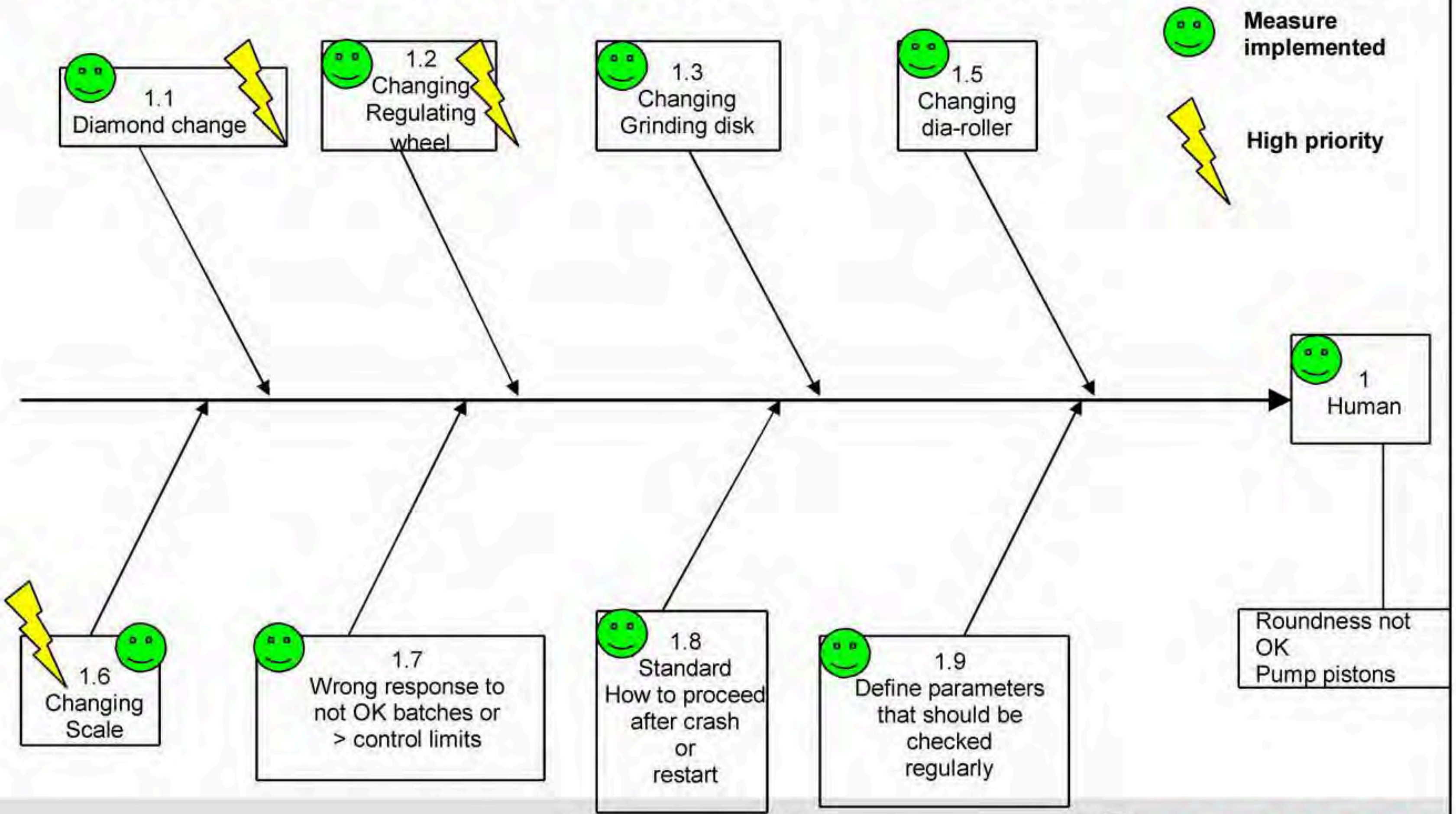

Fig. 2: Cylinder head of piston seized

Task force for CP4 piston seizure



Task force for CP4 piston seizure

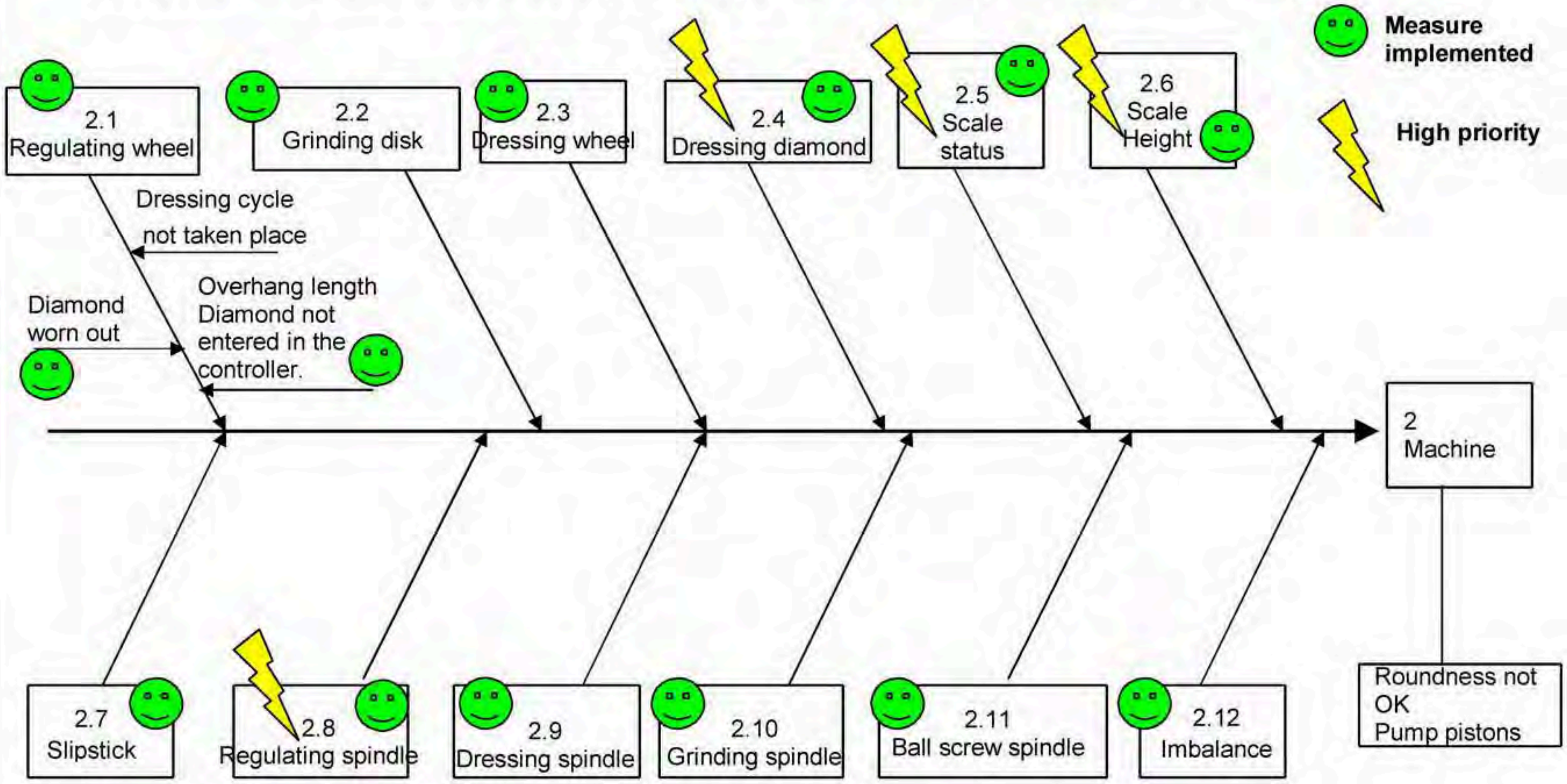
Ishikawa roundness influencing variable - human



BOSCH

Task force CP4 piston seizure

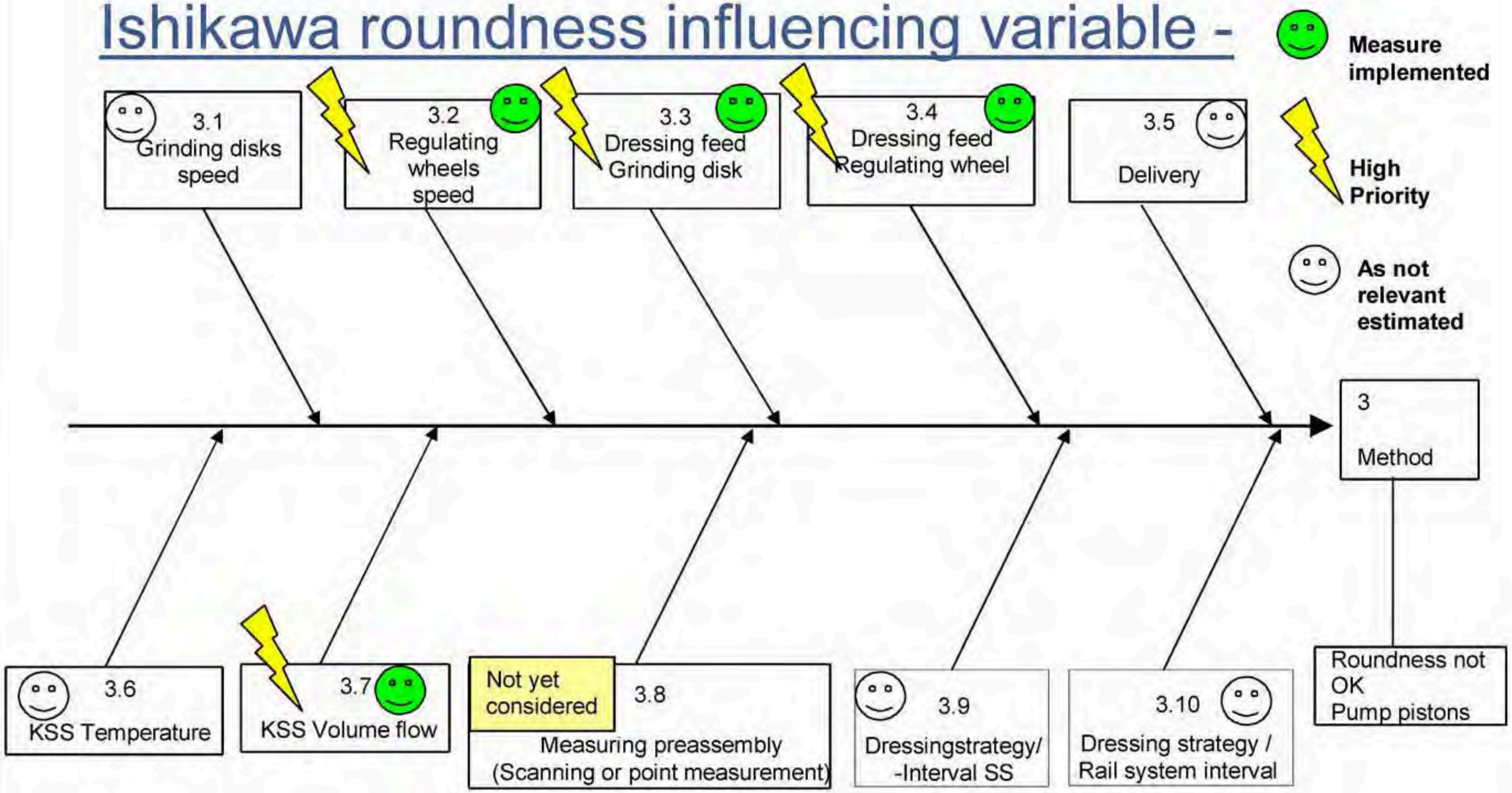
Ishikawa roundness influencing variable -



BOSCH

CP4-Pumppistons Mikrosa

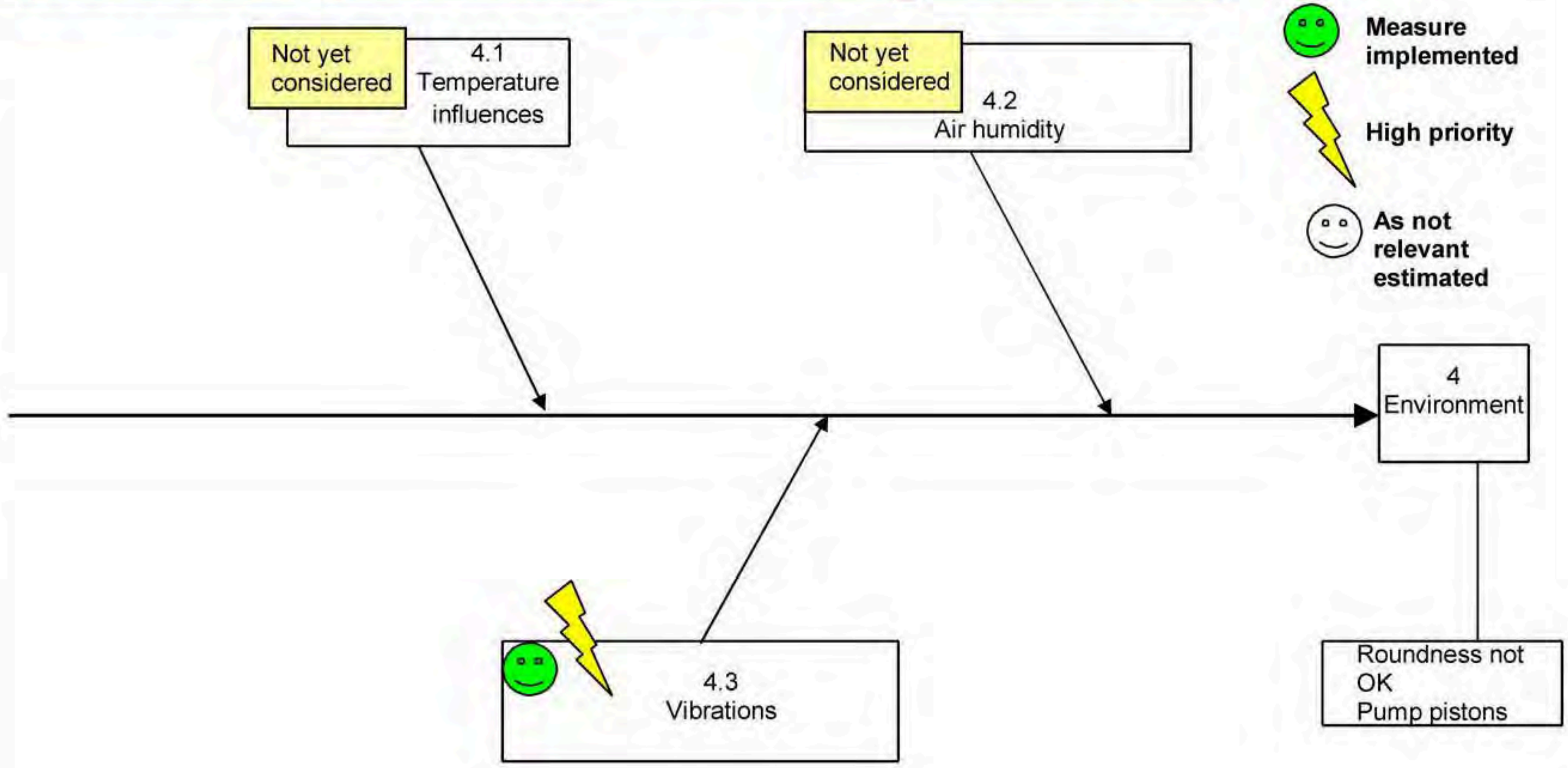
Ishikawa roundness influencing variable -



BOSCH

CP4 pump piston - Mikrosa

Ishikawa roundness influencing variable -



BOSCH

ENTIRE PAGE CONFIDENTIAL

Measures package of MSC4/W011210 - Mikrosa - pump piston CP4 - human

date	No.	Detected by	Deviation / problem	Recurring faults (x)	Cause	Immediate measure Corrective actions	Person in charge Dept. / name	Deadline	finished
Jun 19	1.1	Non-responsive content removed	After diamond change, the MAE may be set up incorrectly		Standard not defined	Define / review standard	Non-responsive content removed	6.25.2009	finished
Jun 19	1.1		After diamond change, the MAE may be set up incorrectly		Standard not defined	Implement in FuP / Training	Non-responsive content removed	7.3.2009	finished
Jun 19	1.2 - 1.5		How to change regulating wheel, grinding disk, diamond and dia-roller		Standard not defined	Define standard	Non-responsive content removed	6.23.2009	finished
Jun 19	1.2 - 1.5		How to change regulating wheel, grinding disk, diamond and dia-roller		Standard not defined	Implement in FuP / Training	Non-responsive content removed	7.3.2009	finished
Jun 19	1.9		Inspection intervals of level of scale and diamond overhang length		Standard not defined	Define standard	Non-responsive content removed	6.23.2009	finished
Jun 19	1.9		Inspection intervals of level of scale and diamond overhang length		Standard not defined	Implement in FuP / Training	Non-responsive content removed	7.3.2009	finished
Jun 22	1.6		Incorrect setting of scale		Standard not defined	Define standard and integrate in FuP	Non-responsive content removed	6.22.2009	finished
Jun 22	1.7		Improper response to batch release not OK or control limit exceeded		See OPL for batch release	See OPL for batch release	-	-	finished
Jun 22	1.9		Wear of parts, such as scale or single-point diamond		Inspection interval not defined	Define standard for inspection interval and in FuP integrate	Non-responsive content removed	7.3.2009	finished
Jun 23	1.8		There are situations, such as a crash of the controls, Can lead to changes or damage. The MAE will accept is put into operation immediately.		Absence of a written the approach, following e.g. Crash to be avoided.	- Define standard for parts and parameters that must be checked. Acceptance conditions after a crash. Implement in FuP - inspection of bearing damage to drive motors, regulating wheel and dressing spindle, clearance of all four ball screw spindles in the regular preventive maintenance measures	Non-responsive content removed Non-responsive content removed	7.3.2009 07.07.2009	finished Finished

Storage location: \\bosch.com\dfsrb\DfsDE\LOC\Fe[redacted]\CP4\Planung\67_Pumpenkolben\50_Schleifen Kolben Mikrosa\13 Task Force Kolbenklemmer\Berichtwesen Audi\02.10.2009\Maßnahmenliste Mikrosa Ishikawa Mensch.xls

Person in charge: [redacted]
Date: 12.8.2009

EA11003EN-00228[1]

ENTIRE PAGE CONFIDENTIAL

Measures package of MSC4/W011210 - Mikrosa - pump piston CP4 - machine

date	No.	detected by	Deviation / problem	Repeat Fault (X)	Cause	Immediate measure Corrective actions	Person in charge Dept. / name	Deadline	finished
Apr 30	2.8	[redacted]	Control spindle shows slack		Control spindle wear	Replacing the control spindle	[redacted]	2. May	finished
7. May	2.5	[redacted]	Scale surface broken in		Wear of scale	Replacing the scale	[redacted]	8. May	finished
7. May	2.6	[redacted]	Scale height is not optimal		Standard not defined	Standard defined	[redacted]	8. May	finished
7. May	2.3 and 2.9	[redacted]	Dressing spindle and dia-wheel show too much slack or are worn out		Spindle and dia-wheel wear	Replacing spindle and dia-wheel	[redacted]	8. May	finished
Jun 10	2.4	[redacted]	Deviation from parameter setting single-point diamond		Standard not defined	Single-point diamond parameter in software has been corrected	[redacted]	Jun 10	finished
Jun 22	2.4	[redacted]	Deviation from parameter setting single-point diamond		Standard not defined	Integrate standard in FuP	[redacted]	Jul 8	finished
Jun 16	2.1	[redacted]	Topography of regulating wheel not OK		Single-point diamond worn out	Define replacement intervals and integrate in FuP	[redacted]	Jul 3	finished
Jun 16	2.1.1	[redacted]	Topography of regulating wheel not OK		Dressing cycle has not taken place	Monitoring of dressing the regulating disk	[redacted]	Jul 15	faults
Jun 16	2.1.2	[redacted]	Topography of regulating wheel not OK		Diameter of the regulating wheel is usually calculated by MAE, taking into account the overhang IAK of EKD. -> An incorrect value in the controller leads to a rail system speed which is different from the indicated value. -> Roundness is not ensured, especially in process-boundary layers (e.g. minimum diameter. regulating wheel / grinding disk).	Measure overhang length and enter in the controller or adjust overhang length of EKD	[redacted]	Jun 19	finished
Jun 16	2.2	[redacted]	Topography of the grinding disk not OK		Dia-wheel wear	Define replacement intervals and integrate in FuP	[redacted]	Jul 3	finished
Jun 16	2.2.1	[redacted]	Topography of the grinding disk not OK		Dressing not optimal	Define dressing feed default in FuP	[redacted]	Jul 3	finished
Jun 16	2.7	[redacted]	Slip-stick effect of regulating wheel with workpiece		Topography of regulating wheel not OK	See sections 2.1 and 2.1.1	[redacted]	Jul 15	finished
Jun 22	2.12	[redacted]	Imbalance or concentricity of the rail system and / or SS		Vibrations	vibration analysis: - Geometric instability - Dynamic instability (Mikrosa2) - Dynamic instability (Mikrosa1) - Long-term process monitoring	[redacted]	7.6.2009 7.10.2009 7.14.2009 7.20.2009 7.31.2009 See PowerPoint presentation on "Vibrations analysis"	finished Finished Finished
Jun 22	2.9 - 2.11	[redacted]	Concentricity of the spindles not OK		Vibrations	vibration analysis: - Geometric instability - Dynamic instability (Mikrosa2) - Dynamic instability (Mikrosa1) - Long-term process monitoring	[redacted]	7.6.2009 7.10.2009 7.14.2009 7.20.2009 7.31.2009 See PowerPoint Presentation "Vibration analysis"	finished Finished Finished

Person in charge: [redacted]
Date: 12.8.2009

Storage location: \\bosch.com\dfsrb\DfsDE\LOC\Fe[redacted]\CP4\Planung\67_Pumpenkolben\50_Schleifen Kolben Mikrosa\13 Task Force Kolbenklemmer\Berichtwesen Audi\02.10.2009\Maßnahmenliste Mikrosa Ishikawa Mensch.xls

EA11003EN-00228[2]

ENTIRE PAGE CONFIDENTIAL

Measures package of MSC4/W011210 - Mikrosa - pump piston CP4 - machine

date	No.	detected by	Deviation / problem	Repeat Fault (X)	Cause	Immediate measure Corrective actions	Person in charge Dept. / name	Deadline	finished
Sep 28	3.2	Non-responsive content removed [redacted]	Default, when regulating wheel speed to be adjusted		Standard not defined	Define standard in package of measures	Non-responsive content removed [redacted]	See Ishikawa Machine	finished
Sep 28	3.3		Default, when dressing feed Grinding disk must be adjusted		Standard not defined	Define standard in package of measures		See Ishikawa Machine	finished
Sep 28	3.4		Default, when dressing feed Regulating wheel must be adjusted		Standard not defined	Define standard in package of measures		See Ishikawa Machine	finished
Sep 28	3.7.1		pressure fluctuations in the KSS		Upstream MAE at the KSS line cause pressure surges	Analysis of volumetric-flow rate and Locating the pressure surge inducers		Sep 29	finished
Sep 28	3.7.2		pressure fluctuations in the KSS		Upstream MAE at the KSS line cause pressure surges	Installation of pulsation dampers in the Check affected KSS lines -> Obtaining proposal -> Order		10.24.2009 acc. to 3.7.3	finished
Sep 28	3.7.3		pressure fluctuations in the KSS		Upstream MAE at the KSS line cause pressure surges	Installation of a new additional inflow line proposal and return line Mikrosa connection to the line		Prepare create. Date of installation n 10.29.09 11.11.2009	finished Finished Finished
Dec 4	3.1		Influence of grinding disk speed		Incorrect input value or incorrect Drive	entry of the correct value according to PDB, monitoring grinding disk speed		04.12.	finished
Dec 4	3.5		Influence on delivery		Incorrect entry value(s) in Penetration curve; Incorrect over-allowance for blank	Entry of the correct value according to PDB; Incoming goods inspection		04.12.	finished
Dec 4	3.6		KSS temperature		Temperature fluctuation in the Central supply	Production stop + information to FCM		04.12.	finished
Dec 4	3.9.1		SSB dressing interval larger / smaller Desired value		Incorrect entry value	Entry of the correct value according to PDB		04.12.	finished
Dec 4	3.10.1		Dressing interval rail system is higher / lower than desired value		Incorrect entry value	Entry of the correct value according to PDB		04.12.	finished

Storage location: \\bosch.com\dfsrb\DfsDE\LOC\Fe[redacted]\CP4\Planung\67_Pumpenkolben\50_Schleifen Kolben Mikrosa\13 Task Force Kolbenklemmer\Berichtwesen Audi\02.10.2009\Maßnahmenliste Mikrosa Ishikawa Mensch.xls

Person in charge: [redacted]
Date: 12.8.2009

ENTIRE PAGE CONFIDENTIAL

Measures package of MSC4/W011210 - Mikrosa - pump piston CP4 - environment

date	No.	detected by	Deviation / problem	Repeat Fault (X)	Cause	Immediate measure Corrective actions	Person in charge Dept. / name	Deadline	finished
Sep 30	4.3	Non-responsive content removed	Vibrations in the machine that can influence the process		component wear in the Machine	Check whether useful in-process vibration measurements can be performed on MAE	Non-responsive content removed	see power point "Vibration analysis"	finished
Sep 30	4.3		Vibrations in the machine that can influence the process		component wear in the Machine	Performing vibration measurements and examine whether striking features exist		see power point "Vibration analysis"	finished
Sep 30	4.3		Vibrations outside the machine, that may influence the process		Vibrations caused by passing vehicles Vehicles or other MAE	Perform vibration measurements during external vibration Inclusion of a vibration measurement during, e.g. forklift traffic in comparison to the "idle status" -> contractor appointed -> NO effect of passing vehicles (milkrunner, forklifts). Striking features come from lowering of pallets with lifting cart, which is in principle prohibited in the workshop during machine operation.		Oct 8	finished

Storage location: \\bosch.com\dfsrb\DfsDE\LOC\Fe[redacted]\CP4\Planung\67_Pumpenkolben\50_Schleifen Kolben Mikrosa\13 Task Force Kolbenklemmer\Berichtwesen Audi\02.10.2009\Maßnahmenliste Mikrosa Ishikawa Mensch.xls

Person in charge: [redacted]
Date: 12.8.2009

Task force for CP4 piston seizure

Milestones

Phase3	T
3.1 Preparation of fault tree / Ishikawa "piston seizure"	06.29.09 √
3.2 Handling of OPL (Open Point List) from fault tree / Ishikawa	In progress
3.3 Lessons learned for Mikrosa2 and Bosch Jihlava plant	
3.3.1 Supplementation of VI measures	07.07.09 √
3.3.2 Increasing frequency of general analysis	07.07.09 √
3.3.3 Transmission of system according to Bosch Jihlava plant	07.08.09 √
3.3.5 Recording of "lessons learned" drive CPx	~~08.31.2009~~ 09.30.09 √
4.3 Sustainable process safety in the FMEA (Failure Mode and Effects Analysis)	09.30.09 √

BOSCH

Task force for CP4 piston seizure

Milestones

Overview of lessons learned: Transfer of knowledge gained on grinding machines to CP4 IPN	**Deadline**
Focus:	
1. Review and completion of existing preventive maintenance measures on grinding machines in CP4 IPN (see page 3)	**09.30.09** √

BOSCH

Task force for CP4 piston seizure

Milestones

Roll out "lessons learned" CP4 grinding machines (Review and completion of existing preventive maintenance measures)	Deadline
• HTTs (intake valve piston)	CW31 √
• [redacted] (cylinder head)	CW32 √
• [redacted] (camshaft)	CW33 √
• [redacted] (roller support)	CW34 √
• [redacted] (roller support)	~~CW35~~
	CW40 √

Task force for CP4 piston seizure

Milestones

2. Introduction of TPM teams at selected equipment (such as bottleneck machines)	
2.1 TPM team defined and equipment selected (Mikrosa, ECM, HTT)	**09.29.09** √
2.2 Performance of actual status analysis of the selected equipment	**10.12.09** √
3. Introduction of status-based maintenance with focus on warehouse condition monitoring at selected grinding machines in CP4 IPN	
3.1 Recording of a vibration measurement during, e.g. forklift traffic in comparison to the "idle status"; for details, see Ishikawa OPL environment	**10.08.09** √

BOSCH

Task force for CP4 piston seizure

Milestones

3.2 Supplementation of the existing vibration measurement on the grinding spindle by drive motor regulating wheel and dressing spindle. Preparation of proposal and schedule for implementation **10.09.09** √

BOSCH

Task Force piston seizure CP4

Vibration analysis

Target

An experimental analysis of static and dynamic behavior of the grinding machine **KRONOS S (from Mikrosa)** with the aim of getting clear evidence from the measurement data for the cause of the impermissible formation of 5-layered surface structures, etc. observed on CP4 piston.

Execution

1. Phase

Literature review and working out the kinematic and structurally dynamic boundary conditions for the mechanism behind the formation of surface structures. Finished √

2. Phase

In-process evaluation of the actual values of the position and engine speed controls of the axles and spindles of KRONOS S

that are digitally available in CNC Siemens 840 D. Finished √

3. Phase

Experimental analysis of structural dynamics and the determination of the inherent frequencies of the machine structure suitable for the mechanism for formation of these surface structures.

 [redacted]

BOSCH

Task Force piston seizure CP4

Vibration analysis

Execution

2. Phase

In-process evaluation of the actual values of the position and engine speed control of the axles and spindles of **KRONOS S** that are digitally available in CNC Siemens 840 D.

as of 07/10/2009

Analysis on the machine with the axis X1 (infeed axis of grinding disk), X4 (infeed axis of regulating wheel) and the engine speeds of grinding disks and regulating wheels during the process. Three states of the grinding disk were examined: After dressing, between two dressing cycles and just before dressing.

Conclusions

Currently, there are no process-influencing abnormalities in the components analyzed above

 [redacted]

BOSCH

Task Force piston seizure CP4

Vibration analysis

Execution

3. Phase

Experimental analysis of structural dynamics and the determination of the inherent frequencies of the machine structure suitable for the mechanism for formation of these surface structures.
The analyses were carried out on the KRONOS S no. 2 (new machine) due to capacity constraints

as of 07/10/2009
The machine was equipped with accelerometers and excited at standstill with a momentum and frequency responses of the signals were determined. In the frequency responses, the inherent frequencies of the machine are recognizable.

Conclusions
In the frequency responses measured on KRONOS S no. 2 at idle status, two inherent frequencies - EF1 ~ 134 Hz and EF2 ~ 186 Hz - that would be **suitable** in principle **for the mechanism for the formation of the surface structures can be recognized.**

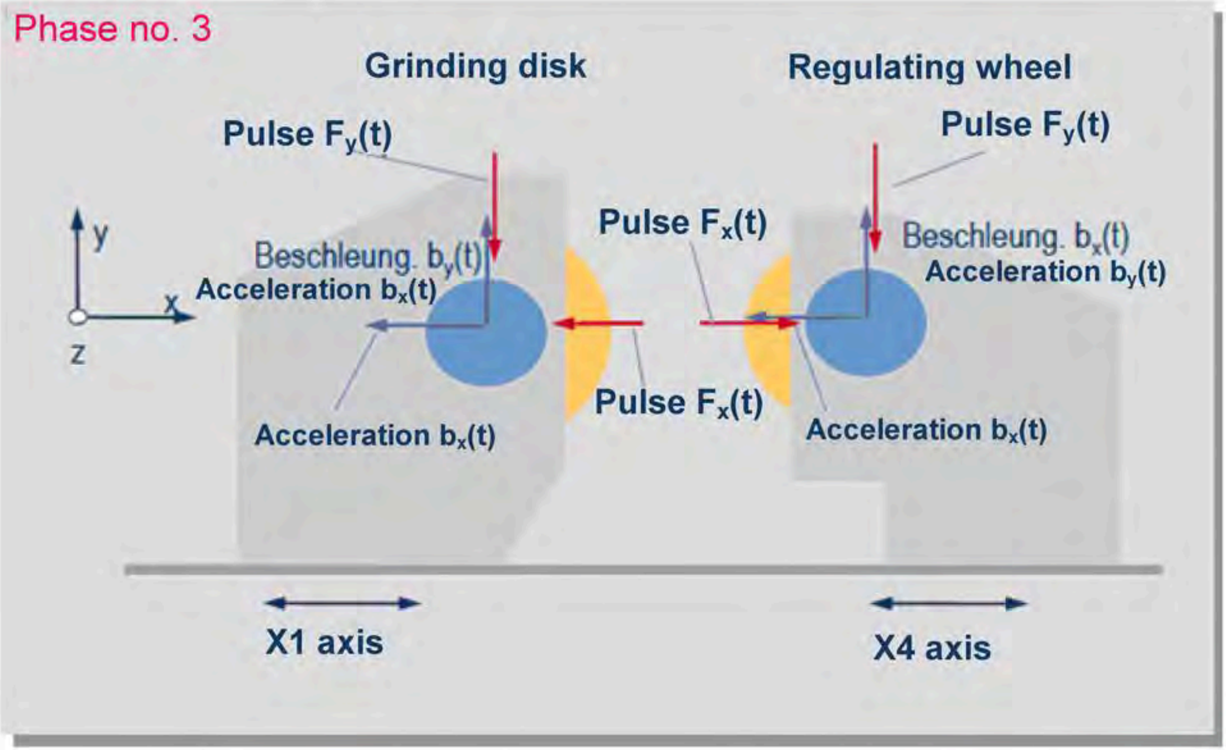
The analysis must be repeated on the KRONOS S no. 1.

 [redacted]

BOSCH

Task Force piston seizure CP4

Vibration analysis



BOSCH

Task Force piston seizure CP4

Vibration analysis

Further procedure

3. Phase (continued)	V	T
Repeating the analysis on KRONOS S no. 1	Kleckner	07/14. √
Evaluation of the above-mentioned analysis on KRONOS S no. 1	Kleckner	07/15. √
Starting long-term process monitoring through vibration analysis using PROSI	Kleckner	07/20. √

as of 7/16/2009
The machine was equipped with accelerometers and excited at standstill with a momentum and frequency responses of the signals were determined→ similar to Machine2

CONCLUSIONS
Likewise, minimal differences that are due to the fact that Mikrosa1 has been in operation for a long time are to be noted. Otherwise, no striking feature has been noticed.

 [redacted]

BOSCH

Task Force piston seizure CP4

Vibration analysis

3. Phase (continued) as of 7/30/2009

Target
An experimental analysis of static and dynamic behavior of the grinding machine **KRONOS S** with the aim of getting clear evidence from the measurement data for the cause of the impermissible formation of 5-layered surface structures, etc. observed on CP4 piston.

Implementation	**V**	**T**
3. Phase		
3D measurement of the accelerations of grinding disks and regulating wheels for MIKROSA 1 between **two** dressing processes.		
The application of the sensor directly on the scale is in **preparation**.	Kleckner	7/30/2009 √

Conclusions
The acceleration signals measured on MIKROSA 1 do not show **any striking features** during the grinding process as of now. To detect the vibrations that could be the cause for the formation of the 5-layered structures, targeted measurements directly on the scale are required (see Implementation).

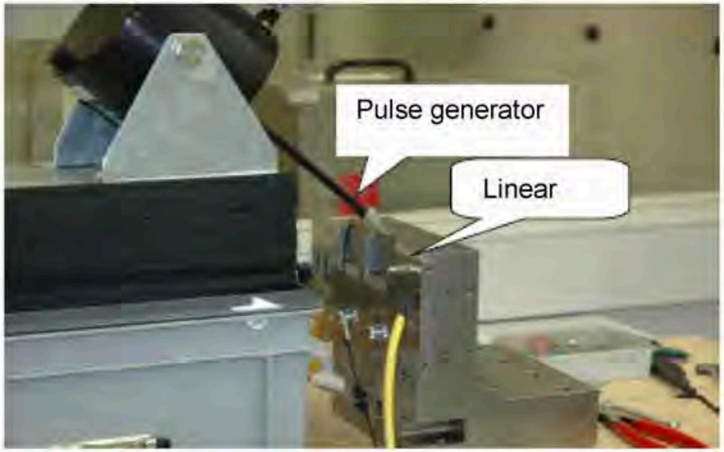
BOSCH

Task Force piston seizure CP4

Vibration analysis

Implementation	Status as of 08/11/2009	**V**	**T**
3. Phase			
The application of the sensor directly on the scale is in **preparation**.		[redacted]	07/30/2009 √

The following sensors were installed in a testing linear scale (same as series, but worn out): "Acoustic emission Kistler Z16852X3" and accelerometer Brüel & Kjaer 8309. The linear scale was excited with momentum (see picture)



Conclusions

The trial shows opportunities to evaluate roundness errors in the process.

Equipping Mikrosa2 (linear) with sensors	Kleckner	08/11/2009 √

Task Force piston seizure CP4

Vibration analysis

Implementation	Status as of 9/25/2009	V	T

3. Phase

With the aim to find a correlation between signal output of sensors and roundness problem, the sensors on the linear scales were mounted directly in the 2 grinding machines.

Mikrosa2 (new MAE)
Even with the adjustment of process parameters, such as
1. dressing feeding speed of regulating wheel,
2. dressing feeding speed of grinding disk and
3. value for altitude H in controller,
roundness error could not be reproduced

Mikrosa1 **(BEFORE overhaul)**
The adjustment of the above parameters led to roundness problems (not 5-layered)

Conclusions
With the trial, it is confirmed that the roundness error occurs only when all 7 deviations occur.

[redacted] ~~09.04.2009~~ 09/25/2009 √

A correlation between sensor signal and roundness error has to be worked out yet. Initial evaluations indicate that the variation of process parameters do not lead to impermissible 5-layered surfaces.

BOSCH

Task Force piston seizure CP4

Vibration analysis

Summary as of 12/08/2009

All dynamic analyses and experimental adjustments performed on the machine did not show any abnormality on the formation of a roundness error in the form of a 5-layered structure.

A machine with signs of wear of various components (Mikrosa 1) shows roundness deviations, but not in the form of a 5-layered structure. These roundness deviations can be detected by sensors.

Machine Mikrosa 1 was overhauled by Mikrosa from 08/18. to 08/21/2009.

This leads to further steps:

Repetitive measurement on Mikrosa 1 after overhaul, Non-responsive content removed

	~~D. 10/14/2009~~	D 10/30/2009 √
Supplementation of the controller by Siemens add-on module for evaluating the machine's internal signals (comprehensive Q-monitoring):		
→ Presentation of "status monitoring" by Mikrosa in Feuerbach plant		10/23/2009 √
→ Decision whether Siemens or Mikrosa monitoring tool		10/30/2009 √
→ Proposal by Mikrosa for "status monitoring"		11/13/2009 √
→ Order "status monitoring"	~~11/20/2009~~	**12/2/2009** √
→ Introduction of "status monitoring" on pilot basis in Feuerbach		**1/25/2010**
Introduction / implementation of the warehouse condition monitoring (See milestones roll out lessons learned, point 3, pages 4 and 5)		10/2009 √

 [redacted]

BOSCH

Reapproval of Feuerbach plant pump piston

piston seizure

- **Since 06.19.2009, preferred supply of Jihlava plant pistons to Audi due to failures (piston seizure) with Feuerbach plant pump piston**
- **Fault analysis concluded and causes identified, measures introduced**
- **Implementation of further preventive measures is in progress. Improved verification is defined by series-accompanying SPC. Introduction after presentation**

PROPOSAL

- **Measure of preferred installation of Jihlava plant piston from Q-perspective no longer useful**

- **Note: Feuerbach plant pistons were installed for all other customers over the entire period → No internal and external failures**

BOSCH

EA11003EN-00233[0]

ENTIRE PAGE CONFIDENTIAL

High-pressure pump 03L 130 755/ 755A/755J Hall/Field 2008 /09 /10/11 Status as on. 06.29.2011

POS	GEN	FIELD	Ökm	Mileage in km	EZL	DATE	VEHICLE	ENGINE l/kW	Engine	Engine number	Vehicle identification number	AUDI	VW	COMPLAINT	Origin
5			X	0		16.01.2008	Passat	2.0l/103	CBA	377880	[illegible]		X	Rail pressure not OK	Non-responsive content removed
7			X	15		28.05.2008	Passat	2.0l/103	CBA	088313			X	Engine no longer starts up after a mileage of 15 km	
9			X	0		03.06.2008	Passat	2.0l/103	CBA	097355			X	Engine does not start up	
10			X	0		17.06.2008	Passat	2.0l/103	CBA	123110	[illegible]		X	No rail pressure	
11			X	0		17.06.2008	Passat	2.0l/103	CBA	123108	[illegible]		X	No rail pressure	
33			X	0		18.09.2008		2.0l/103						Does not start. Low pressure of the pump is not ok	
67			X			26.02.2009		2.0l/103	CBD	[illegible]			X	Fuel pump with deficiency HPP 2X built-in. Engine [illegible] 2. Engine [illegible]	
114		X		53,214	09.12.2008	13.03.2009	Passat	2.0l/103	CBA	[illegible]	[illegible]		X	Function not OK	
119			X			29.05.2009		2.0l/103	CBB	107863			X	No rail pressure	
127			X			16.06.2009		2.0l/103	CBD	101988			X	No rail pressure	
177		X		12,833	25.06.2009	02.10.2009	Passat	2.0l/103	CBA	223044	[illegible]		X	Engine controller lights up under load when engine is at operating temperature	
194			X			21.01.2010		2.0l/103	CCJ	[illegible]			X	HPP does not build up rail pressure	
202		X		27,572	19.02.2009	14.12.2009	Passat	2.0l/103	CBA	174887	[illegible]		X	Vehicle does not start up, chips in the fuel filter	
211			X			08.01.2010		2.0l/103	CBA	152270			X	Engine does not start up	
222			X			06.01.2010		2.0l/103	CBB	115572			X	HPP does not deliver	
414			X			11.10.2010		2.0l/103	CFF	[illegible]			X	Engine does not start up	
463		X		6,124	02.11.2009	29.07.2010	Audi	2.0l/103			[illegible]	X		No information on the part of Audi	
506		X		5,266	01.09.2010	24.11.2010	Transporter	2.0l/103	CAAC	[illegible]	[illegible]		X	Engine does not start up	

POS	Part number VW	YEAR	Month	Day	LR. no.	Plant	QT No.QK No.Ref no.	SHIPPING	Preliminary analysis VW/Bosch	ROOT CAUSE ANALYSIS Bosch	MEASURES	Feedback/Originator	Cross-check DISS/KD-Rep Difference/Striking feature	No trouble found / drivetrain damage
5	03L 130 755	08	01	16	BPT [illegible]	515	Non-responsive content removed	Metering unit delivered without		Pump piston seized	Change of the conditioning of the piston ring groove (new parts) current condition: piston grooves are turned. Planned condition: Piston grooves are cut.	finished		
7	03L 130 755	08	05	16	BPT [illegible]	515		IKB 732233 08.28.08		Pump piston seized	Change of the conditioning of the piston ring groove (new parts) current condition: piston grooves are turned. Planned condition: Piston grooves are cut.	finished		
9	03L 130 755	08	06	11	BPT [illegible]	515		IKB 732241 09.02.08		Pump piston seized	Change of the conditioning of the piston ring groove (new parts) current condition: piston grooves are turned. Planned condition: Piston grooves are cut.	finished		
10	03L 130 755	08	06	11	BPT [illegible]	515		IKB 732262 09.17.08		Pump piston seized	Change of the conditioning of the piston ring groove (new parts) current condition: piston grooves are turned. Planned condition: Piston grooves are cut.	finished		
11	03L 130 755	08	06	11	BPT [illegible]	515		IKB 732262 12.09.08		Pump piston seized	Change of the conditioning of the piston ring groove (new parts) current condition: piston grooves are turned. Planned condition: Piston grooves are cut.			
33		08	06	22	BPT [illegible]	515		Skoda Auto		Particles at the intake valve				
67	03L 130 755	08	09	30	BPT [illegible]	515		IKB 732354 11.27.09	Metering unit disconnected by Mr. [redacted] and Mr. [redacted] no chips under the metering unit	Problem description: Fuel pump is the cause for the deficiency. A high-pressure pump is mounted at the second engine. Fault pattern was confirmed. [illegible] Corrosion was found on the overflow valve. Rust on pump piston, roller support, overflow valve, cylinder head, IV system	Customer responsibility: rust on the internal pump parts	Non-responsive content removed		
114	03L 130 755	08	03	30	BPT [illegible]	515		VA 99108 [illegible]	Intervention at the HPP pump: screw for tightening metering unit is missing, metering unit wrongly assembled. Metering unit disconnected by Mr. [redacted] chips, corrosion. (Drivetrain damage)	Analysis: visual inspection: missing metering unit screw not ok; inspection of inflow and return connections; particles found not ok; [illegible]	Pump drivetrain damage			
119	03L 130 755	09	03	27	BPT [illegible]	011		IKB 733228 [illegible]	Engine examined in the hot test by Mr. [redacted] metering unit [illegible] valve is open Mr. [redacted] drops the high-pressure fuel pump	Analysis: pump piston jammed in the cylinder head - cylinder head [illegible] to grinding process	Bosch responsibility: immediate measures in the production of pistons 05.07.09 100% pre-securing test 05.14.09 refined 100% pre-securing test, analysis of grinding process is undertaken.			
127	03L 130 755	09	03	25	BPT [illegible]	011		IKB 733242 06.18.09	metering unit disconnected, no chips or damage	Analysis: [illegible] Deviations from the standard: [illegible]	Bosch responsibility pump piston jammed: formation of a Table Form for piston jamming 05.07.09 100% pre-securing and 05.14.09 refined 100% pre-securing test, analysis of grinding process is undertaken.			
177	03L 130 755	08	04	10	BPT [illegible]	515		VA 99235 10.16.09	metering unit disconnected, chips at the metering unit and in the bore	Analysis: [illegible]	Customer responsibility Complaint rejected			
194	03L 130 755 J	10	01	11	BPT [illegible]	515		Test report 790520 10 01.24.2010	metering unit disconnected, no chips or damage. A-shaft can be easily rotated	Analysis: Pump piston jammed. [illegible]	Bosch responsibility Increase of the scavenging pressure from 1800 to 200 bar, 2000 bar for all CP1.1 [illegible] the Audi 2 pistons.			
202	03L 130 755	09	01	11	BPT [illegible]	515		VA 99369 01.11.2010	metering unit disconnected, minimal fine chips, otherwise OK	Analysis: [illegible] Analysis of the deposit: [illegible]	Warranty decision R6: Rejected, customer responsibility. Unsuitable fuel, pump drivetrain damage			
211	03L 130 755	09	09	25	BPT [illegible]	515		Test report 790902 10 04.07.2010	094/10	Analysis: [illegible]	Increase of the rinsing pressure from 1800 to 2000 bar for all CP4.1 => objective: keep pump jamming mode. Was already introduced for CP4.2. Introduction of a new piston press-in mandrel for the pre-assembly in the cylinder head. Introduction of the 100% roundness measurement of the piston			
222	03L 130 755	09	11	19	BPT [illegible]	515		Test report 790902 10 04.07.2010	093/10	Analysis: [illegible]	Increase of the rinsing pressure from 1800 to 2000 bar for all CP4.1 => objective: keep pump jamming mode. Was already introduced for CP4.2. Introduction of a new piston press-in mandrel for the pre-assembly in the cylinder head. Introduction of the 100% roundness measurement of the piston			
414	03L 130 755 L	10	08	11	BPT [illegible]	515		Test report 792385 10 11.11.2010	metering unit disconnected. Chips in the bore and on the metering unit screen	Analysis: [illegible]	Warranty rejected. Customer responsibility. Unsuitable fuel			[illegible]
463	#NZUG!	09	10	16		515				Analysis: [illegible]	Bosch responsibility drivetrain damage/turned tappet. Improvement in cleaning activities at FeP + JeP. Optimization of the assembly processes			
506	03L 130 755 J	10	08	11	BPT [illegible]	515		VA 99737 01.19.2011	A shaft turns slowly. Metering unit disconnected, chips in the bore and metering unit screen	Analysis: [illegible]	Warranty rejected, wrong fuel			[illegible]

Torsional vibration measurements @ Audi V6

W19 engine measurements

Non-responsive content removed

125 Bosch 1886–2011

BOSCH

Torsional vibration measurements @ Audi V6

Torsional vibration measurements @ W19 engine

Initial situation

- Vehicle measurements with W19 EU5 show torsional vibrations of +/- 850 rpm (vehicle)
- Vehicle measurements with W19 EU5 show torsional vibrations of +/- 660 rpm (vehicle)

Further work done

- Torsional vibration measurements on the engine under variation
  - Tensioning roller EU5 and EU6
  - Displacement of pump orientation (simulation of incorrect installation or mounting position of EU6)

Result

- Engine measurements at W19
  - with EU5 idler pulley show torsional vibrations of +/- 490 rpm (engine)
    - upon incorrect installation, torsional vibrations rise to +/- 940 rpm (engine)
    - EU6 mounting position compared with the EU5 on the engine in terms of torsional vibrations
  - with EU6 idler pulley, the torsional vibrations fall to +/- 380 rpm (engine)

BOSCH

Torsional vibration measurements @ Audi V6

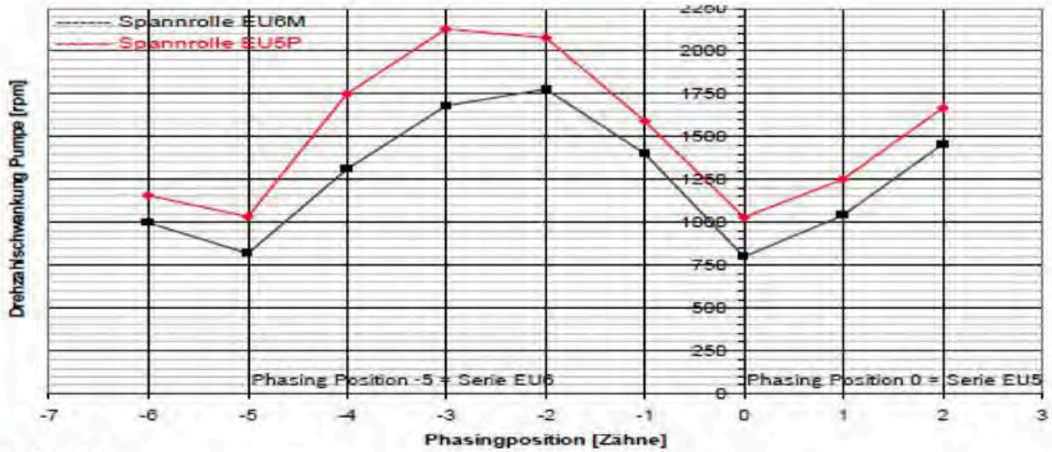
Torsional vibration measurements @ W19 engine

Proposed further work

→ Comparison of engine and vehicle measurements -> determination of vehicle drivetrain impact
- Repetitive measurement with EU5 engine idler pulley
- Measurement with EU6 engine idler pulley

Torsional vibration measurements @ Audi V6

Results: Speed fluctuation (p-p) pump = f (phasing position), @ 2,440 rpm (3,250 rpm engine) W19 EU5 (full load)



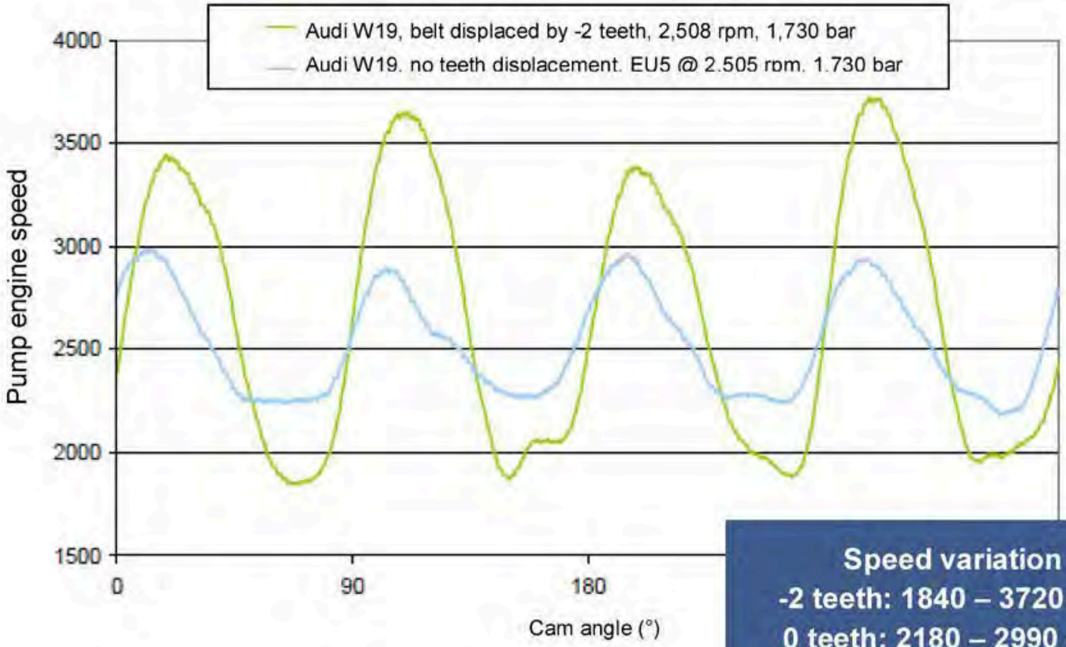
Tensioning roller EU6M
Tensioning roller EU5P
Pump speed fluctuation [rpm]
Phasing Position – 5 = Series EU6
Phasing Position – 0 = Series EU6
Phasing position [teeth]

Summary:

- EU 6 idler pulley leads on average to about 250 rpm less torsional vibration at the pump
- Mounting position 0 or minus 5 teeth found to be the best option
- Misalignment of the pump during pump replacement may lead to significant increase in torsional vibrations

Torsional vibration measurements @ Audi V6

Comparison of teeth displacement: AUDI W19

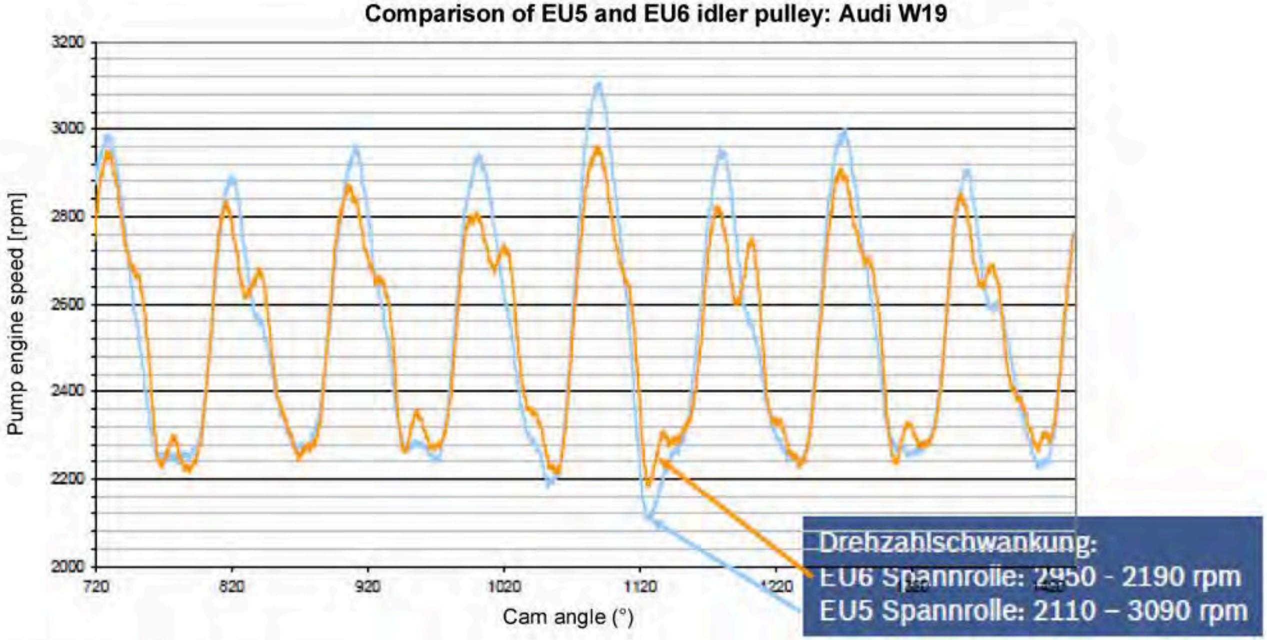


Speed variation
-2 teeth: 1840 – 3720 rpm
0 teeth: 2180 – 2990 rpm

BOSCH

Torsional vibration measurements @ Audi V6

Comparison of EU5 and EU6 idler pulley: AUDI W19



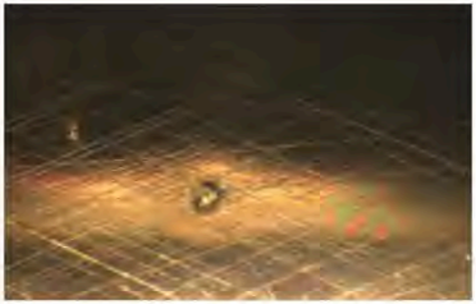
Speed fluctuation:
EU6 idler pulley: 2950 - 2190 rpm
EU5 idler pulley: 2110 – 3090 rpm

Failure of Audi test vehicle

Analysis result

- **Dimensional check of piston OK.**
- **Clearance measurement of cylinder head without bolt is OK**
- **Piston clearance assembly master computer (01.06.2011) OK**
- **Cause of stiff pistons: Entry of particles into the cylinder head as a result of drivetrain damage.**

High particle entry in the HP range



Scattered particles in the piston bore

From: Non-responsive content removed [redacted]
To: [redacted]
CC: [redacted]
Date: 10/20/2008, 9:19:30 AM
Subject: FW: [redacted] Re: [redacted] Re: Status report: CP4 failures with activity plan v_16_10_08 v_20_10_08
Attachments: EHC_0371_ Non-responsive content removed [redacted] Audi, CP4 Übersicht Akltivitäten gegen Triebwerksschäden, Non-responsive content removed [redacted] Liste Triebwerkschäden CP4 09 10 08.xls

Regards,
Non-responsive content removed [redacted]

From: Non-responsive content removed [redacted]
Sent: Monday, October 20, 2008, 9:27 AM
To: Non-responsive content remove
Cc: d [redacted]
Subject: [redacted] Re: [redacted] Re: Status report: CP4 failures with activity plan v_16_10_08 v_20_10_08

Hello [redacted],
I have attached the list with all drivetrain damage at VW and Audi.
Please enter our drivetrain damage and send it to Mr. Non-responsive content removed [redacted].
Thank you
Best wishes,
[redacted]

From: Non-responsive content removed [redacted]
Sent: Thursday, October 16, 2008, 4:21 PM
To: Non-responsive content removed [redacted]
Cc: [redacted]
Subject: [redacted] Re: Status report: CP4 failures with activity plan v_16_10_08

Hello [redacted]

As we discussed, I have attached an assessment of the influences on the HPP drivetrain damage and the planned activities.
Can you please give us the information about the most recently failed U.S. pump?

I have also attached the latest CP4.1/ 4.2 failure list from Mr. [redacted] Audi.

Now you know where things stand!

Regards,

[redacted]

From: [redacted]
Sent: Thursday, September 04, 2008, 7:22 PM
To: [redacted]
Cc: [redacted]
Subject: Re: Status report: CP4 failures with activity plan

Good evening [redacted]

supplemented item (?) on overhead page 1.

As well as the questions asked during the technical meeting - of course, I added them to the open points list as well.

Best regards / mit freundlichen Grüßen

Non-responsive content removed

Robert Bosch GmbH
Non-responsive content removed
www.bosch.com

Non-responsive content removed

From: Non-responsive content removed
Sent: Thursday, September 04, 2008, 1:43 PM
Non-responsive content removed
Subject: Re: Status report: CP4 failures with activity plan
Importance: High

Hello Mr. [redacted] hello Mr. [redacted]

EA11003EN-00240[2]

One important item missing from your/our action plan is the investigation of the very large differences between the failure rates of the 2-stampers (Audi V6) vs. the 1-stampers (VW, BMW R4). Please add this by noon tomorrow.
Thank you.

Best regards

[redacted]

From: Non-responsive content removed
Sent: Monday, September 01, 2008, 7:19 PM
Non-responsive content removed
Subject: Re: Status report: CP4 failures with activity plan

Gentlemen,

I have attached the overview of development and production activities promised for today on the subject of "Reduction of CP4 drivetrain damage at Audi".

The items were presented at the last CP4 technical pump meeting, on 08/27/2008 in NSU.

Best regards / mit freundlichen Grüßen

Non-responsive content removed

Robert Bosch GmbH
Non-responsive content removed
www.bosch.com

Non-responsive content rem
oved

Headquarters: Stuttgart, Court of Registry: Local District Court of Stuttgart Commercial Register no. 14000
Chairman of the Supervisory Board: Hermann Scholl; Management Board: Franz Fehrenbach, Siegfried Dais;
Bernd Bohr, Wolfgang Chur, Rudolf Colm, Gerhard Kümmel, Wolfgang Malchow, Peter Marks;
Volkmar Denner, Peter Tyroller

From: Non-responsive content removed
Sent: Monday, September 01, 2008, 6:50 PM
Non-responsive content removed
Subject: Status report: CP4 failures with activity plan

EA11003EN-00240[3]

Gentlemen,

I had hoped to distribute the activity plan that was agreed upon on Wednesday at the CP4 technical pump meeting at N/EA-6, but Bosch has not yet met the promised deadline. Mr. Ambrock, please send it to this distribution list tomorrow, as I won't be back in the office until Thursday.

<u>News on the failure situation.</u>

Fault: drivetrain damage in the CP4 high-pressure fuel pump
<u>Causes</u> : production-based manufacturing fault from Bosch <u>or</u> market-specific <u>unknown</u> fault cause (see country quotas in section 2 of the attachment)
80 failures in the vehicle after delivery (75 x field; 5 x Q assurance / testing)
38 pumps received for analysis (31 x V6; 7 x R4-TDI)
reported: 45 x Q7 / Touareg 3.0l; 28 x 2.7l; 11 x 2.0l

Non-responsive content removed_ Liste Triebwerkschäden CP4 01.09.08.xls>>

Yours sincerely,

Non-responsive content removed

AUDI AG

Non-responsive content removed

Activities to reduce drivetrain damage

Activities to reduce drivetrain damage

(Focus: export countries Non-responsive content removed

Failure hypothesis:
Drivetrain damage due to combination of stiff roller (production slippage prior to introduction of straight-edge check, etc. 05/01/2008) + country-specific features (fuel, shipping, commissioning).

A) Development activities to reduce drivetrain damage

1) OSP analysis Date: running by [redacted]

1.1) Why is the failure rate in Non-responsive content removed

1.2) Why is the CP4.2 more affected than the CP4.1 ?

List of differences (such as NDCL, filter, production plant, etc.) by [redacted]

1.3) Main questions of Audi

Is Audi more affected than VW (influence of engine/vehicle plant)?

Record VW models vs. delivery figures in the [redacted] list

How are VW/Audi vehicles transported to Non-responsive content removed

What is the failure situation for the inline EFP?

Are the failures rental cars?

Non-responsive content removed

BOSCH

Activities to reduce drivetrain damage

2) Investigations for fuel & striking fuel features

2.1) Water

Estimation: unlikely; however, 1 pump found with visible corrosion

2.1.1) Activity: Replication attempt with sloshing water — Date: done by [redacted]

Result: No drivetrain damage, light traces of tarnishing in housing

2.1.2) Activity: Replication attempt with continual water input — Date: done by [redacted]

Result: Drivetrain damage

2.2) Fuel from [redacted]

Estimation: likely in combination with other influencing factors (influence of special fuel feature steroyl glucosides unlikely)

2.2.1) Activity: Obtain fuel samples from the failure map — Date: running by [redacted]

Result:

2.2.2) Activity: Analyze fuels from failed pumps — Date: running by [redacted]

Result: No striking features to date

Activities to reduce drivetrain damage

2.3) Fuel from [redacted]

Estimation: probably in combination with other influencing factors

2.3.1) Activity: Replication continuous running with not OK roller & Kerosene in fuel Wk40 by [redacted]

2.4) Air in fuel

Estimation: Unlikely

(Vehicle measurements (Leasing Q7) found air in the pump intake)

2.4.1) Activity: Replication test with high air content comp. by [redacted]

Result: no drivetrain damage, but high level of foam formation)

2.4.2) Activity: Investigations with Audi series EFP & Filter planned 09/24/08 by [redacted]

(can Q7 inline EFP draw in air through the filter? – how much?)

2.4.3) Activity: Trial: foam formation with glass pump 09/24/08 by [redacted]

2.4.4) Activity: Continuous running with air entry

2.5) Other fuel peculiarities

Activity: Analysis of fuel deposits Date: running [redacted]

Result: one striking pump so far. Rust, products of fuel aging & traces of chlorine, as well as silicon oxide. The source of the corrosion medium (likely with chlorine) could not be determined. Additional failed pumps are being examined.

BOSCH

Activities to reduce drivetrain damage

3) Belt tension not OK

Estimation: unlikely (striking features on failed pumps with oscillation marks & centerline mini-braking flats 2 x US Q7 with wrong tension pulley)

3.1) Action: Simulation with lower belt tension Date [redacted]

Result: If belt tension is low, torsional drive vibrations can occur (high slippage between roller & roller support -> braking flats)

3.2) Action: Track zig-zag oscillation marks Date [redacted]

Result:

3.3) Action: Pump torque measurements with W19 EU5 & BIN5 with min./max. Tension pulleys Date: [redacted]

Result:

3.4) Action: Endurance running replication with min. belt tension Date: [redacted]

Result:

Activities to reduce drivetrain damage

B) Production activities to reduce drivetrain damage

1) Metal spatters

1.1) Avoidance of metal spatters

Graphite/boron nitride cover holders in C coating plant

• Test new plant	From Wk36
• If test is positive, planned implementation	From Wk42

1.2) Recognizing metal spatters

• Feasibility study: objective measurement procedures	Done
• Decision on series implementation	Wk36

3) Avoid C-layer carry-over

New wash/transport framework for first 100/complete conversion	Wk40

Activities to reduce drivetrain damage

4) Avoiding fusing

Test new holders in C coating with spring-centering for better contact

- Sample, test, modify, and redesign if needed.
  Objective: series implementation after positive test — Wk48

5) Design changes

- Change layering system of roller end from C3 to C2
(test W24 D4, VW package 3)
- Improve seating of press assembly roller support/tappet body.
  R.B. internal test — Wk43

BOSCH

EA11003EN-00242[0]

Principle damage in CP4 high-pressure fuel pump

Keyword - Failure location	Failure country	Veh. no.	Part no. Audi VW	RS no.	CTS / AV3 no.	IDS no.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Non-responsive content removed

Non-responsive content removed

Non-responsive content removed

Non-responsive content removed

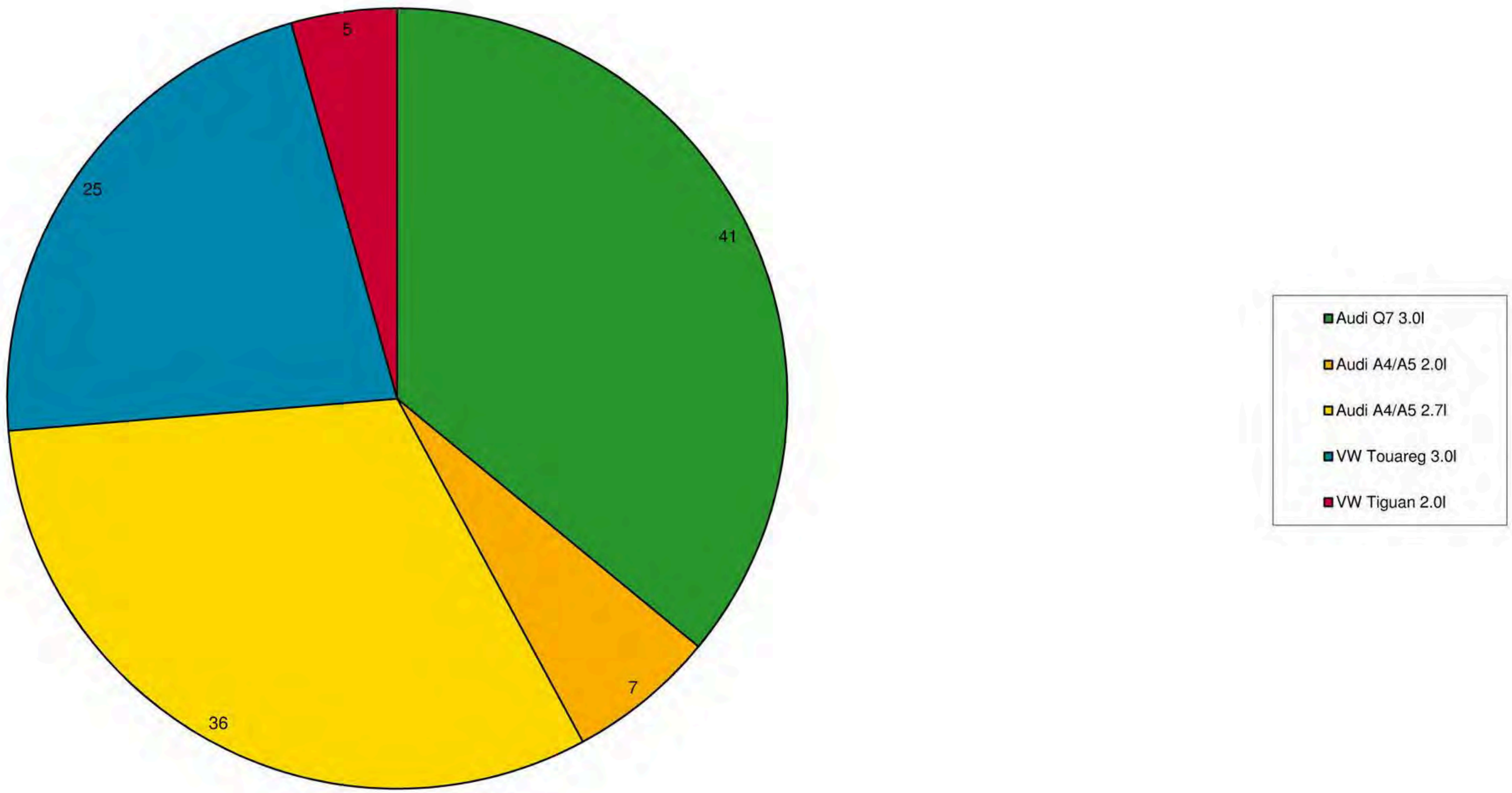
Vehicle failures in the field only

Model	Engine	Market	Failures	Total	Delivery volume Vehicles SOP - June 08	Failure rate per thousand by June 08	Factor above average in worldwide comparison	Factor above average in comparison, [redacted]	Remark
Audi Q7 3.0l	3.0l	worldwide		41	19.344	2,1	---		
		Non-responsive content removed	0		5.685	0,0			
			7		187	37,4	18	#DIV/0!	
			16		317	50,5	24	#DIV/0!	
			3		477	6,3	3	#DIV/0!	
			2		?				1 veh. 2 failures
			5		?				
			3		76	39,5	19	#DIV/0!	
			2		2.612	0,8			
			1		?				
			1		?				
			1		?				
Audi A4/A5 2.0l	2.0l	worldwide		7	87.660	0,1			
		Non-responsive content removed	5		24.813	0,2			
			1		1.724	0,6	7	3	
			1		1.225	0,8	10	4	
Audi A4/A5 2.7l	2.7l	worldwide		36	18.516	1,9			
		Non-responsive content removed	6		5.899	1,0			
			12		243	49,4	25	49	
			10		161	62,1	32	61	
			7		1.985	3,5			
			1		?				
Audi A4/A5 3.0l	3.0l	worldwide		1	?				
		Non-responsive content removed	0						
			1						
VW Phaeton 3.0l	3.0l		1	1	2.807	0,4			Late damage, poor ventilation in 06/07?
VW Touareg 3.0l	3.0l			25	13.266	1,9			
			1		4.780	0,2			
			6		141	42,6	23	203	Suspicion of proportion of biodiesel in [redacted]
			7		1.112	6,3	3	30	
			5		789	6,3	3	30	
			5		2.437	2,1	1	10	
			1		?				
VW Tiguan 2.0l	2.0l		1	5	18.752	0,1			
			1						
			1		?				
		USA	2		?				
AudiA4/A5	unknown	Non-responsive content removed	2						
	unknown		1						
	unknown		1						
Field total			120						

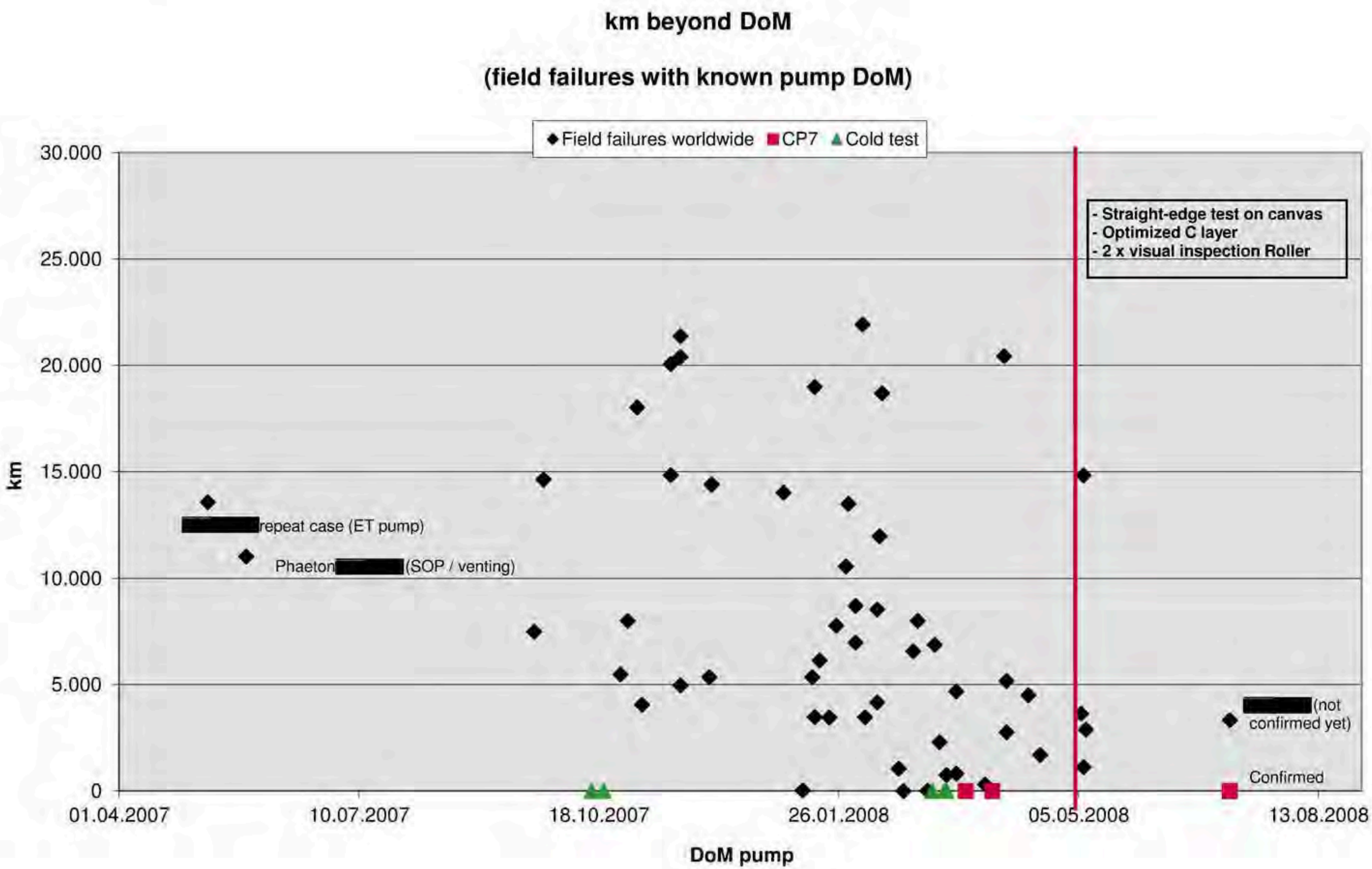
Non-responsive content removed	Qty.	Deliveries	Failure rate (per mill.)
	29	2295	12,6
	33	478	69,0
	3	477	6,3
	20		
	15	62736	0,2

EA11003EN-00242[2]

Number per model / engine
(without individual cases)

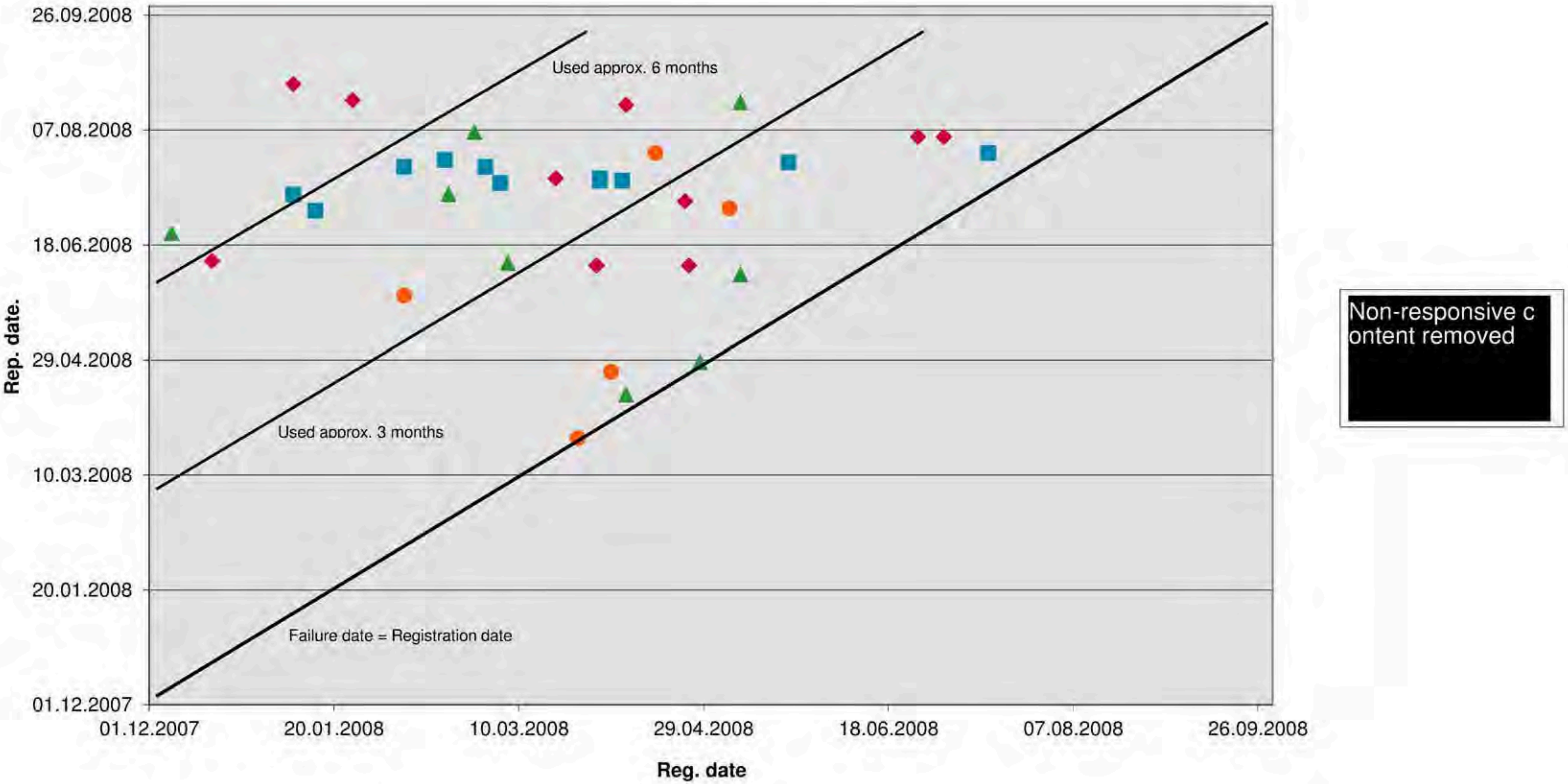


EA11003EN-00242[3]



EA11003EN-00242[4]

Reg. date over rep. date (received pumps only)



EA11003EN-00249[0]

From: Non-responsive content removed
To:
CC:
Date: 4/12/2010, 1:07:15 PM
Subject: FW: Vehicle requirements: 2.0l TDI CR [redacted] market
Attachments: Stellungnahme Q Einsatz 2.0l 103kW TDI CR [redacted] ppt

Hello,

The following mail is for your information.

With best regards

Non-responsive content removed

Volkswagen Aktiengesellschaft   Domicile: Wolfsburg

Court of Registry: Local District Court Braunschweig
Commercial Register no.: 100484
Chairman of the Supervisory Board: Ferdinand Piëch
Executive Board: Martin Winterkorn (Chairman/CEO), Francisco J. Garcia Sanz, Jochem Heizmann, Christian Klingler, Horst Neumann, Hans Dieter Pötsch, Rupert Stadler
Important notice: The above information is automatically added to this e-mail. This addition does not constitute a representation that the content of this e-mail is legally relevant and/or is intended to be legally binding.

>____________________________________
>From: [redacted] >Sent: Monday, April 12, 2010, 1:32 PM

>To: Non-responsive content removed
Non-responsive content removed
>Subject: Vehicle requirements: 2.0l TDI CR China market
>Importance: High
>
>
>Hello [redacted]
>Hello [redacted]
>
>As a result of new findings (see statement), we need additional vehicles for Q assurance for 2.0l TDI CR EU4 in [redacted] >

>Statement:
>
>
>
>
>
>Please forward the additional requirement (€502,400) to product management for approval.
>I cannot order the vehicles for verification until then.
>
>Thank you
>
>>Best regards

>
Non-responsive content removed
>

Use of 2.0l 103kW TDI CR EU4 for [redacted] (planned SOP Wk45/10)

Q statement on use of 2.0l 103kW TDI CR for the [redacted] market

Due to new findings by Bosch from the [redacted] market, a failure rate of up to 100% must be expected with the currently planned high-pressure fuel pump in connection with the locally available fuel quality. The primary causes of this are high water content, low viscosity and lubricity, and other impurities in the fuel. This will require a new anti-wear package from Bosch for the injector unit. Verification-capable parts are not expected until Wk 27/10.

Therefore [redacted] requires 6 vehicles with mileage of 100,000 km each for the verification run in [redacted]

Vehicles approved to date:

1 0S vehicle (via EU4 poor fuel quality countries)

1 0S vehicle (via FBU market [redacted])

Vehicles to be approved:

4 0S vehicles (open)	*(SHK €12,400 + AL €358,000 =)*	€370,400
2x 50,000km (for the already approved vehicles)		€72,000
6x flight costs to [redacted]	*(per vehicle: €10,000)*	€60,000
	Total	**502,400**

Qualitätssicherung

Status: 3/18/2010

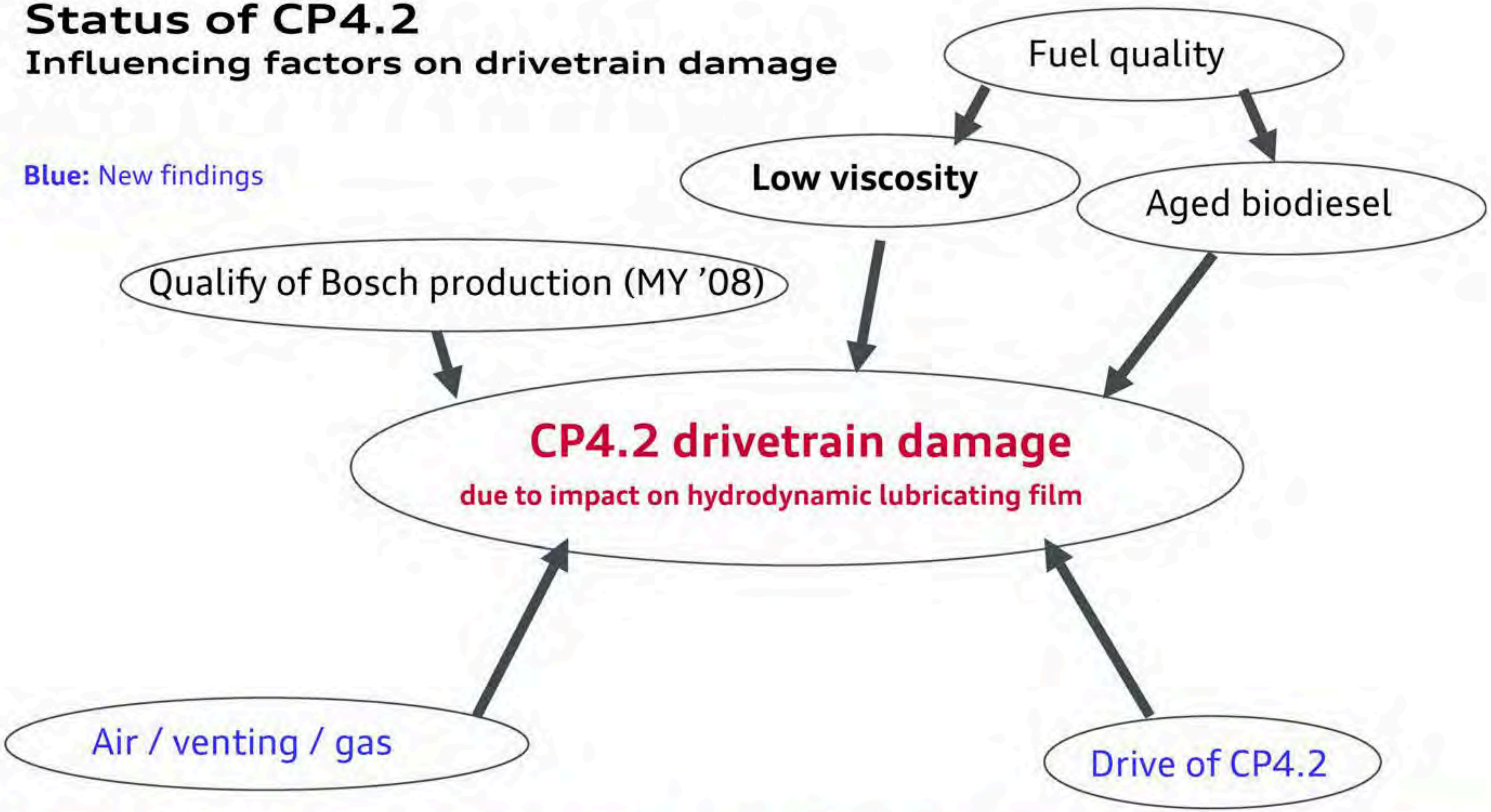
Audi
Vorsprung durch Technik

Status CP4.2 Wk24

Non-responsive content removed

Status of CP4.2
Influencing factors on drivetrain damage

Blue: New findings



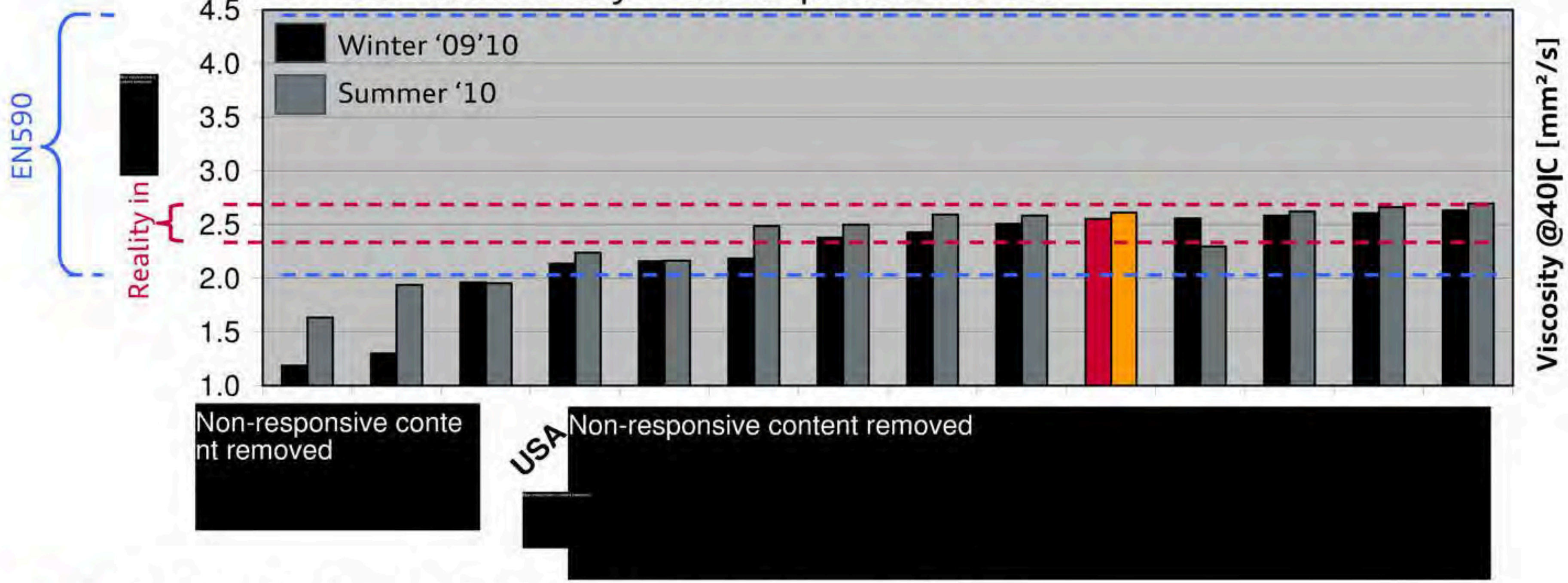
Mixed friction between roller and roller support results in wear of CP4 and must be avoided under all conditions.

-> Development target of a robust CP4: **Ensure stable hydrodynamic lubricating film** between roller and roller support under all conditions!

Status of CP4.2

Low viscosity - the <u>common</u> denominator in [redacted] parts of U.S.

Minimal fuel viscosity in the respective market:



- Low viscosity due to addition of kerosene or gasoline
- Additional increased hazard of gas bubble formation due to evaporation of highly volatile contents

⇨ Reduced lubricating film thickness between roller and roller support

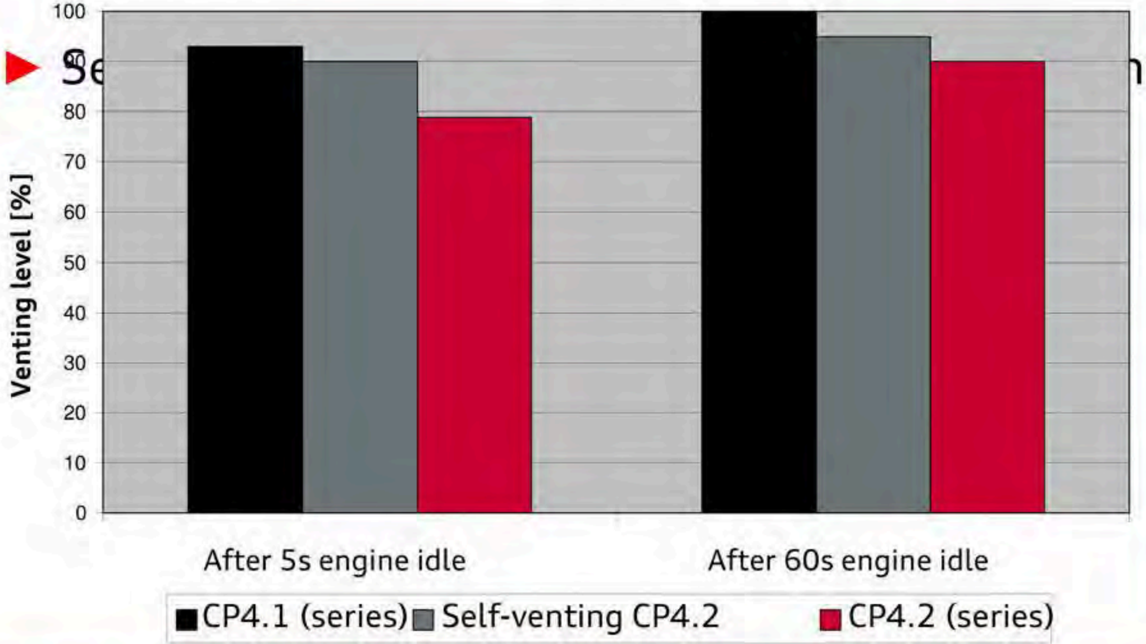
The lowest fuel viscosity levels worldwide are found in the major failure markets, [redacted] especially in winter.

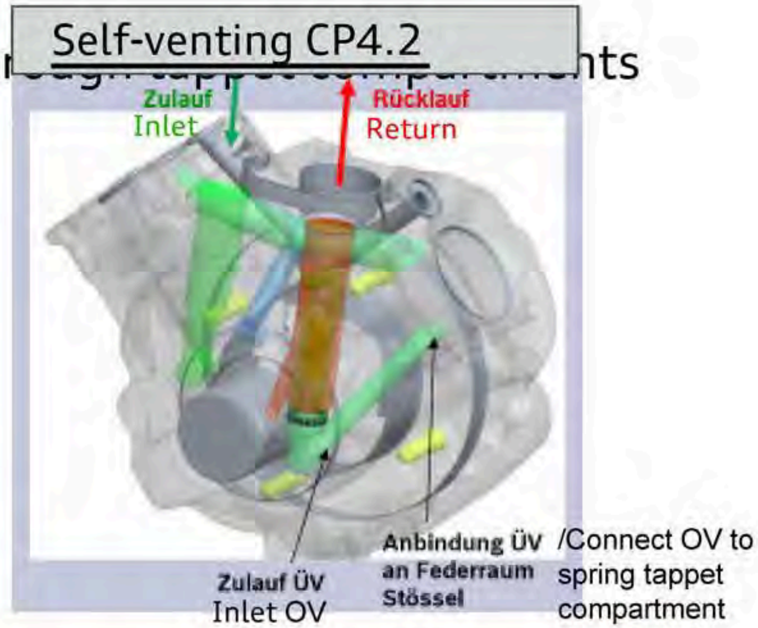
Status of CP4.2

Venting capability of high-pressure fuel pump

- Current version of CP4.2 vents much more poorly than CP4.1:
  - CP4.1: direct connection between tappet and drivetrain compartment (called the "handle")
  - CP4.2: no connection between tappet and drivetrain compartment

  -> Air in tappet compartment can only bleed to the drivetrain compartment through the roller support. Return directly from the drivetrain compartment.





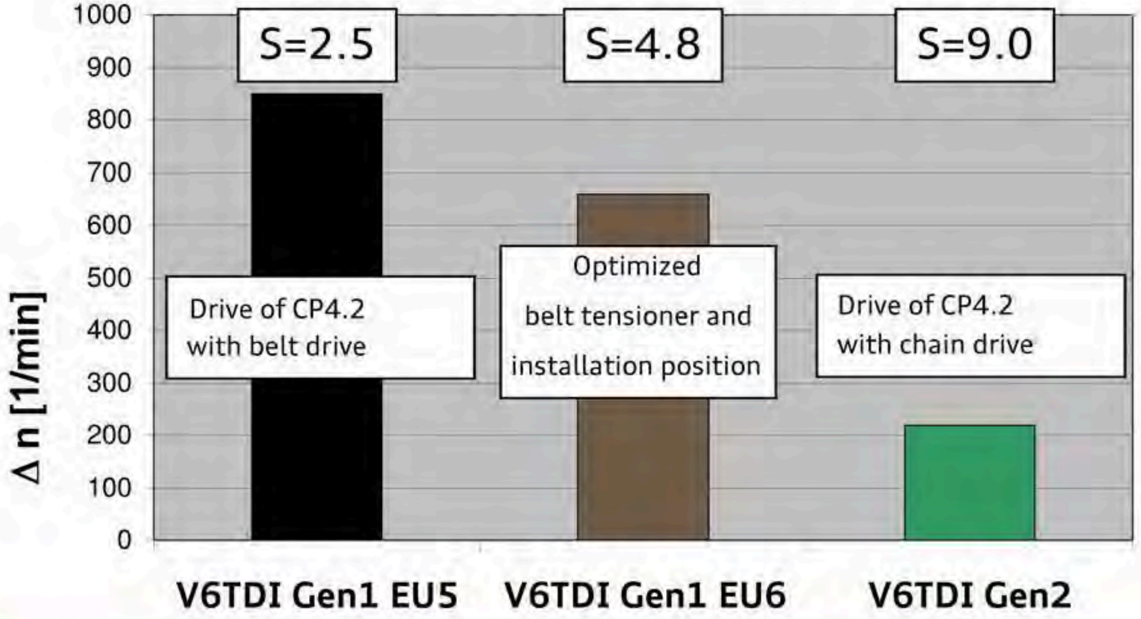
A self-venting CP4.2 improved venting capability to CP4.1 level and further reduced temperature in the drivetrain compartment by ~10K compared to RP2

Status of CP4.2
Drive influence - speed fluctuations on roller

- Large torsional vibrations when starting up the high-pressure fuel pump result in large speed fluctuations of the roller in operation.

→ Impact on hydrodynamic lubricating film between roller and roller support

Maximum torsional vibrations on the CP4.2



S = Security against slippage between roller and camshaft with EN590 fuel

Reducing the torsional vibrations of the CP4.2 reduces the risk of slippage between roller and cam, and thus the danger of flattening

Status of CP4.2
Roadmap

Year	2011	2012	2013	2014	
Calendar week	45	22	36	18	
Short-term activities	Gen1+Gen2		MP	Evo	**Effectiveness**
RP1+ (Delta compared to current series only C3.1 layer) C3.1 layer with greater resistance to wear, but still good characteristics in roller warm-up	X				**Medium**
EU6 Belt tensioner for EU5 (Gen1 only!) poss. only CS: Reduction of torsional vibration	X				**High**
Self-venting high-pressure fuel pump		X			**High**
Dynamic tappet package					
Reduction of piston Ø+ lift adjustment: Reduce drivetrain load by 30%			X		**High**
Optimized cam profile (3-harm. cam): Dynamic alignment on fillet eliminated, reduced smoothing of camshaft			X		**Medium**
Independent spring plate "WWU tappet": Calmed tappet movement --> less smoothing of the camshaft			X		**Medium**
Visco package "Plus"					
Optimized support behavior RS, camshaft, roller: Reduction of der surface pressing -> more stable hydrodyn. lubricating film				X	**High**
Increase pressure in drivetrain compartment Reduction of evaporation of highly volatile components				X	**High**
Measures being examined					
Optimization of edge chamfer for roller support		Decision in 2012			
Lubrication bore in roller support					
Optimized wrap angle					
Increased roller diameter 12mm					

Development risk:
- Low (green)
- Medium (yellow)
- High (red)

Status of CP4.2

Measures Matrix – Roadmap and impact

2009

		2010	2011	2012	2013	2014
Quality of production (Bosch)	MP1 MP2		✓			✓
Viscosity (hydr. lubricating film)		AWP1	AWP2 AWP1+ ✓	Dynamic tappet package		Visco package "Plus" ✓
Biodiesel (Temperature)			EFP ✓	Self-venting		✓
Gas / air			Measure ✓	CP4.2	P increase drivetrain compartment	✓
Drive		V6TDI Gen2 OK	✓	Optimized belt tensioner (only CS/Gen1)		✓

EA11003EN-00275[0]

BOSCH

From	Person responsible	Tel	Fax	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	6/1/2007

Log

Receiver [redacted]

For Info

Host [redacted]

Participants
VW: [redacted]
Audi: [redacted]
Bosch: [redacted]

[redacted]

Head

Log

Organiz.

Date/Location

Topic **Status of CP4 Drivetrain Failures**

Suggestions from Audi and VW on Turned Tappets

- Monitor rail pressure in rinse thread during filling and rinsing of the pump on the series test bench.
- Operate the pump with "poor" operating conditions (low revolutions, low pressure) on the test bench.
- Open 200 pumps and check for preliminary damage.
- Check calibration of temperature sensors in inlet and return. Background ΔT window in range 1°C.

- Carry out and assess theoretical examination "storage of spring force".
- Check spring, spring plate and tappet body geometries, examine tolerance chains and view parts of failed pumps during next visit.

BOSCH

Von	Bearbeiter	Tel	Fax	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	01.06.2007

Protokoll

Status Triebwerksausfälle CP4

- Investigate optimal sliding conditions of spring, spring plate, and tappet body, e.g., through C-coated spring plate, dual sliding washer, additional lubrication for functional test.
- Poorly filled/unfilled pump => Roller does not turn / turns poorly
  - Examine subject in more detail
  - How to achieve optimal conditions at all Bosch / Audi / VW plants.
- Check lubrication of roller in roller support after friction coefficient test with special lubricant, currently inspection oil
- Check lubricity of inspection oil – compare with Diesel fuel.

- Storage of current pumps with regard to aging of inspection oil in service pumps. Check whether such pumps are at increased risk of non-turning roller.

- Audi statement: If no solution to the cause of the fault is found, the run-in of pumps at Bosch will have to be considered.

Subject: CP4 robustness

DS-PC/ENP-Boecking

TOP meeting on Tuesday, October 27, 2009

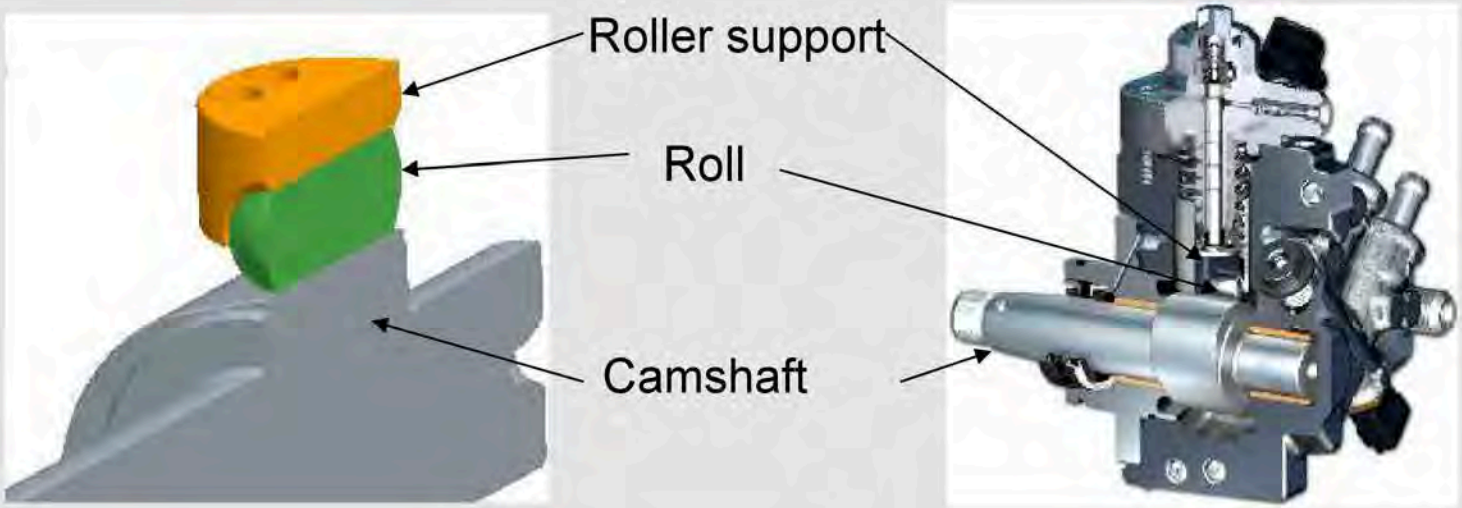
BOSCH
Technik fürs Leben

Audi
Vorsprung durch Technik

Subject: CP4 robustness

Cause-effect relationship CP4 drivetrain damage

Cause of drivetrain damage is operation with impermissible fuel qualities and/or high component function sensitivity.



TOP meeting on Tuesday, October 27, 2009

BOSCH
Technik fürs Leben

Audi
Vorsprung durch Technik

Subject: CP4 robustness

Influence of fuel quality

Low lubricity (kerosene, water, ...)

- In start case (mixed friction area), results in increased wear in roller/roller support assembly (up to 200 rpm)

Low viscosity [redacted] diesel, kerosene, water….)

- Results in small lubricating film thickness -> Increased friction / component contact -> Increased slippage (roller stops)

Water in fuel

- Influence as emulsion: see lubricity & viscosity
- Free water (in droplet form) can result in hydrogen embrittlement / stress corrosion and thus to fatigue of the roller partner

TOP meeting on Tuesday, October 27, 2009

Subject: CP4 robustness

Measures to increase robustness - fuel, critical markets

Lubricity

- Continue development of wear-optimized C layer (already being tested for medium duty application) — SOP 07/10

Viscosity

- Optimize texture/surface of roller — done
- Optimize texture/surface of C layer in roller support — SOP 07/10
- Optimize component tolerances (play) roller-roller support — SOP 07/10

Water

- Implementation of water separator required for critical markets — OEM
- Avoid fatigue through more high-grade substances on camshaft / roller (pre-tests with high-grade material pairing underway) — 04/10

  After completion of pre-tests, long-term testing needed — SOP ?

TOP meeting on Tuesday, October 27, 2009

Subject: CP4 robustness

Reduce component function sensitivity in current series

- Switch washing before C coating
  (from watery to HC cleaning)
  ➔ Major test completed — Wk 43
  ➔ Possible implementation date (Approval from all customers required) — Wk 46
- 100% Conversion to visual inspection roller support from technoscope to camera inspection — E 4/2010

TOP meeting on Tuesday, October 27, 2009

BOSCH
Technik fürs Leben

Audi
Vorsprung durch Technik

Corrosion of injection components?

Results of initial water separation tests:

- Two structurally identical Passat CC 2.0l 103kW TDI CR
- New injection systems (HPP, injectors, rail, HP lines)
- Fuel vehicle 1: CEC RF 06-03 + 2% water
- Fuel vehicle 2: CEC RF 06-03 + 7% RME + 2% water
- Same route driven
- Then 4 stand time

- First execution: Filter without water separator
- Second execution: Filter with water separation and extra water collection space;

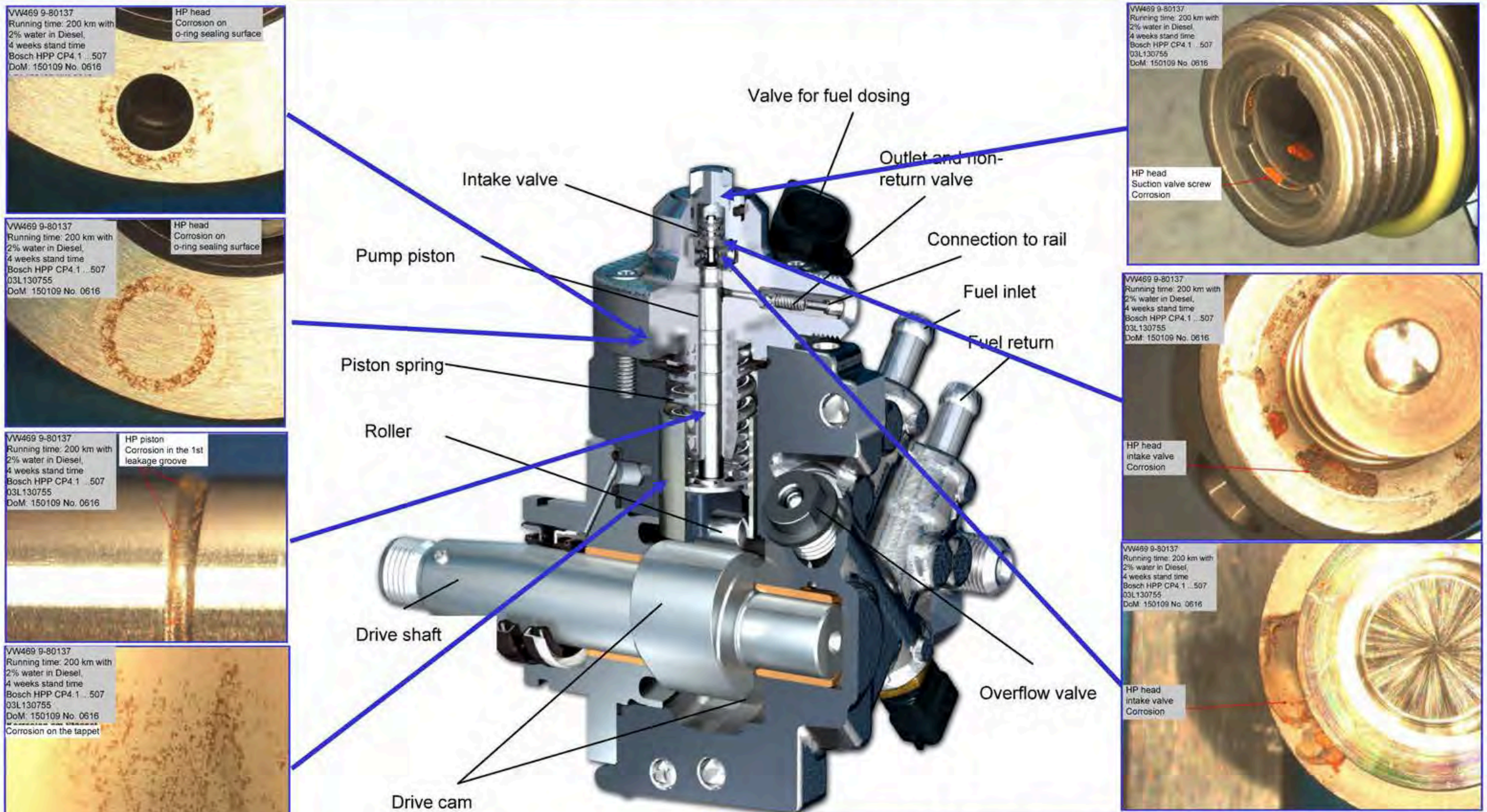
Results Ł

EA11003EN-00332[1]

Vehicle Investigations for Water Separation

Test_1 without water collection space:

Damage to high-pressure fuel pump CP4.1, Vehicle_1 (VW469-8-0137, CEC + 2% water)



Damage determined by Non-responsive content removed

Vehicle Investigations for Water Separation

Test_1 without water collection space:

Damage to injector CRI3-2, vehicle_1 (VW468-9-0137, CEC + 2% water)

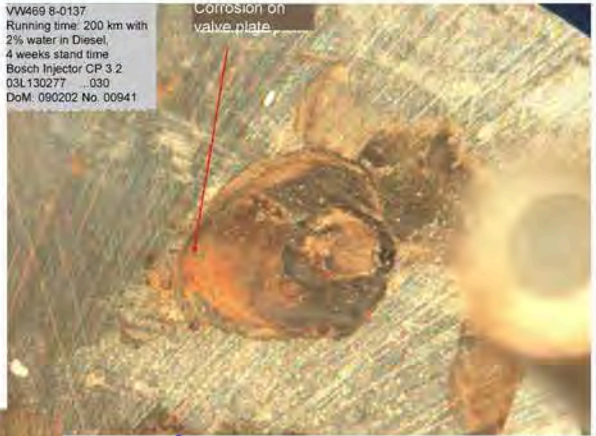
The 4 assemblies:

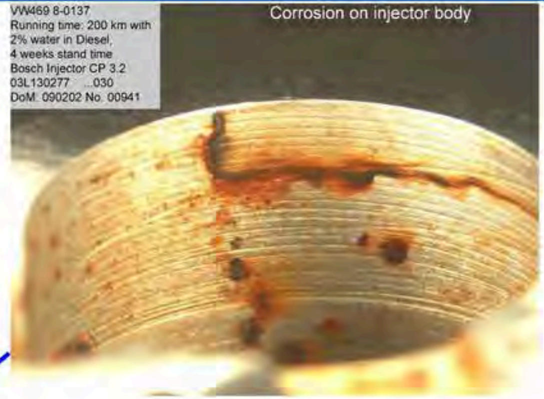
Actor module

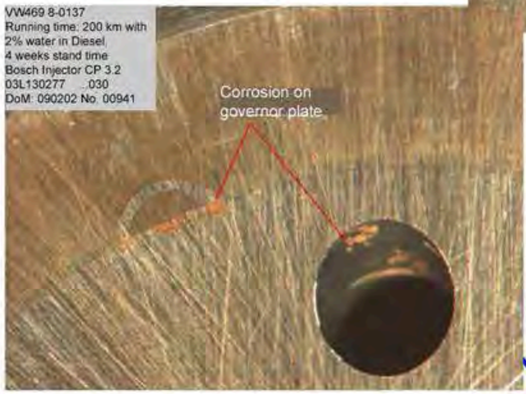
hydraulic coupler

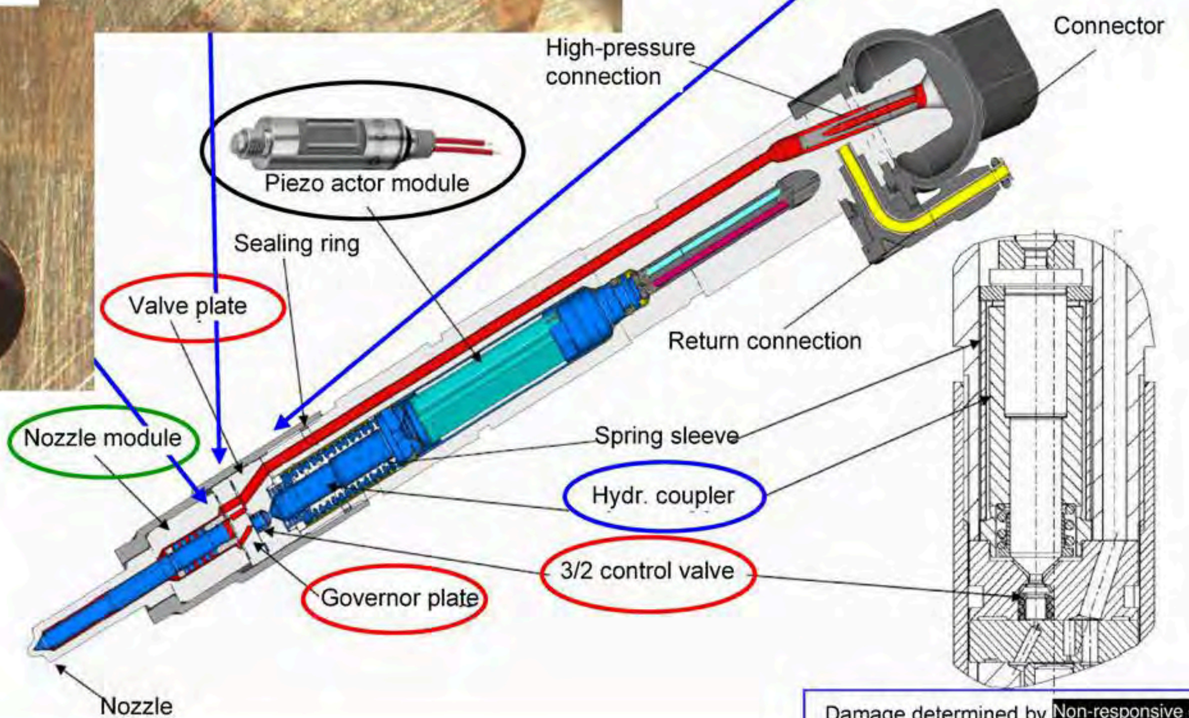
Control/servo valve

Nozzle module







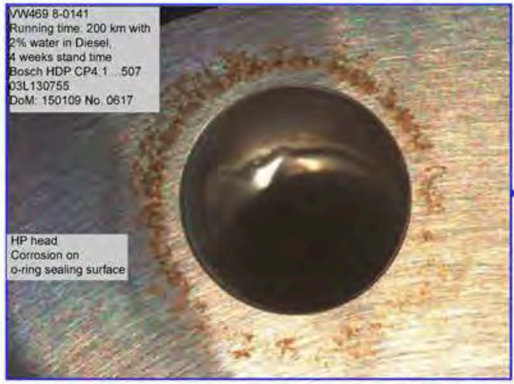


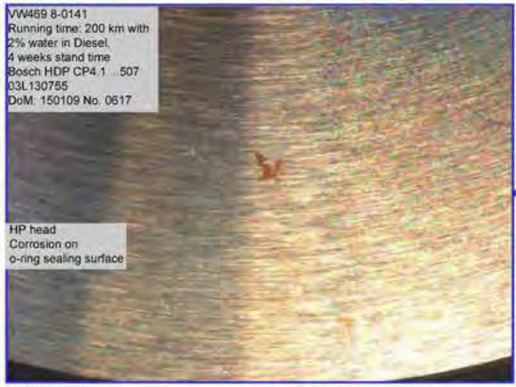
Damage determined by Non-responsive content removed

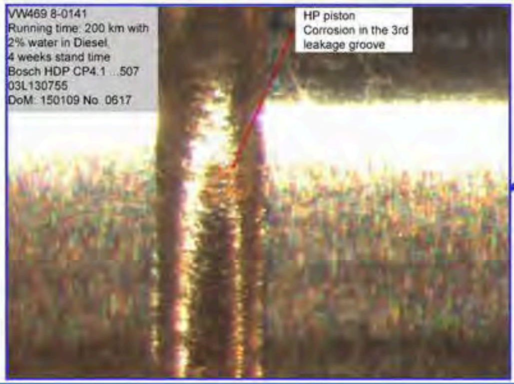
Vehicle Investigations for Water Separation

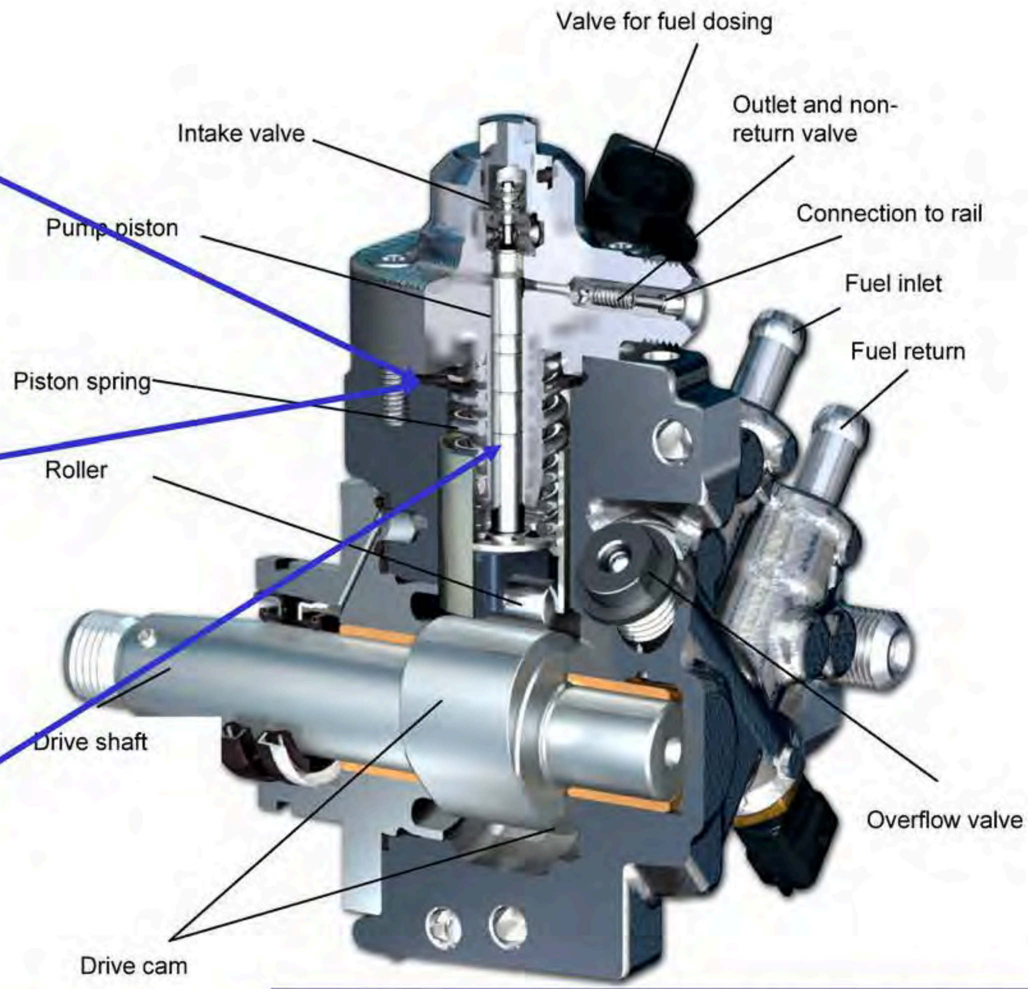
Test_1 without water collection space:

Damage to high-pressure fuel pump CP4.1, Vehicle_2 (VW469-8-0141, CEC +7% RME +2% water)







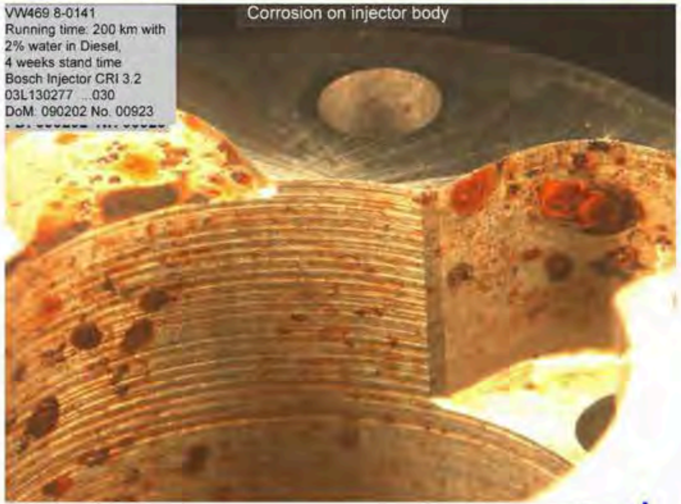


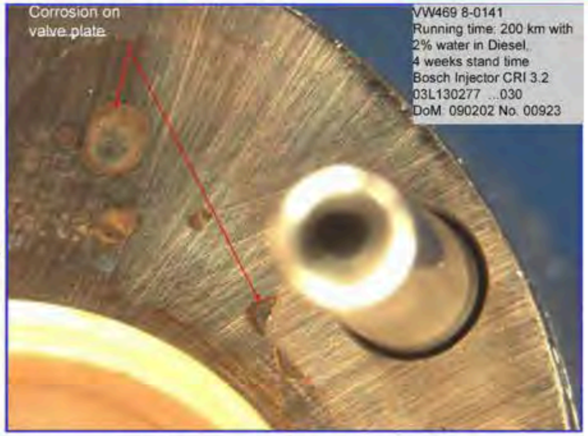
Damage determined by Non-responsive content removed

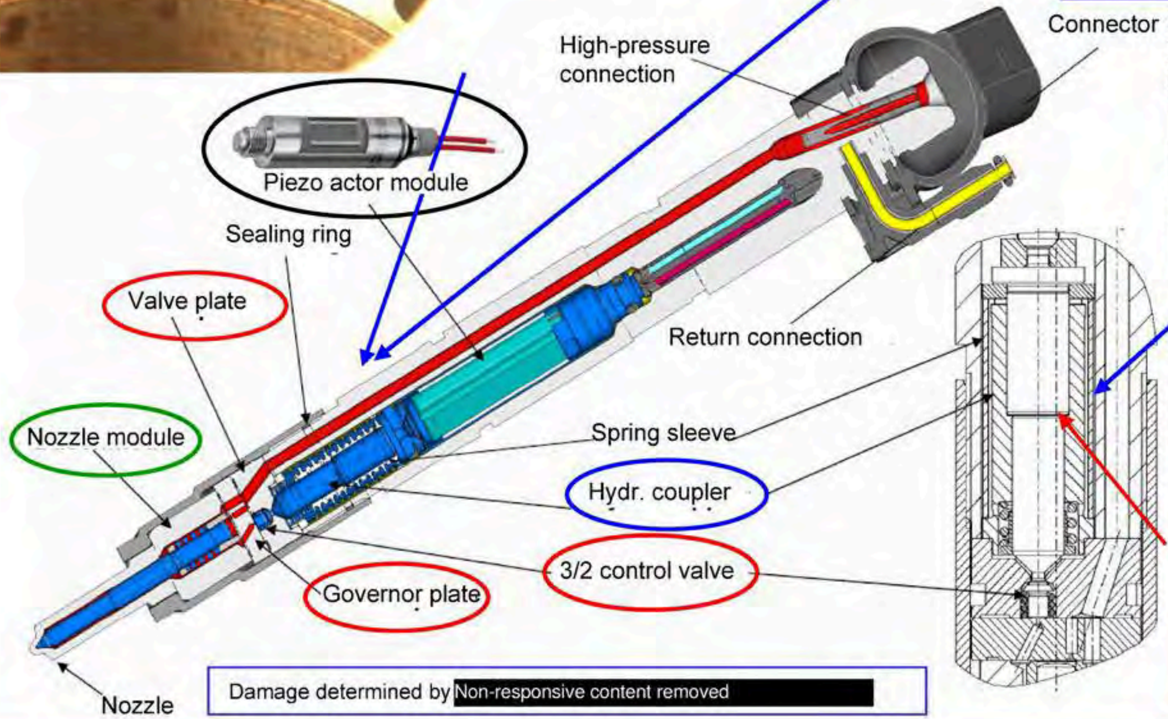
Vehicle Investigations for Water Separation

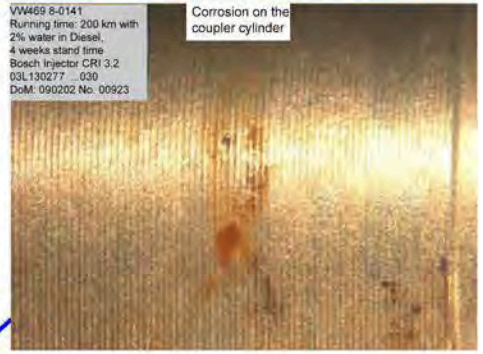
Test_1 without water collection space:

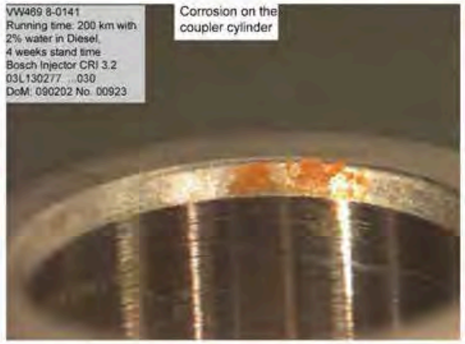
Damage to injector CRI3-2, Vehicle_2 (VW469-8-0141, CEC +7% RME +2% water)









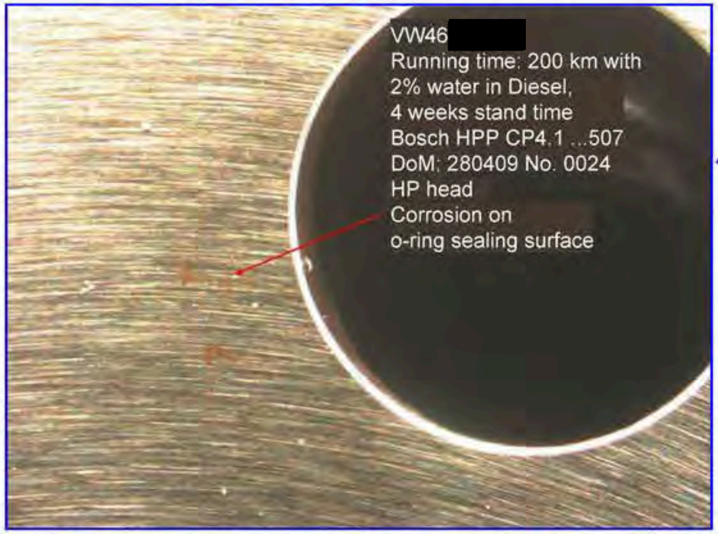


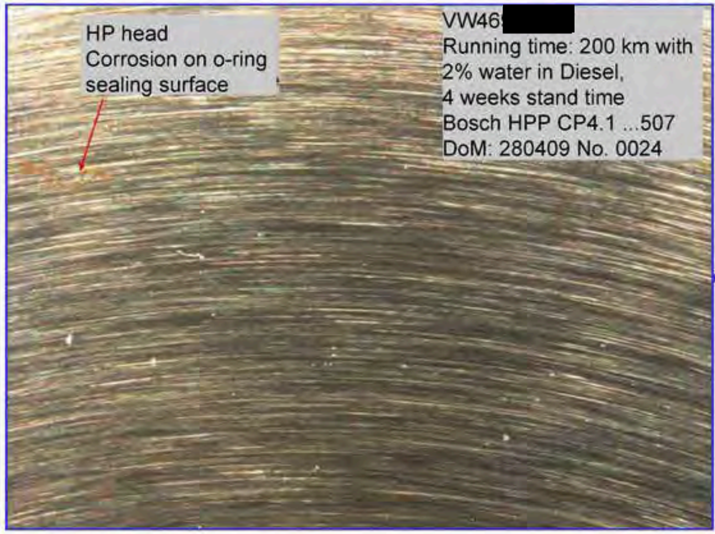
Damage determined by Non-responsive content removed

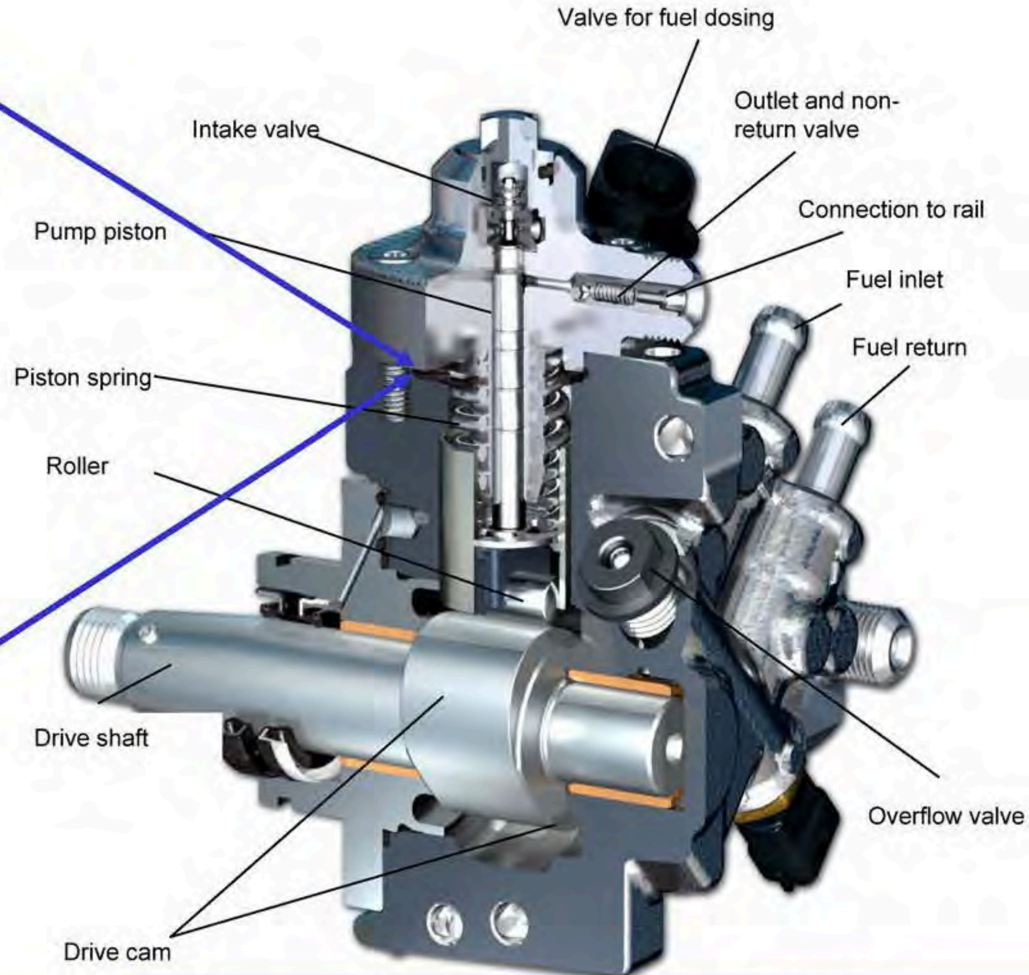
Vehicle Investigations for Water Separation

Test_2: With water collecting space:

Damage to high-pressure fuel pump CP4.1, Vehicle_1 (VW469-8-0137, CEC + 2% water)







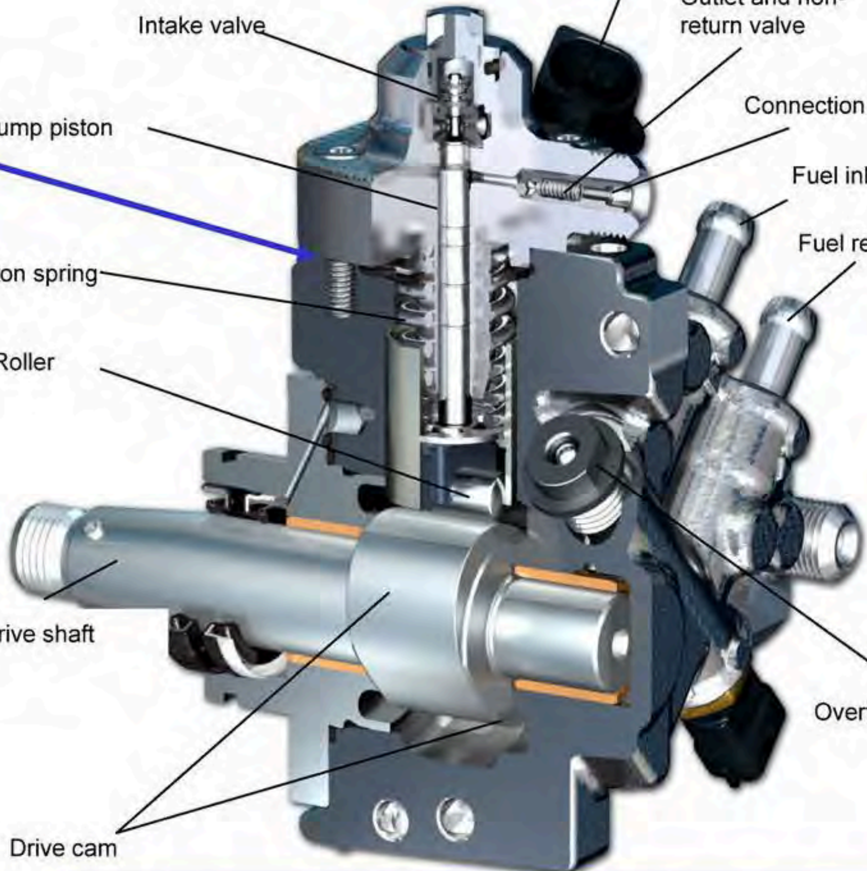
No damage symptoms on injector

Damage determined by Non-responsive content removed

Vehicle Investigations for Water Separation

Test_2: With water collecting space:

Damage to high-pressure fuel pump CP4.1, Vehicle_2 (VW469-8-0141, CEC +RME + 2% water)

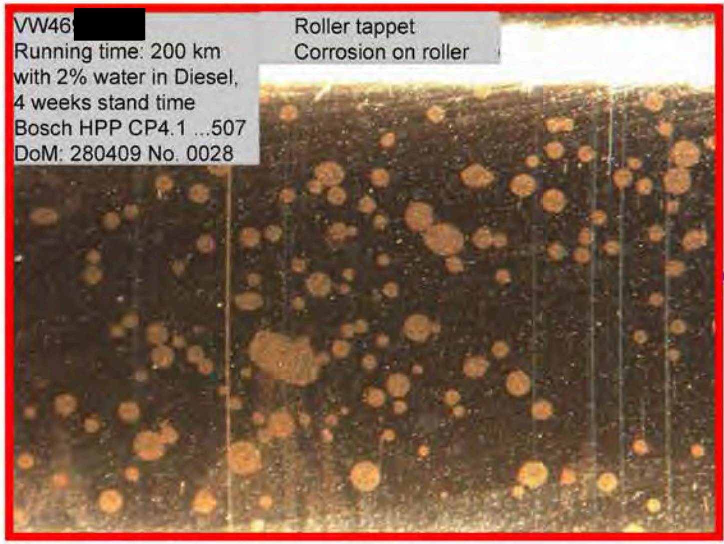


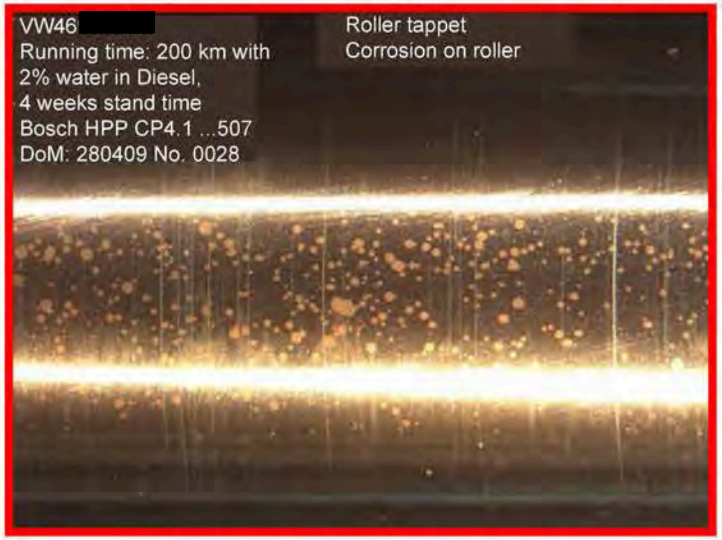
Damage determined by Non-responsive content removed

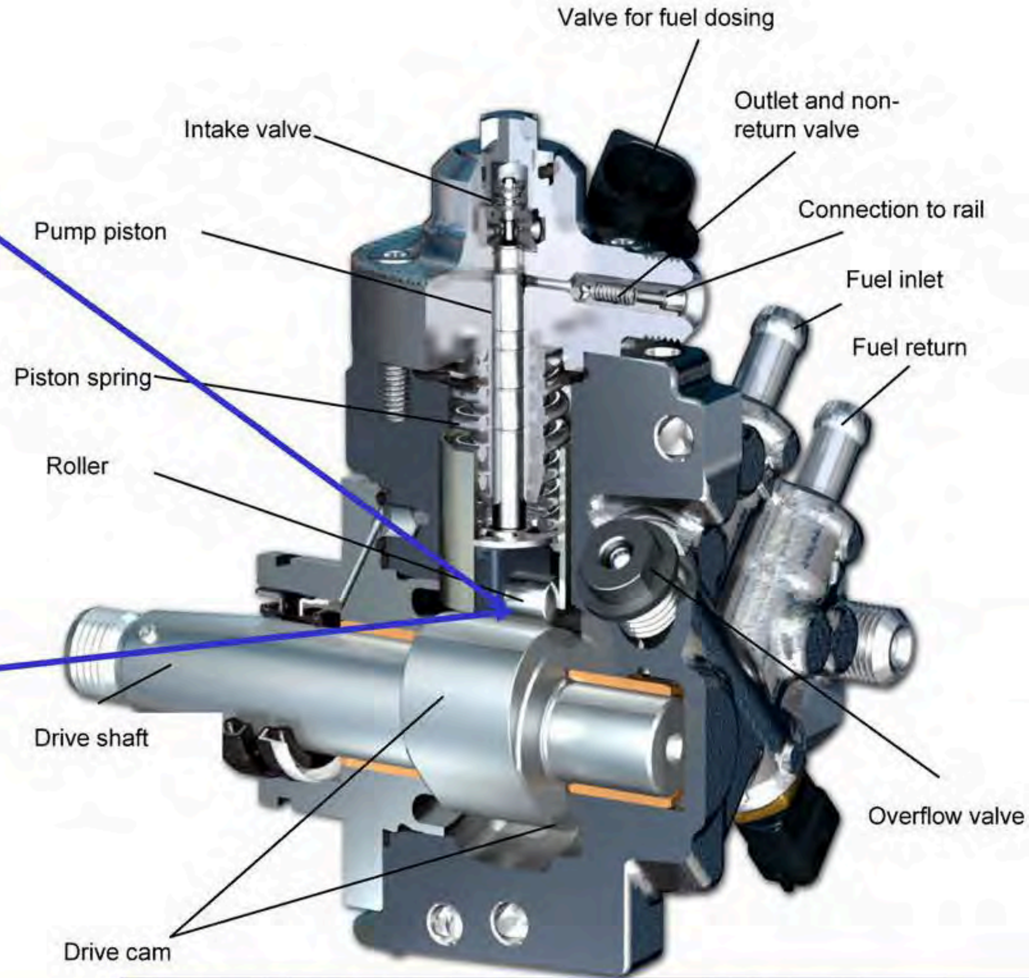
Vehicle Investigations for Water Separation

Test_2: With water collecting space:

Damage to high-pressure fuel pump CP4.1, Vehicle_2 (VW469-8-0141, CEC +RME + 2% water)







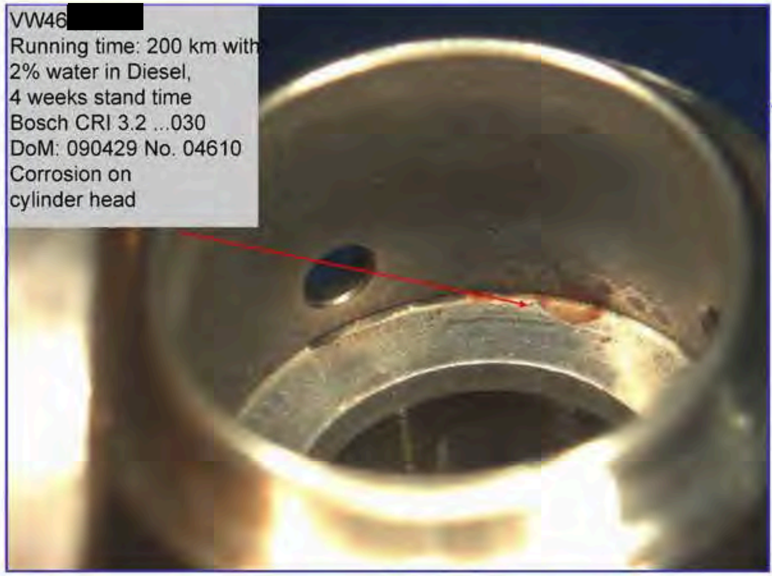
Judged to be not OK

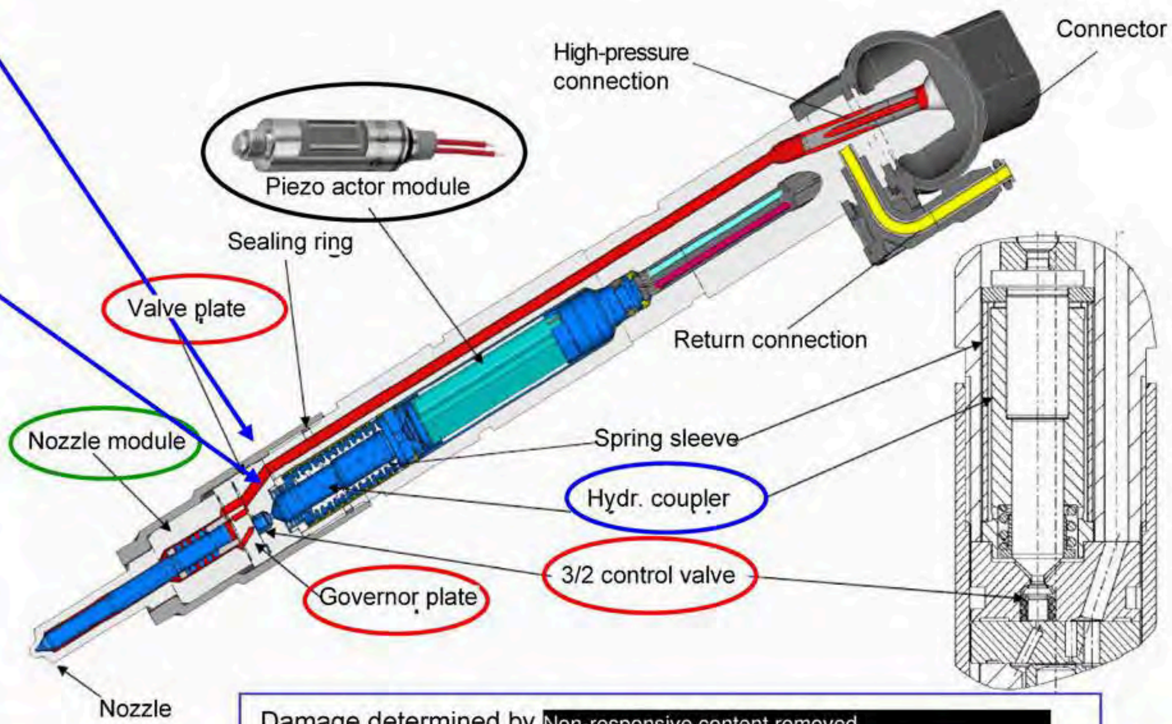
Damage determined by Non-responsive content removed

Vehicle Investigations for Water Separation

Test_2: With water collecting space:

Damage to injector CRI3-2, Vehicle_2 (VW469-8-0141, CEC +RME + 2% water)





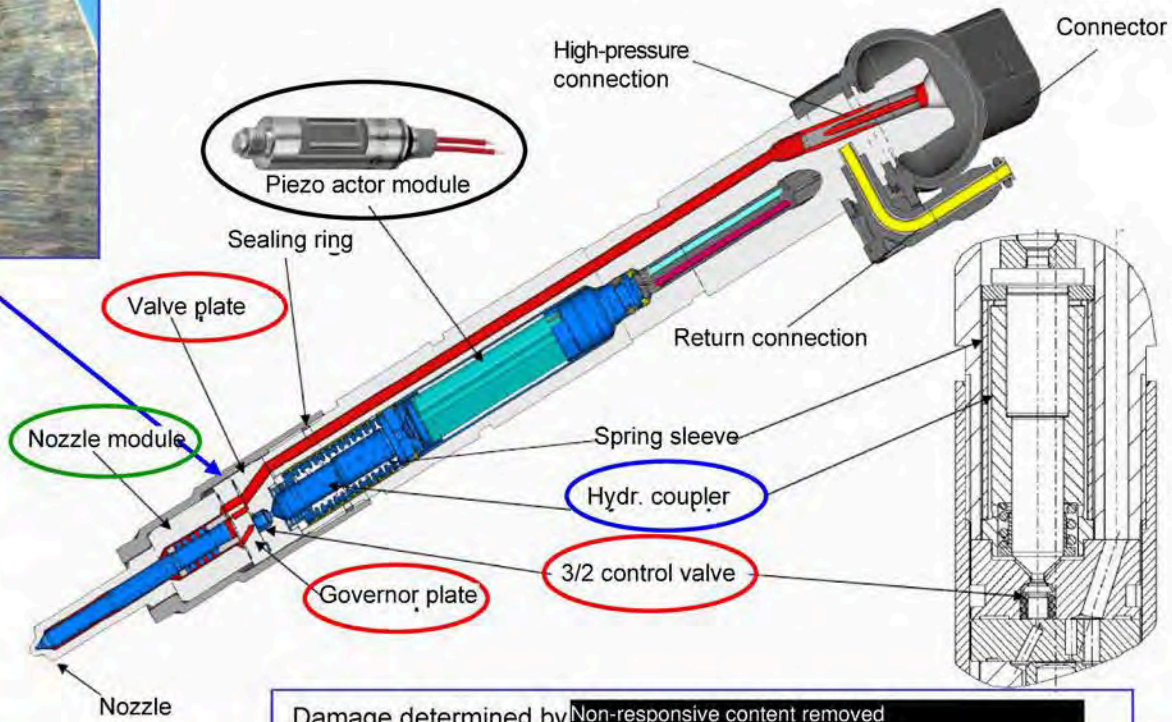
Damage determined by Non-responsive content removed

ENTIRE PAGE CONFIDENTIAL

EA11003EN-00332[9]

Vehicle Investigations for Water Separation

Test_2: With water collecting space:
Damage to injector CRI3-2, Vehicle_2 (VW469-8-0141, CEC +RME + 2% water)



Damage determined by [redacted]

Water separation – Status May 2010

Agenda:

- Development of requirements (TCD) and standards
- Work areas
- Results from the 3 work areas
    - System (vehicle)
    - Filter
    - Fuel
- Competitor situation
- Outlook

Development of TCD requirements

2/23/2009

Water separation degree >= 93% from 2% emulsion at max. flow quantity, otherwise according to ISO 4020:2001

4/27/2009

Water separation degree >= 93% for project-specific flow quantity, otherwise according to ISO 4020:2001 or SAE J1488 Revised AUG1997

11/19/2009

Water separation degree >= 93% according to SAE J1488, but with fuel with IFT 8-11 and DSEP >50. The fuel is manufactured as a blend of ULSD and FAME. Once the revised ISO 16332 standard is available, this standard will be preferred.

Source: BOSCH TCDs

Comparison of

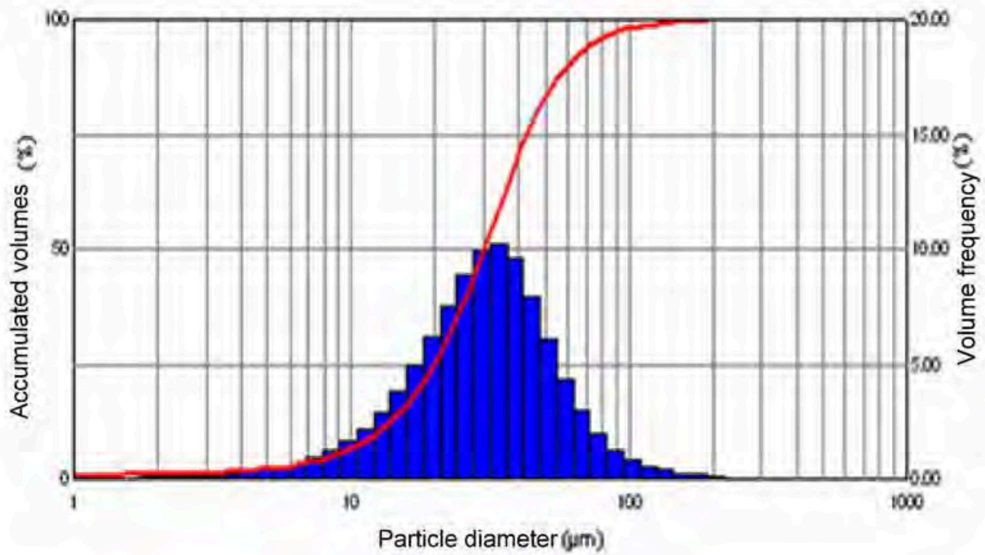
Comparison between ISO 4020 2 SAE J 1488 2 ISO TS 16332					
parameters	**ISO 4020**	**SAE J 1488**	**ISO TS 16332**	**ISO TS 16332**	**Vehicle**
Flow quantity	50 l/h or multiple	By agreement	By agreement	???	50 220 l/h
Emulsion formation	Membrane pump	Centrifugal pump	Blend	?	Tank EFP
Average temperature	23°C ±5°C	26.6°C ±2.5°C	23°C ±2°C		up to 70°C
Fuel	Customary without free water	with IFT 25 30 mN/m	CEC RF 0603 (IFT 15mN/m)		Differs worldwide
Water content	2%	0.25% of flow quantity	1500 ppm (standard)		up to 1500 ppm (acc. to K Q list)
Surface tension	n/a	25 30 mN/m	15 mN/m		Differs worldwide
Droplet size	n/a	n/a	60 Fm	?	See next slide

revised

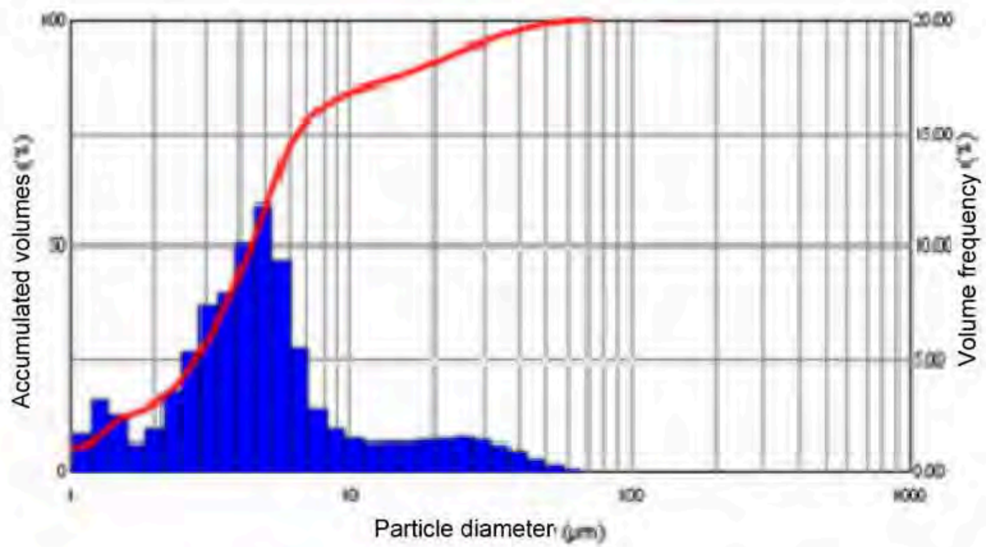
Droplet size distribution

Measurements of droplet sizes

- Measurement on vehicle and test bench



Supply unit only
Average droplet diameter ~12 µm

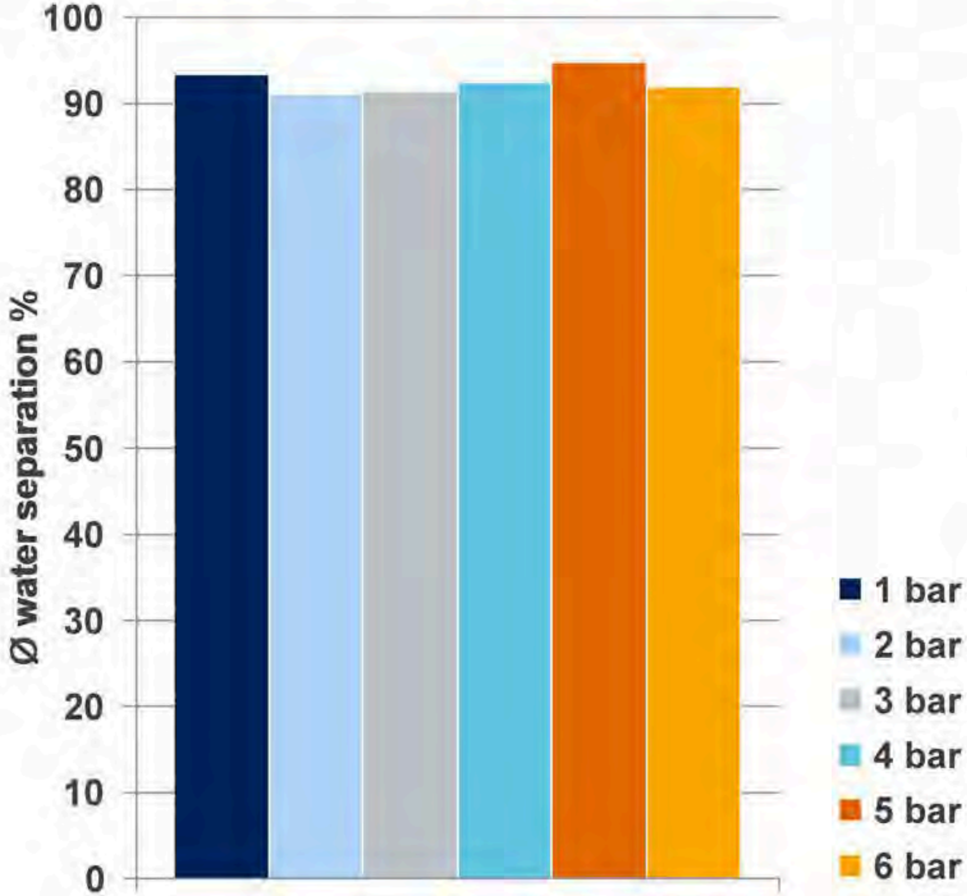


Entire vehicle incl. HPP average
droplet diameter ~5 µm

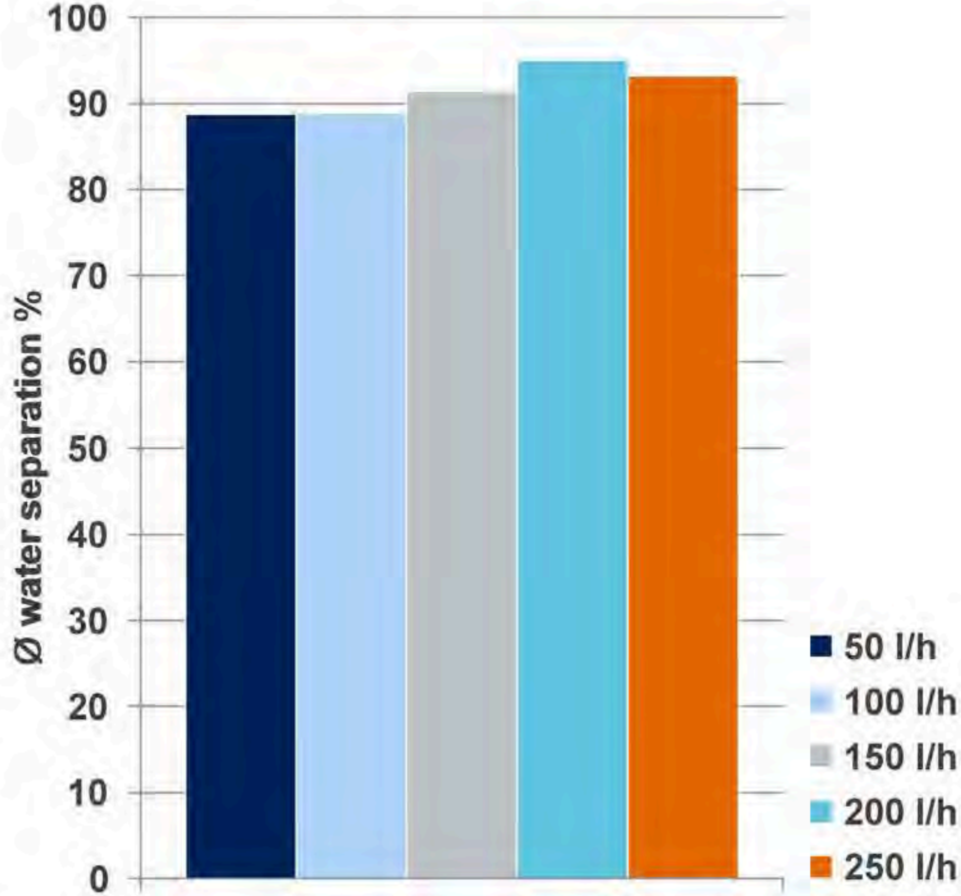
Pre-status

Investigation Results 2 System

Variation of pressure
at constant volume stream (150 l/h)

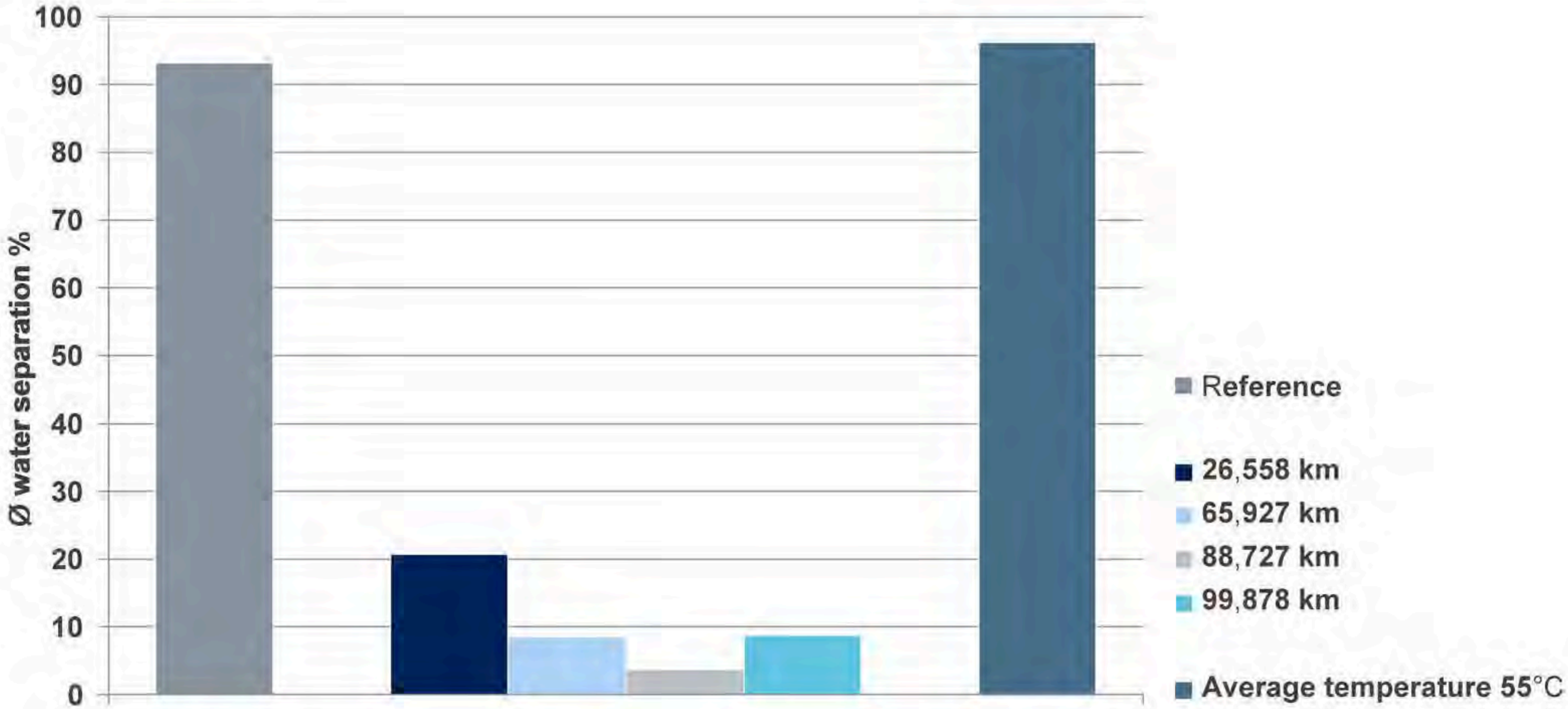


Variation of volume stream
at constant pressure (4 bar)



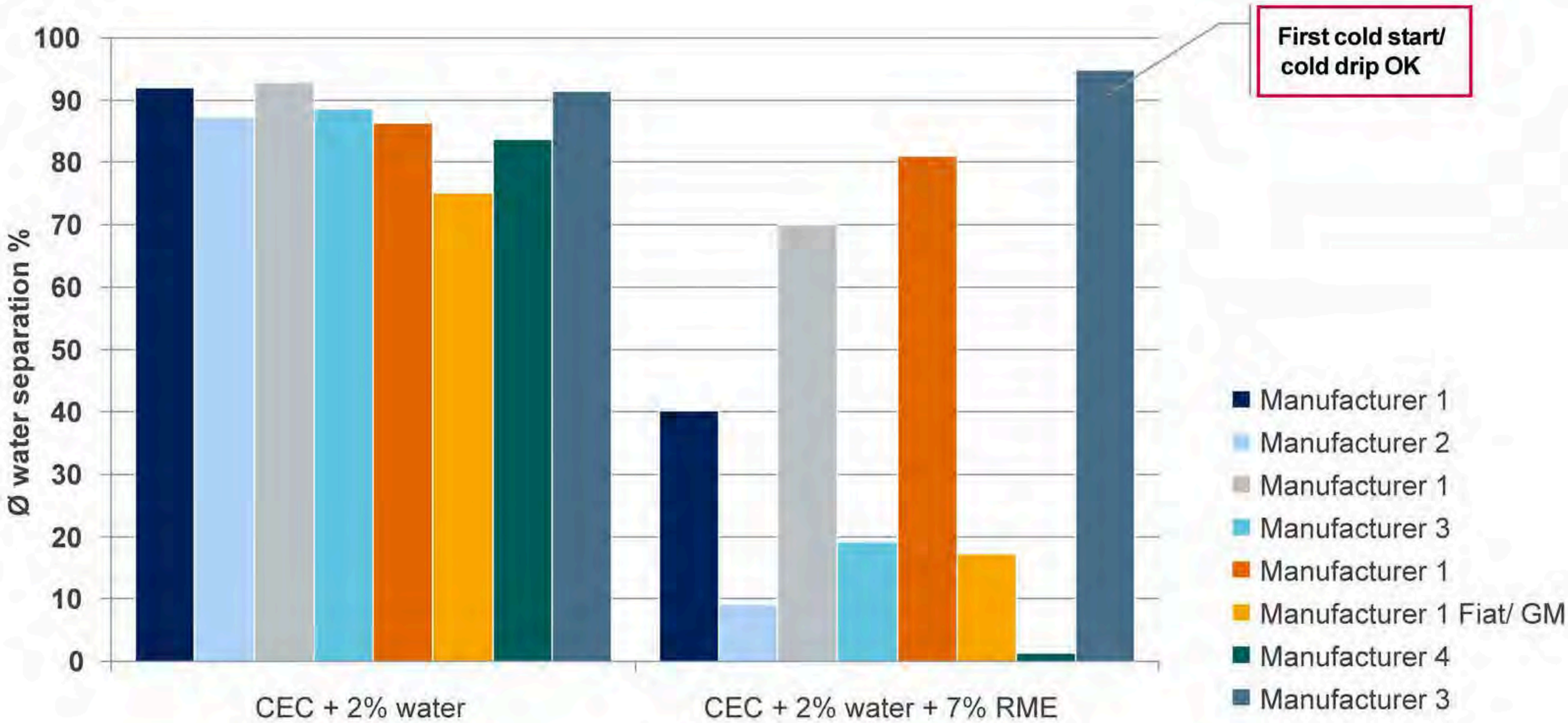
Water quantities determined without titration; only volume-based

Investigation Results 2 System



Water quantities determined without titration; only volume-based

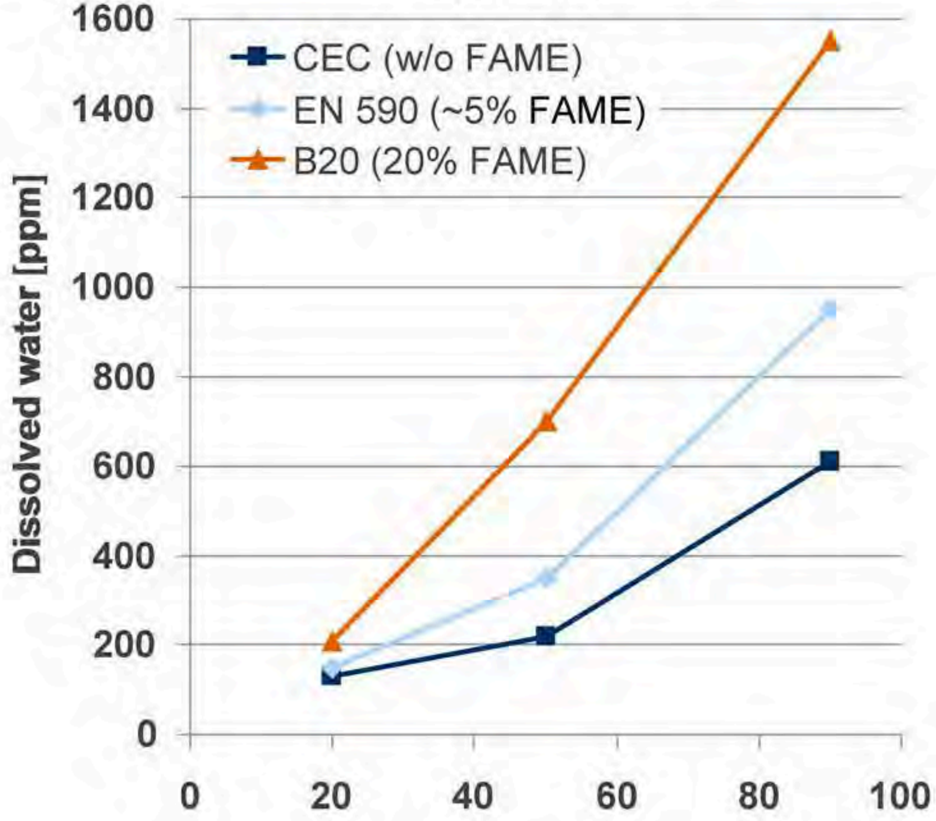
Investigation Results 2 Filter



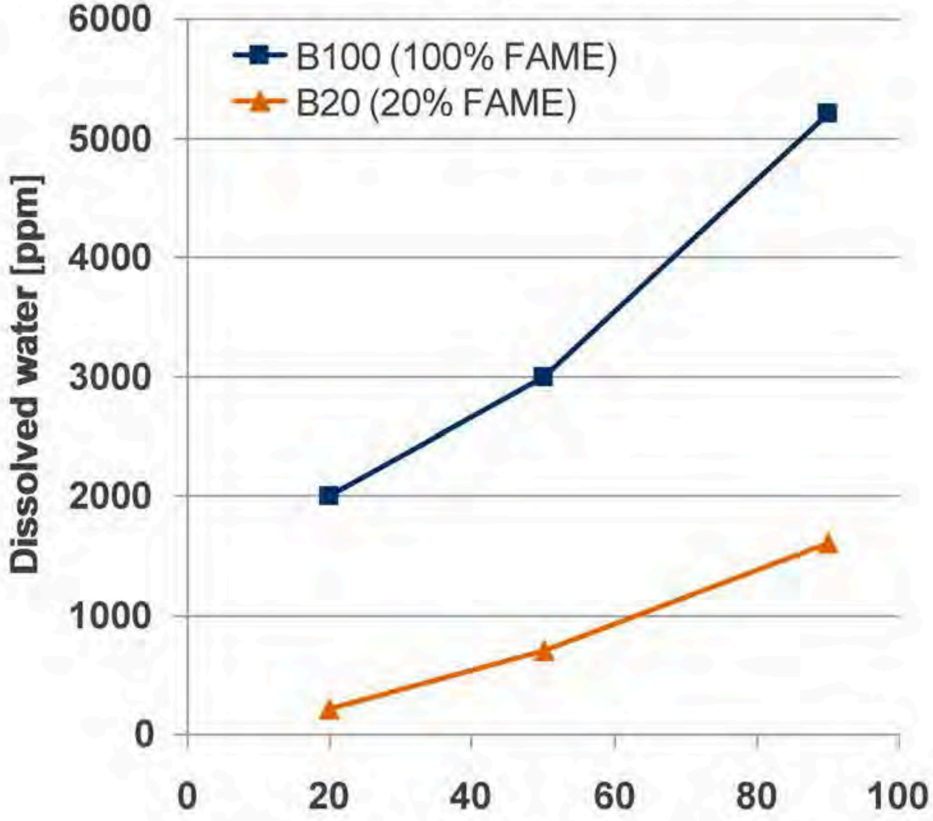
Water quantities determined without titration; only volume-based

Water solubility

Filling station diesel under DIN EN 590
Ability to absorb water



Biodiesel under EN 14214
Ability to absorb water

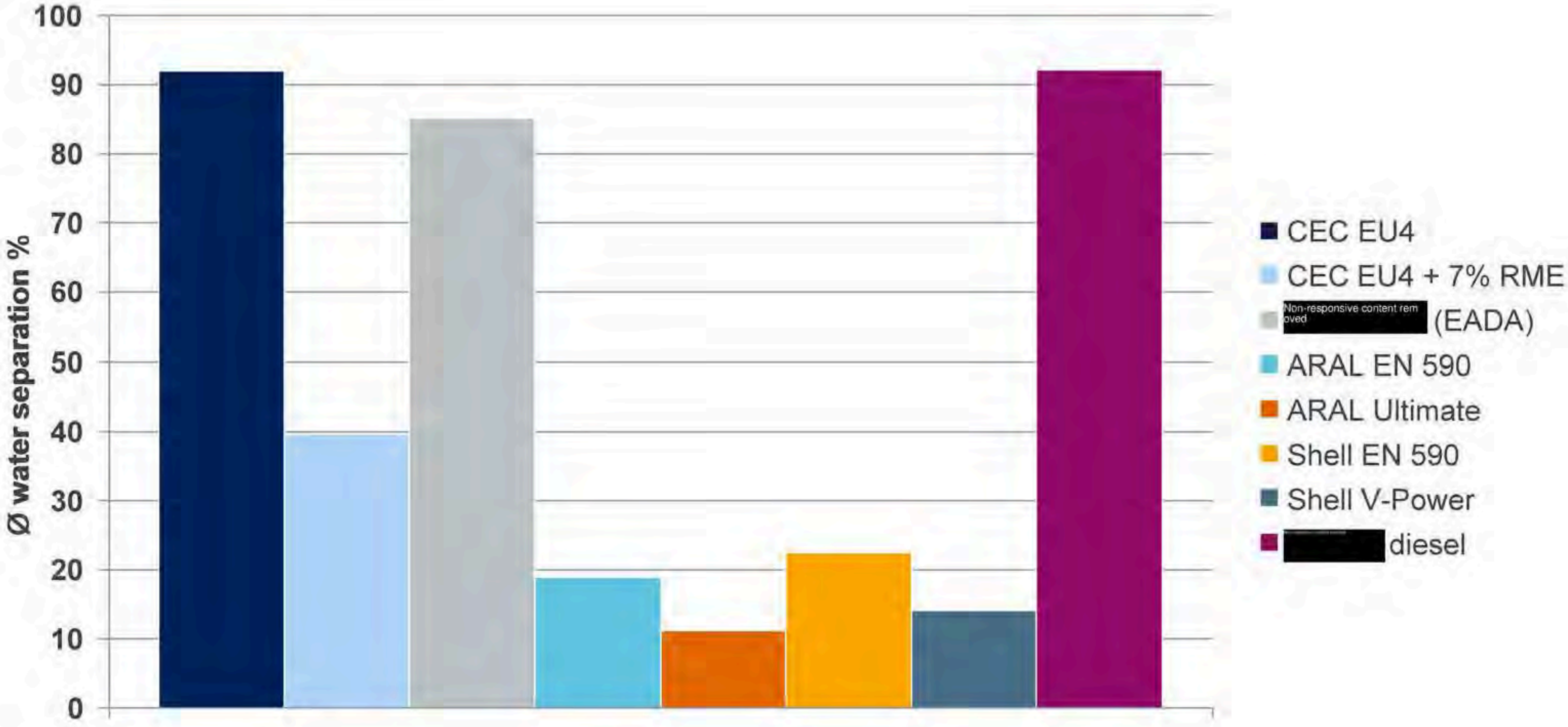


Under DIN EN 590, ~50 ml of water can dissolve in 60l of filling station diesel at 80°C.

10ml for 40l corresponds to 250ppm

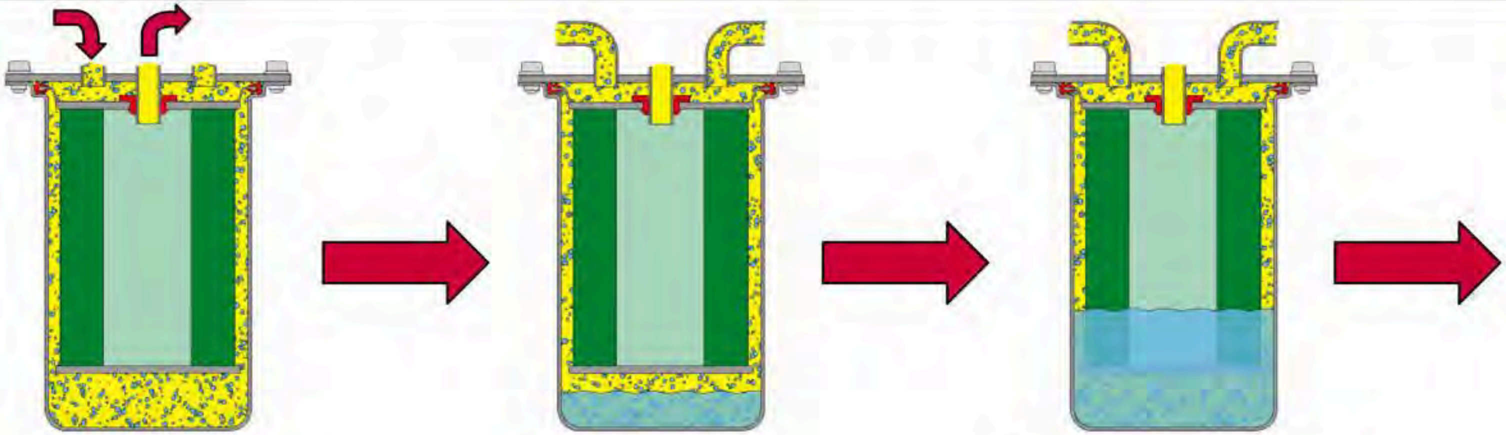
Under EN 14214, ~280ml of water can dissolve in 60l of biodiesel at 80°C.

Investigation Results 2 Filter

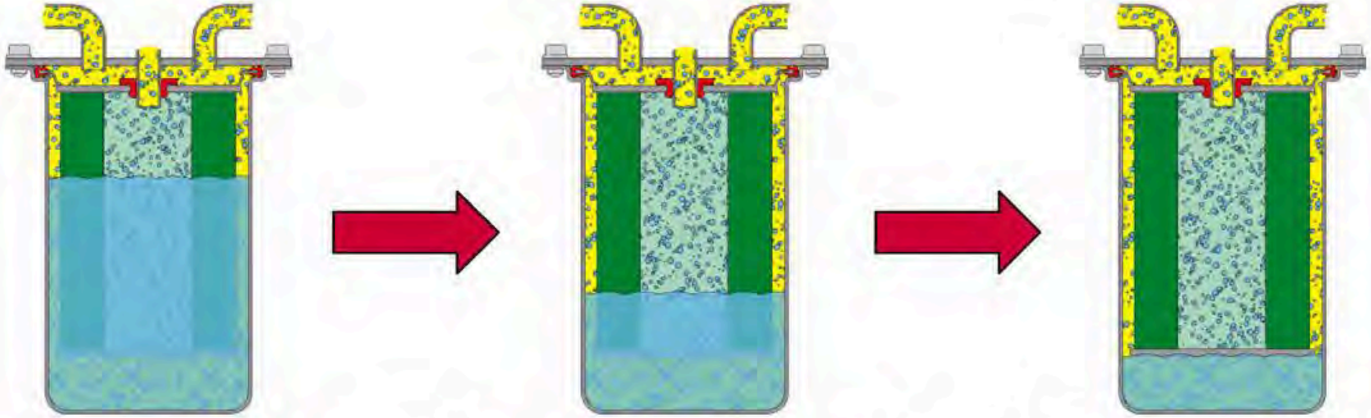


Water quantities determined without titration; only volume-based

Water separation without water disposal



Fuel containing water · **Separated water collects** · **Separated water passes filter element** · **Separated water reaches maximum level**



Water separation stops, water reaches clean side · **Already separated water reaches the clean side** · **Low water level set as new balance**

➔ Water separation without water disposal is not sensible!

➔ Water sensor needed!

Work areas - Summary

Legend

→	Neutral
↑	Improvement
↓	Deterioration

Water separation performance / ability

System

Size	Influence
Volume stream	→
Pressure	→
Temperature	→
Mileage	↓
Improper use	↓

Filter

Size	Influence
Filter area	→
Competitors	→
New concepts	↑

Fuels

Size	Influence
Reference diesel	→
Filling st. EN590	↓
Ultimate / V Power	↓
Ref.Diesel + RME	↓
[redacted]	→
	→
Additional sulfur	→

Problems - Challenges 2 Outlook

- **Further investigations**
  - Investigate new filter concepts with soiled filters
  - Gather additional findings on chemical relationships
    ➔ Doctoral thesis/theses
- **Challenges**
  - *The clarification of the "why" is lacking for many questions*
    - *Reason: Lack of analysis options*
  - *Low level of knowledge on fuels in the various markets*
    - *Large countries* Non-responsive content removed *make sampling difficult*
  - Very large variances in fuel quality
- **Problem**
  - No in-house development of water separators - only test of market supply

End

Fuel System Diesel Filter with Water Separation

- The use of CR systems in countries with critical water content far beyond EN 590 requires the use of water separation systems, in [redacted] opinion.
- The use of water separation system is required by the supplier for critical water content levels.
- Improved membrane separators must be used in EFP systems.
- The separation level described in DIN 4020 is completely unrealistic.
- Sensors must be implemented for sporadically high levels.
- The limited frequency of occurrence on the world market does not justify general water separation; VW favors upgrades/special equipment.
- There were failures due to water content during the test/verification of 2.0 + 1.6 CR.
- The use of water separation systems is also considered to be required for other OEMs that are active globally.
- Up to 30% of damage caused by corrosion in critical markets can be traced to injection system failures.

Fuel System Diesel Filter with Water Separation

Damage to injection systems

Feedback from system suppliers all show significant corrosion damage from field returns to various components/parts

High-pressure fuel pump:

- Drive shaft
- Housing
- Cam running surface
- VCV
- Springs
- Slide shoe
- Roller (CP4.x failures!)
- Intake valve
- Overflow valve piston

Injector:

- Magnet anchor
- Control valve/valve seat
- Pressure bore/stress corrosion

System:

- PCV/PCV in rail
- Filter housing

Non-responsive content removed

Fuel System Diesel Filter with Water Separation

Worldwide assessment of fuel qualities with regard to water

	2006 Critical water content max.)	2007 Critical water content (max.)	2007 Free water	Conspicuous in In past	[redacted] assessment: Water separation needed
Non-responsive content removed	1250	389		-	x
	205	3884	x	-	x
	-	32300	x	?	x
	205	-	-	-	-
	223	-	-	-	-
	-	-	x	x	x
	2859 (Skoda)	463	x	x	x
	241	-	-	-	-
	338	-	-	-	-
	626	-	-	-	-
	223	-	-	-	-
	1786	1212	x	-	x
	397	-	-	-	-
	-	-	-	x	- Endurance run 2007/08 not critical

Non-responsive content removed

Fuel System Diesel Filter with Water Separation

Status of water separation, VW projects

Vehicle	NSF	Polo GM	MQB	PQ35	Touareg	Phaeton	Crafter	RPU
Markets	Non-responsive content removed [redacted]	Non-responsive content removed [redacted]	Non-responsive content removed [redacted]	USA	all	all	all	all
Deadline	t.b.d.	SOP 14/10	t.b.d.	Eliminated with CR (date open)	Series production	Series production	Series production	SOP 48/09
Type of separation	t.b.d.	Drain bolt	t.b.d.	Riser	Riser	Riser	Drain bolt	Drain bolt
Part number	t.b.d.	6R0.127.400.A	5Q0.127.400	1K0.127.400.F	7L6.127.401.H	3D0.127.400.C	2D0.127.399.D	2H0.127.401
Picture	In Process		In Process					

Non-responsive content removed [redacted]

Fuel System Diesel Filter with Water Separation

Volkswagen
Laboratory
Wolfsburg

Non-responsive content removed

11-Z-09-00477_1
Damage analysis development
Order receipt: 12.02.2009
Report date: 05.03.2009

USA fuel filter

Draft	Interim report no.	Concluding report:	Number of interim reports:	

Part number	Designation	Drawing date	Supplier	Note
1K0.127.400.F	Fuel filter		A0002921 00 - MANN UND HUMMEL	-

1 Task

A vehicle in the USA failed after just a few miles due to pump damage. The sample taken from the fuel filter

11-Z-09-00477/2   Fuel sample from fuel filter   2009-02-12

will be examined with regard to water content and compared to the American specification.

2 Summary

The examined sample 11-Z-09-00477/2 consists of approx. 96% water and 4% diesel fuel. The existing water can result in damage to both the fuel filter and other parts of the fuel system, such as the fuel pump, due to its corrosive impact.

3 Individual results

Inspection	Unit	Soll lt. DIN EN 590	Soll lt. ASTM D 975-04c	11-Z-09-00477/1
Composition				
Water	mg/kg	<200	-	967000
	Weight %	-	0.05	967

4 Method

Water content was determined in accordance with EN ISO 12937.

Failure USA with water in DK

9106 mi

Non-responsive content removed

Fuel System Diesel Filter with Water Separation

- HPP at GDV-EWP failed after 67,000 km, no pressure build-up possible.
- Cause: piston spring break in both cylinders. Piston seizure due to spring fragments
- Parts to central laboratory for analysis.

Measure 1:

Release spring end

Background:

Contribution of pressure tension then also possible in transition to first wind

Measure 2:

Additional fine peening

Background:

Improve surface quality, additional pressure tension

Introduced at 0 series, status C5.3, V530

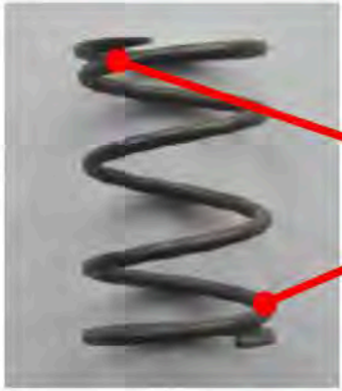
Continental PCR2.4 piston spring break due to corrosion

Non-responsive content removed [redacted]

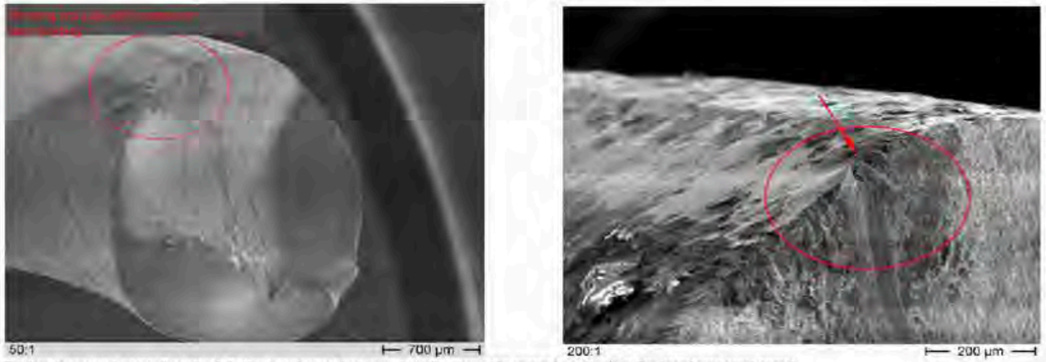
Fuel System Diesel Filter with Water Separation

Problem:

In water test, break of piston springs on 2 of 2 pumps in area; see Fig. 1 after 29/52h (target for successful test: 150h).



Break location (on both spring ends at times)



Friction trace and corrosion attack in the breakage start area (winding top side corrosion attack in the breakage start zone)

Analysis:

Cause of break **Pitting corrosion and hydrogen-induced vibration corrosion,**caused by aggressive diesel-water mixture

Fuel System Diesel Filter with Water Separation

CP4 FG 08-04-2009: Water in fuel

Water in fuel

Corrosion: Audi CP4.2 (AU716E218; 162 000km)

Diesel Systems

4

BOSCH

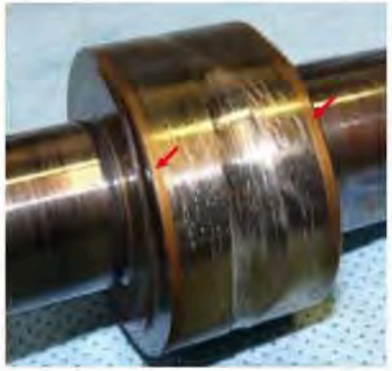
Non-responsive content removed [redacted]

Fuel System Diesel Filter with Water Separation

CP4 FG 08-04-2009: Water in fuel

Water in fuel

Corrosion: VW CP4.1 (2546km)



Diesel Systems

5

BOSCH

Non-responsive content removed

Fuel System Diesel Filter with Water Separation

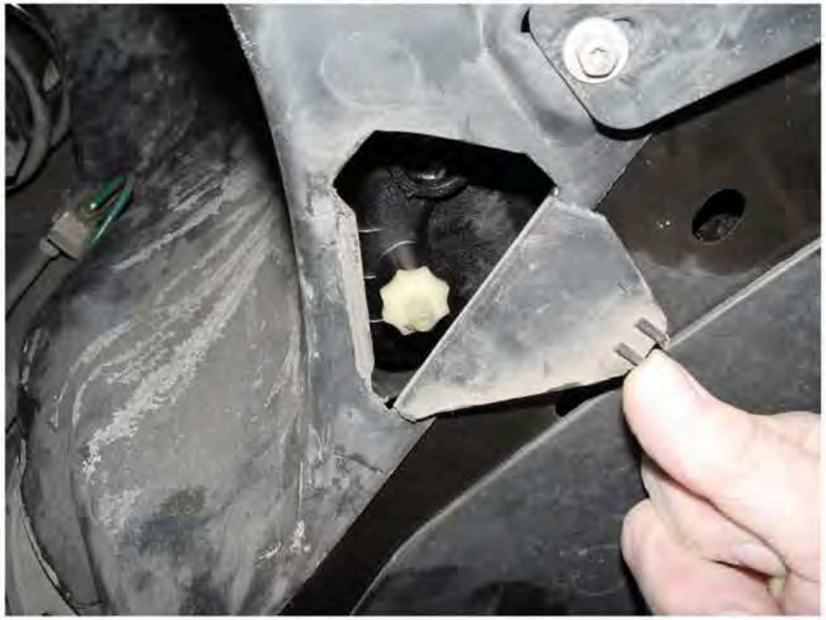
Fiat Punto 1.3

Toyota Avensis 2.2

Non-responsive content removed [redacted]

Fuel System Diesel Filter with Water Separation

Renault Modus

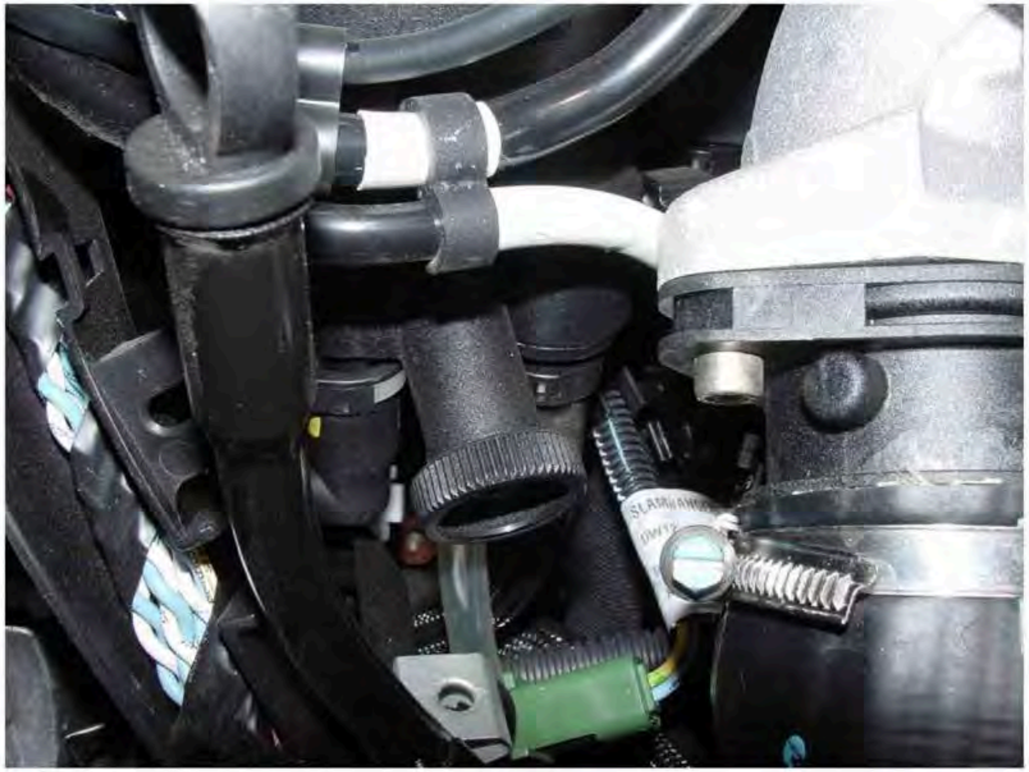


Toyota Yaris

Fuel System Diesel Filter with Water Separation

Opel Corsa 1.3l

Citroen C5 HDI



Non-responsive content removed

Fuel System Diesel Filter with Water Separation

Opel Vectra 2.2 l

Non-responsive content removed

Fuel System Diesel Filter with Water Separation

Fuel injection pump failure analysis

In many cases the fuel pump was failed due to poor quality of DIESEL fuel and presence of moisture / water content.

1. **Sulfur contents:** The excessive sulfur contents in the fuel the more wear of internal parts of Rotary fuel injection pumps. (The Standard sulfur contents limit is below **500 ppm**.)

2. **Moisture / Water presence:** Presence of Moisture in fuel is the major cause of fuel injection pump failures. Moisture/water in the fuel will damage the vanes of vane cell pump (supply pump), cam plate, main shaft, roller and hydraulic governor unit etc.

In Skoda cars fuels system is not provided with any aid or equipment to separate moisture in the Diesel fuel.

Non-responsive content removed

Fuel injection pump failure analysis

It has been observed that the fuel (diesel) available in various parts of country [redacted] having lot of moisture contents which causes severe damage to the internal components of fuel injection pump.

As per **M/s. Bosch** [redacted] **Limited –** [redacted] preliminary investigation report which carried out on 2003, it says out of 36 nos. of dispatched FIPs from SAIPL, the 13 nos. of FIPs internal components completely corroded due to the presence of moisture in the fuel. These pumps are suspected to be beyond repairable conditions.

Conclusion & requirements

It is very much require to have sensor for detecting moisture & water contents in the fuel system also with water drain plug like fuel filter 1JO 127 401 A in all type of engines in the [redacted] market.

Fuel System Diesel Filter with Water Separation

CP4 FG 08-04-2009: Water in fuel

Water in fuel

RB requires water separation in critical fuel markets

Impact of water in fuel

- Corrosion of components can cause
  - Functional failure (stuck MU, OV piston, ...)
  - Drivetrain damage (stuck HP piston, camshaft, roller)
- **Increased wear**
  - Due to high friction coefficient between roller/roller support with w.c.
    Drive-train damage

Diesel Systems

1 vertraulich [redacted] 07.04.2009 [redacted]

BOSCH

Non-responsive content removed [redacted]

Fuel System Diesel Filter with Water Separation

TCD — BOSCH

Technical Customer Documentation
Diesel Injection Technology — Common Rail

Do not distribute to third parties. The most recent version is valid.

System Requirements for Water Separator — KM 45 110 005

The actual efficiency of water separators achieved with additive filling station fuels is usually less than the efficiency measured underDIN ISO 4020, Part 1.

3. Strategic water separators

* General demand for water separators for valve-controlled (2) injection systems when fuel quality cannot be guaranteed under DIN EN 590:2003

  Separation level according to DS requirements (>=93 % from 2 % emulsion at max. flow quantity, other through DIN ISO 4020, part 1, increased requirements in critical regions)

  - Add existing requirements to file of affected hydraulic components

* General recommendation for water separators for valve-controlled injection systems
  - Arrangement before delivery pump if possible, possibly separate from fuel filter
  - Storage volume is consumption-dependent and country-specific, at least 200 ml
  - Water level sensor with warning lamp and error recording in error memory
  - Activation threshold for water level sensor at half-filled water storage reservoir

* Rejection of warranty for corrosion damage
* Rejection of warranty for wear damage traced to fuel with water content

[illegible]	[illegible]	[illegible]	Non-responsive content removed
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	
[illegible]	Änderung	Datum	

Non-responsive content removed

8.4.2 Filter Requirements

8.4.2.1 Water Content

Water content of fuel acc. to EN 590 upstream of the fuel filter.
Filter with water separator required.

Water separation rate > 95% over lifetime at max. flow rate through the filter (acc. to DIN/ISO 4020 part 1, point 6.5).

In specification ISO 4020 a certain water droplet size is specified. The water separation efficiency is depending on the water droplet size.
With use of an intank pump the water droplet size will be strongly reduced so that the water separation efficiency will also strongly decrease.

8.4.2.2 Particle Contamination

Particle contamination of fuel acc. to EN 590 in front of the fuel filter.
Required filter efficiency ISO/TR 13 353 (1994) must be > 94.5% for particle size 3 - 5 µm or conterminous in accordance with the new standard:
Required filter efficiency ISO 19438, initial efficiency > 84% for particle size 5 µm(c)
No glass fibers are allowed.
Filter requirements are only valid in combination with the allowed fuels.
During filter changes it has to be ensured that no contamination get on the clean side of the filter..

ENTIRE PAGE CONFIDENTIAL

EA11003EN-00341[0]

Filter Presentation AUDI, NSU, 01/22/2007

Automotive Aftermarket

BOSCH

Non-responsive content removed

[redacted]

Non-responsive content removed

[redacted]

BOSCH

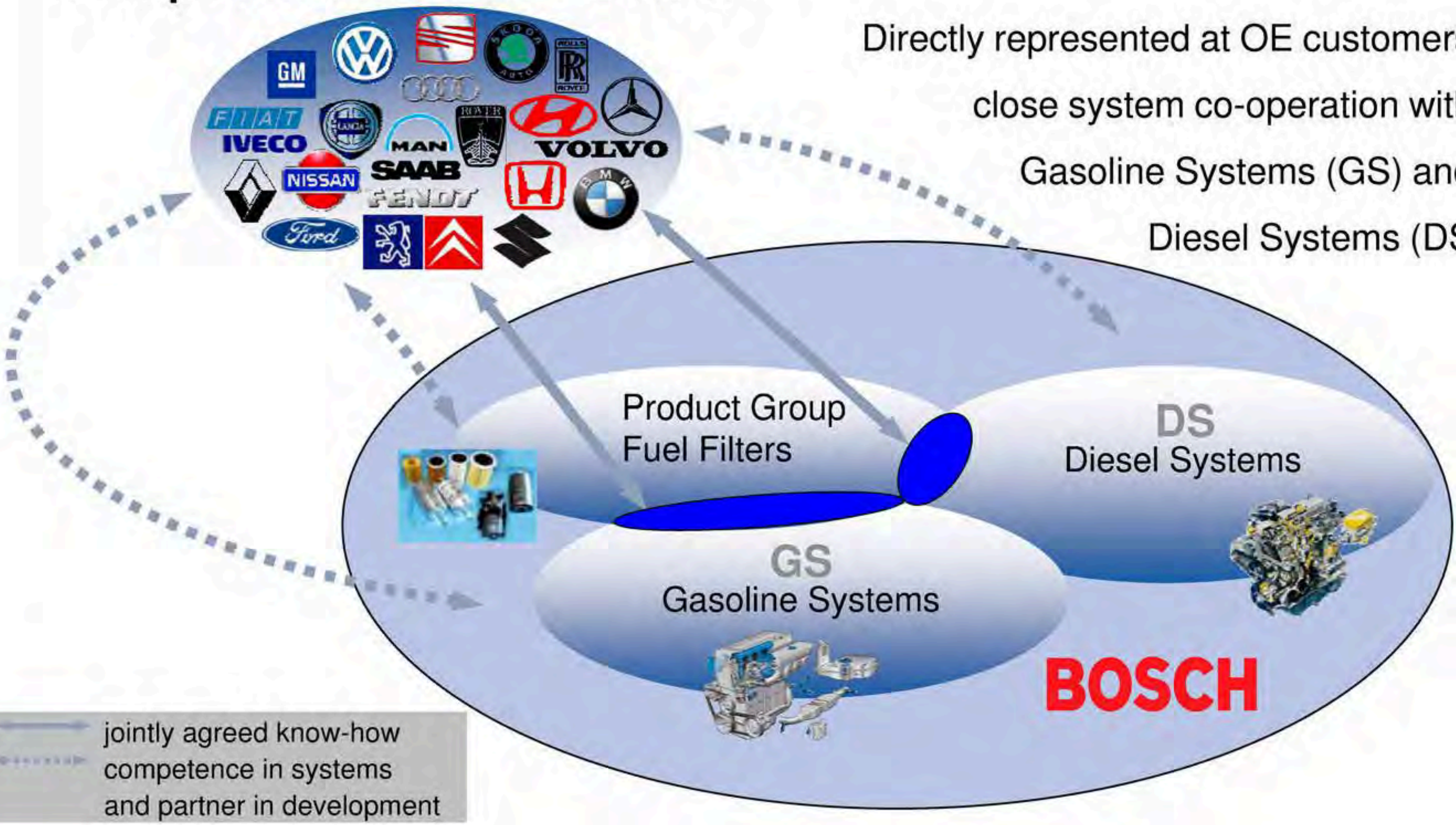
Non-responsive content removed

[redacted]

Filter Presentation AUDI, NSU, 01/22/2007

Cooperation within Bosch

Directly represented at OE customers, close system co-operation with Gasoline Systems (GS) and Diesel Systems (DS)



Automotive Aftermarket

BOSCH

Presentation Bosch Fuel Filters

WORLDWIDE FILTER PRODUCTION

➡ Strong worldwide presence within the Filter market

RBEF Fuel Filter Plant and Engineering in Spain

Test facilities in Alcalá/Madrid, Spain

- DIN ISO 4020
- ISO TR 13353; ISO TS 13353 (2002)
- ISO 19438 2003
- vibration tests: resonance, 3D
- climatic tests: Thermal shock
- resistance to fluids, recirculation
- endurance tests, humidity tests
- Pulsation test, pressure test
- Salt spray test, climatic tests
- General tests (e.g. DSC, sensors)
- SEM, IR analysis, Metrology

Test facilities in Germany

- EMC laboratory
- Numerical simulation
- Vehicle and engine testing
- Component testing with different fuels
- Fuel development; definition of fuels and norms, aggressive fuels, mixed fuels,...
- Fuel surveys
- Corporate research departments: materials, manufacturing meth-ods, physics, electronics

BOSCH

Product portfolio gasoline filters (KFB)

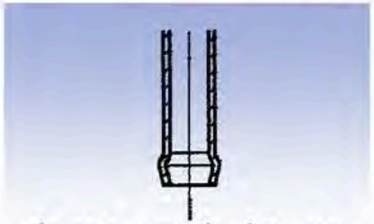
KFB plastic type

KFB steel type with double bordering

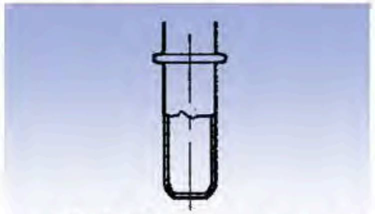
KFB aluminum type

KFB aluminum type

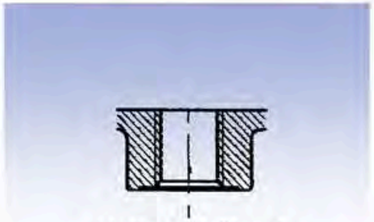
KFB aluminum type with integrated pressure regulator



hose and clamp



quick fit connector



screw type

Filter Presentation AUDI, NSU, 01/22/2007

Product portfolio diesel filters (KFD)

KFD in-line filter
with pre-heater and bracket

KFD assembly with bracket and fuel tubes

KFD plastic filter with
easy-to-change
filter element

KFD Box Filter with electrical
heater, thermo switch and
pressure relief valve

KFD Modular Filter with brack-
et, return and water sensor

Filter element types

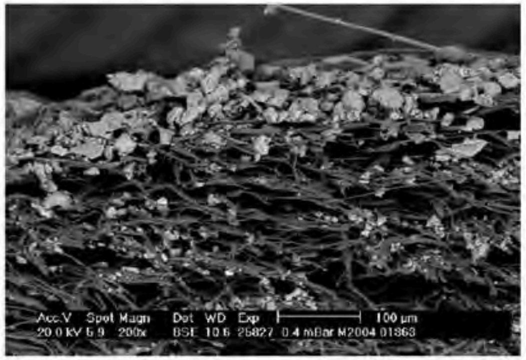
star filter element

coil filter element

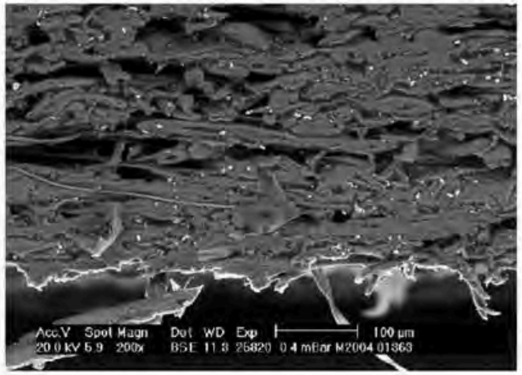
Filter Presentation AUDI, NSU, 01/22/2007

Filter media

Melt-blown

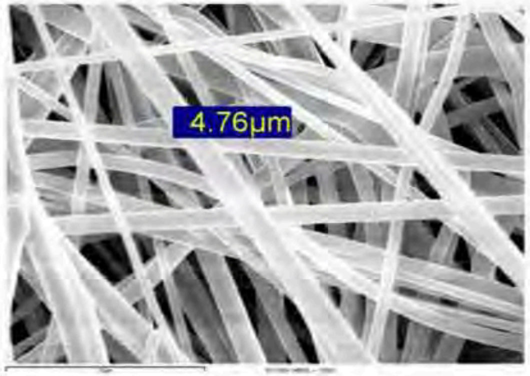


Cellulose

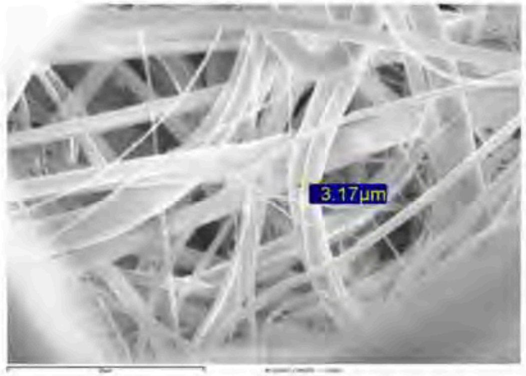


Example for deep filtration with melt-blown paper combination

1st generation



2nd generation

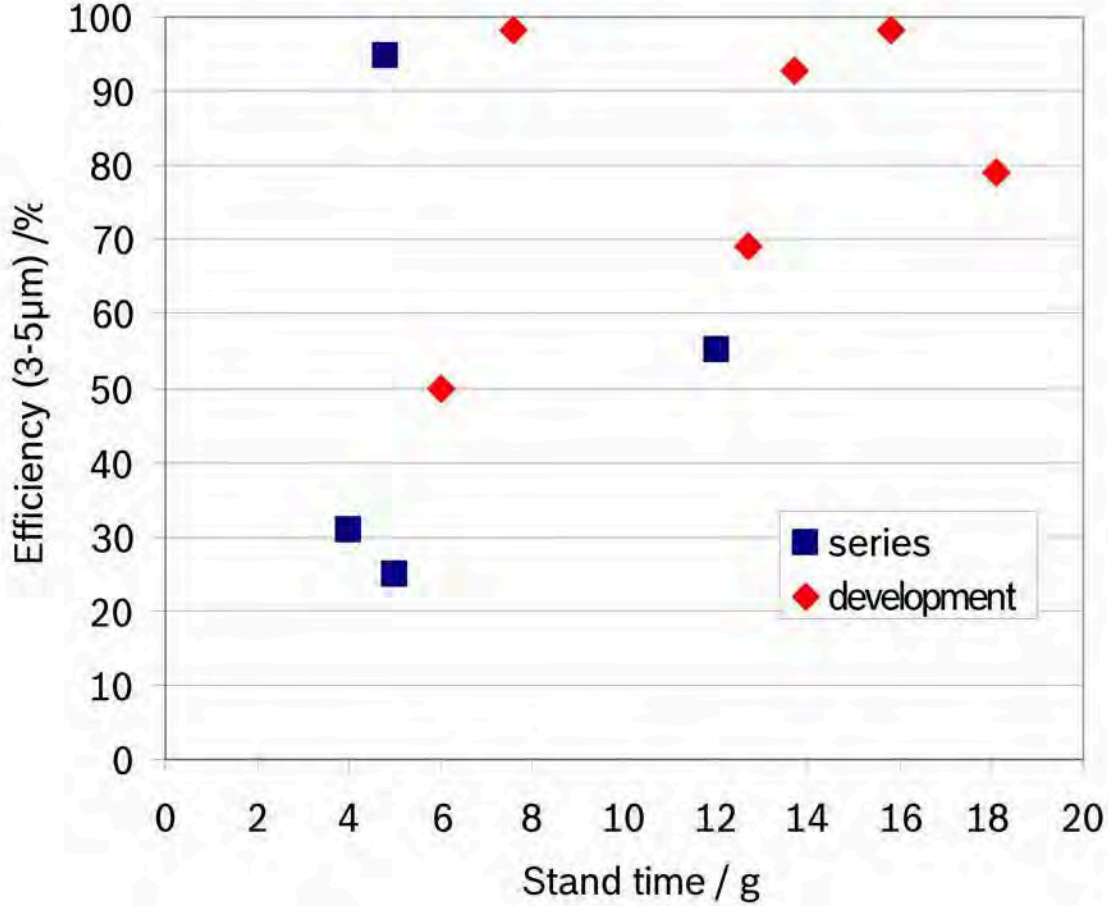


Newly developed melt-blowns for better deep filtration

BOSCH

Filter Presentation AUDI, NSU, 01/22/2007

Filter media portfolio



- New developments allow significant enhancement with regard to stand time and particle separation
- Selection of filter medium dependent on requirements for stand time, efficiency, and water separation
- Series implementation still open

ISO TR 13353

Filter surface: $1400 cm^2$

Presentation Bosch Fuel Filters

Metal Filter Properties

					
Max flow	160 l/h	220 l/h	230 l/h	160 l/h	230 l/h
Working pressure	0...3.5 bar	3...5.5 bar	3...5.5 bar	3...5.5 bar	3...5.5 bar
Water chamber/ Detection level	120 cm3 45 cm3	none	120 cm3 45 cm3	150 cm3 45 cm3	150 cm3 45 cm3
Heater / Water sensor	Yes /Yes	No / No	Yes / Yes	Yes / Yes	Yes / Yes
Changeable element / Change interval	No / 60,000 km	No / 80,000 km	Yes / 60,000 km	Yes, Spin-on / 60,000 km	Yes, Spin-on/ 40,000 km
Particle sep. efficiency per ISO TR 13353 (1994) <severe cond.>	>93.5% at (3-5 µm)	>93.5% at (3-5 µm)	>93.5% at (3-5 µm)	>93.5% at (3-5 µm)	>98% at (3-5 µm)
Water separa-tion ISO 4020	>93% (160 l/h)	None	>99% (230 l/h)	>93% (160 l/h)	>98% (230 l/h)

BOSCH

Plastic Filter Properties

			
Max flow	230 l/h	180 l/h	10 l/h (Urea filter)
Working pressure	3...5.5 bar	3...5.5 bar	up to 5bar
Water chamber/ Detection level	175 cm3 45 cm3	150 cm3 45 cm3	none
Heater / Water sensor	Yes / Yes	Yes / Yes	Yes / No
Changeable element / Change interval	No, Filter is welded / 60,000 km	Yes / 60,000 km	Yes/ 160,000 km
Particle sep. efficiency per ISO TR 13353 (1994) <severe cond.>	>93.5% (3-5 µm)	>93.5% (3-5 µm)	>82% (3-5 µm)
Water separation ISO 4020	>99% (230 l/h)	>93% (180 l/h)	None (Urea filter)

Water sensors

Type A: in series

- Electrical conductivity
- Signal output to lamp to ground/positive or ECU
- Typical detection level 65mm (can be adapted)
- Integrated water drain

Type B: in development

- Float, magnet and reed contact
- Signal output to lamp
- Typical detection level 65mm (can be adapted)
- Integrated water drain

Filter Presentation AUDI, NSU, 01/22/2007

Electric heaters

Finger heater

- PTC
- 150 to 250W
- Assembly from below/ above
- Activation via MOSFET, NTC-integrated

Sandwich heater

- PTC
- 150 or 250W
- Assembly between filter and cap
- Control through external relay, optional with T sensor

Compact heater

- PTC
- 150W
- Controlled through thermostat

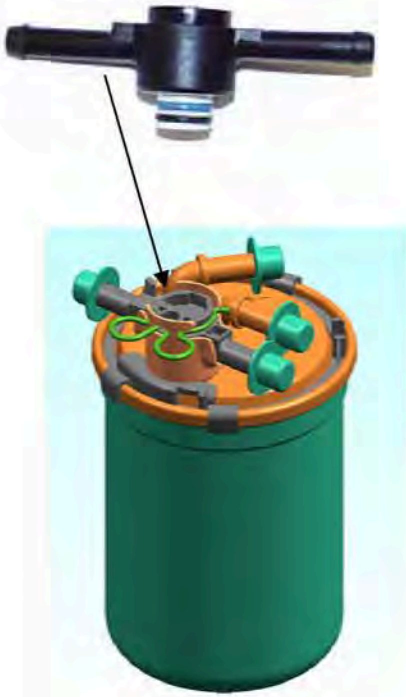
Lead frame

- Resistance
- 40 to 150W
- Can be inte-grated in plastic filter or for use in plastic filter
- Ext. T sensor

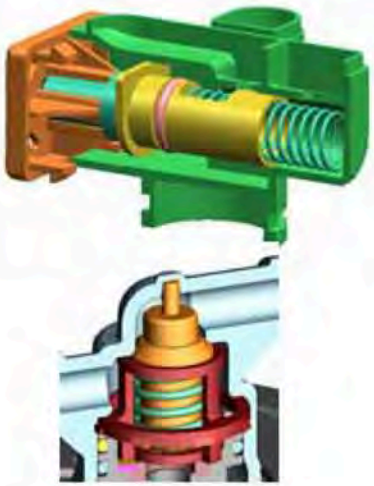
BOSCH

Passive heater

Bi-metal valve

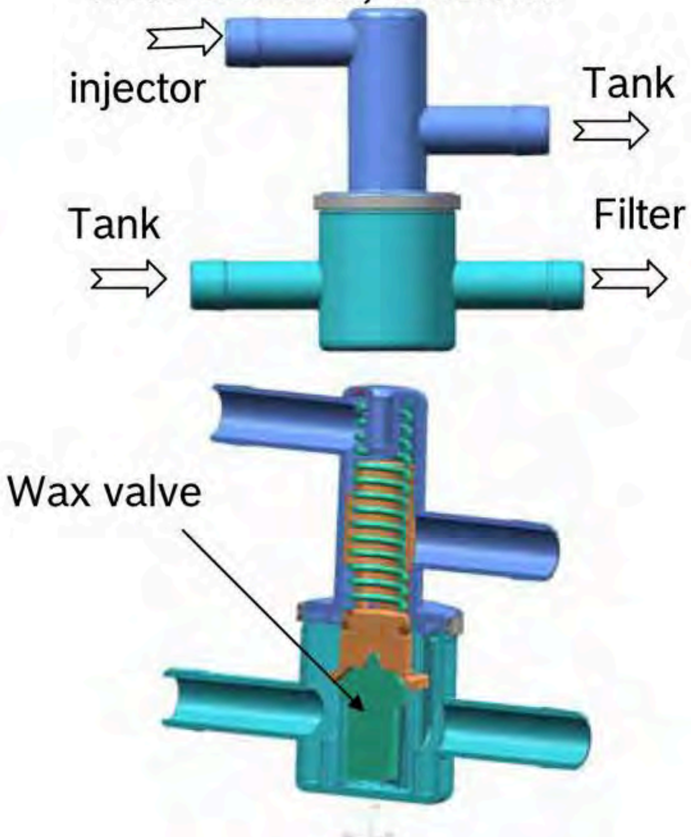


Wax element



integrated in filter

Wax element, external



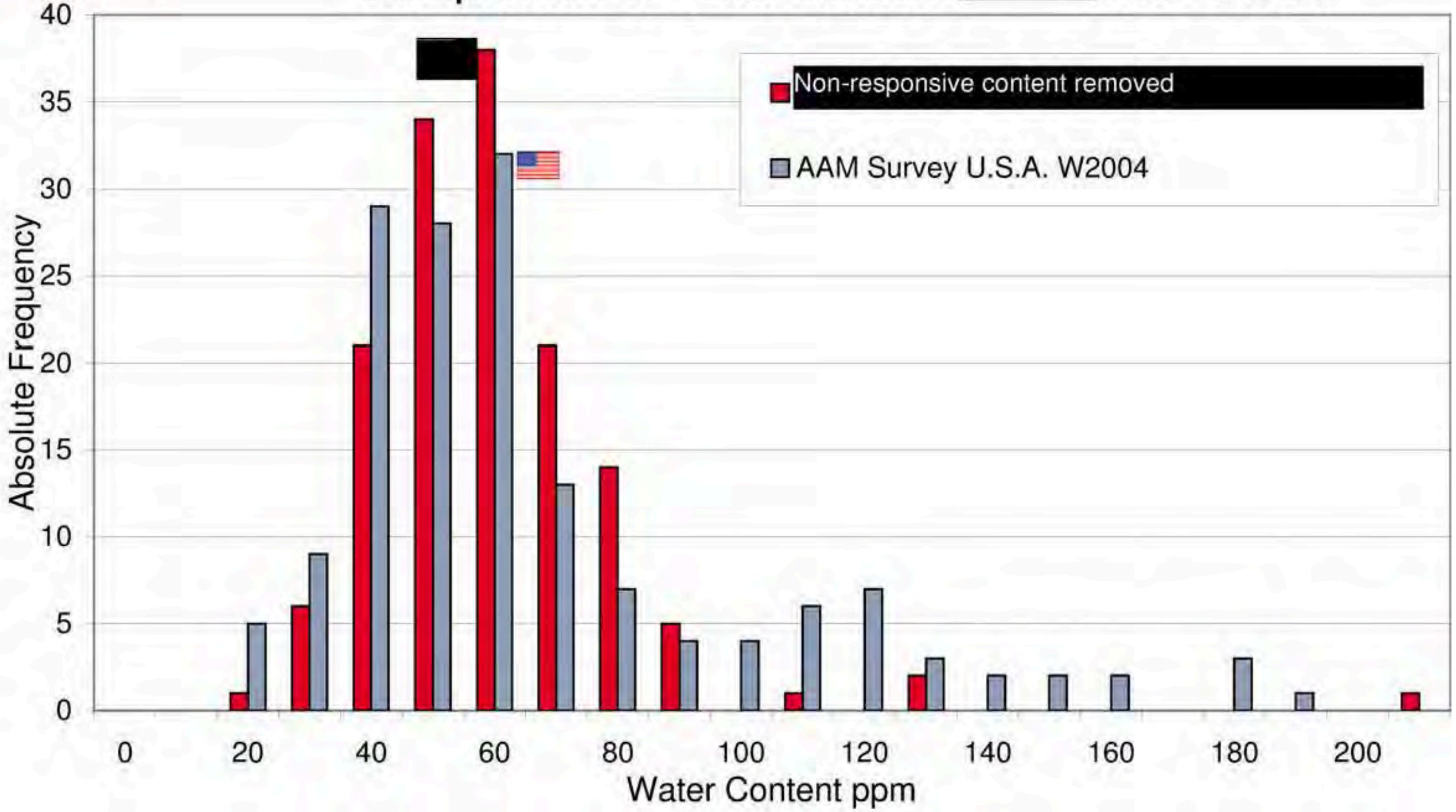
BOSCH

Water separation

Water-caused damage mechanisms

→ **Corrosion**

Comparison of water content [redacted] with U.S.A.



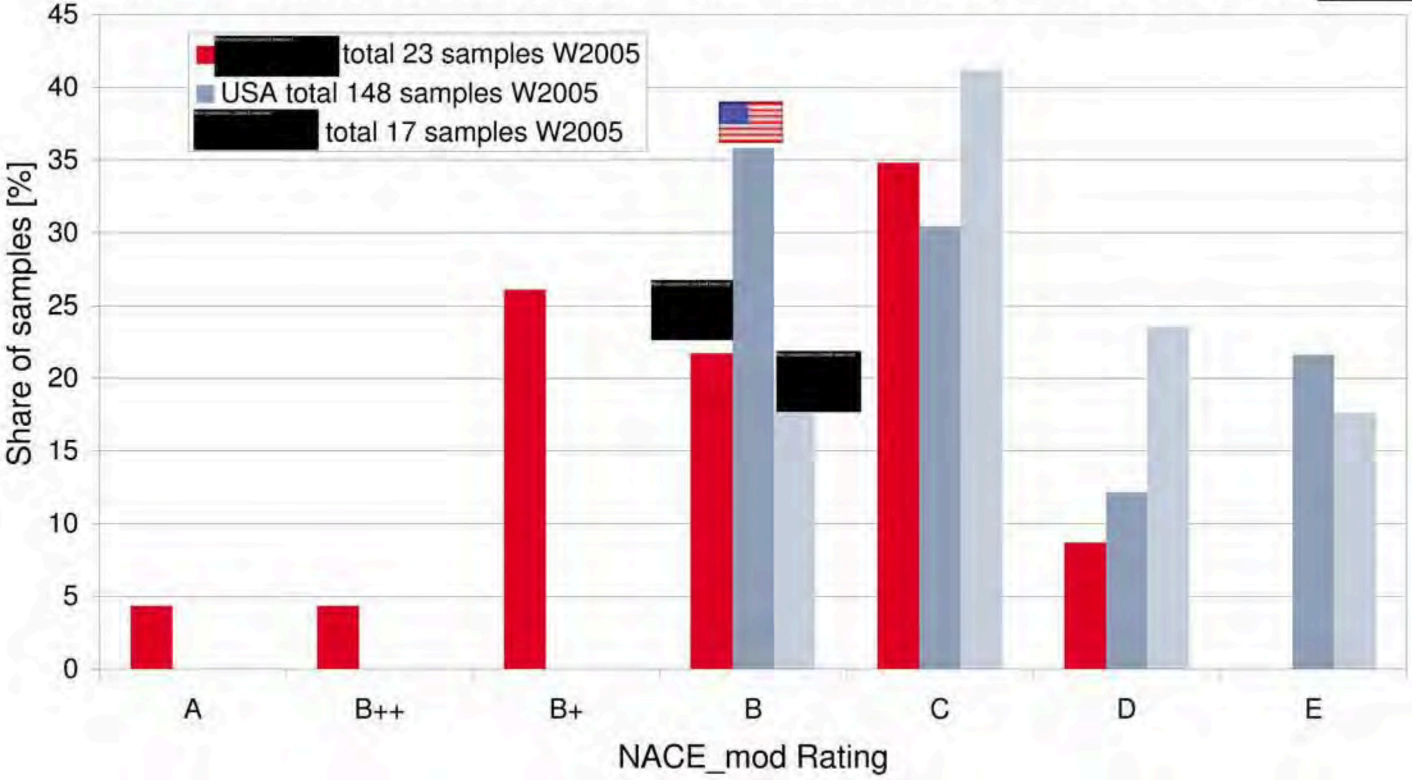
BOSCH

Filter Presentation AUDI, NSU, 01/22/2007

Water-caused damage mechanisms

➔ Corrosion

Comparison of corrosion protection effectiveness [redacted] with USA and [redacted]



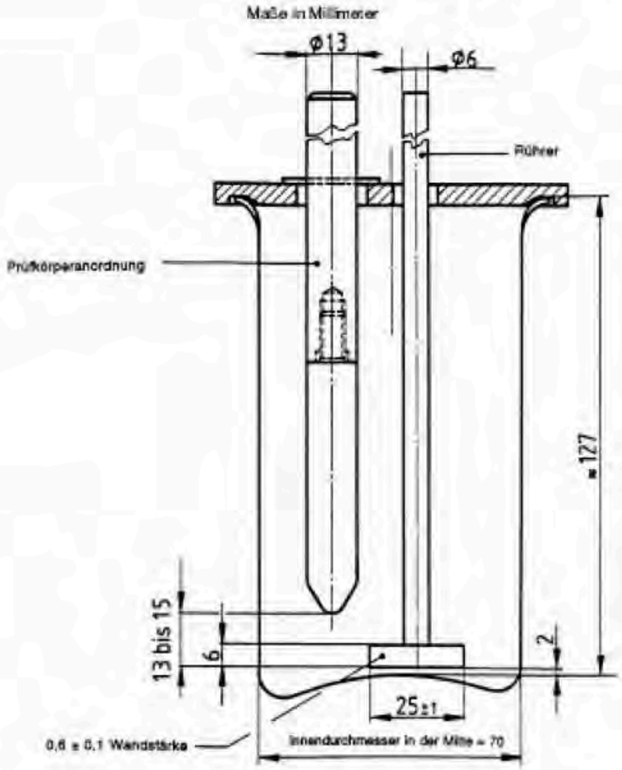
BOSCH

Filter Presentation AUDI, NSU, 01/22/2007

Analysis methods - Corrosion protection effectiveness

Standardized procedures: NACE TM0172
DIN ISO 7120

"Steel rod test"



Principle:

Inspection fluid with 10% artificial seawater
Fill into a cup

Heat cup (ISO: 60°C, NACE 38°C) and stir

Insert blank steel rod

After a defined time (ISO: 24h, NACE 3.5h) analyze corrosion degree

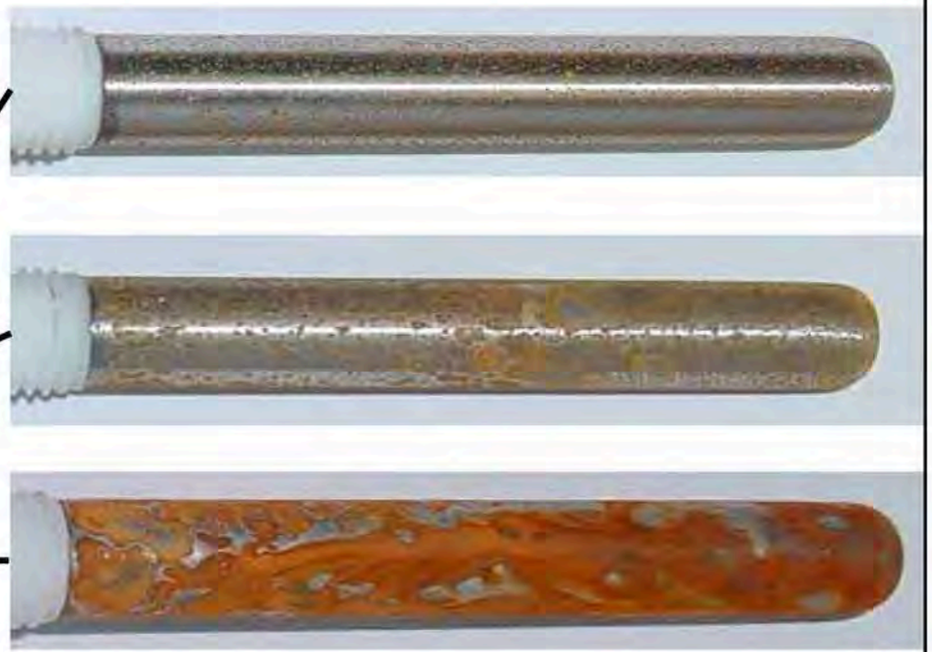
BOSCH

Filter Presentation AUDI, NSU, 01/22/2007

Analysis methods - Corrosion protection effectiveness

Assessment steps according to NACE TM0172

NACE rating	% rust surface
A	0
B++	< 0.1
B+	< 5
B	5-25
C	25-50
D	50-75
E	75-100



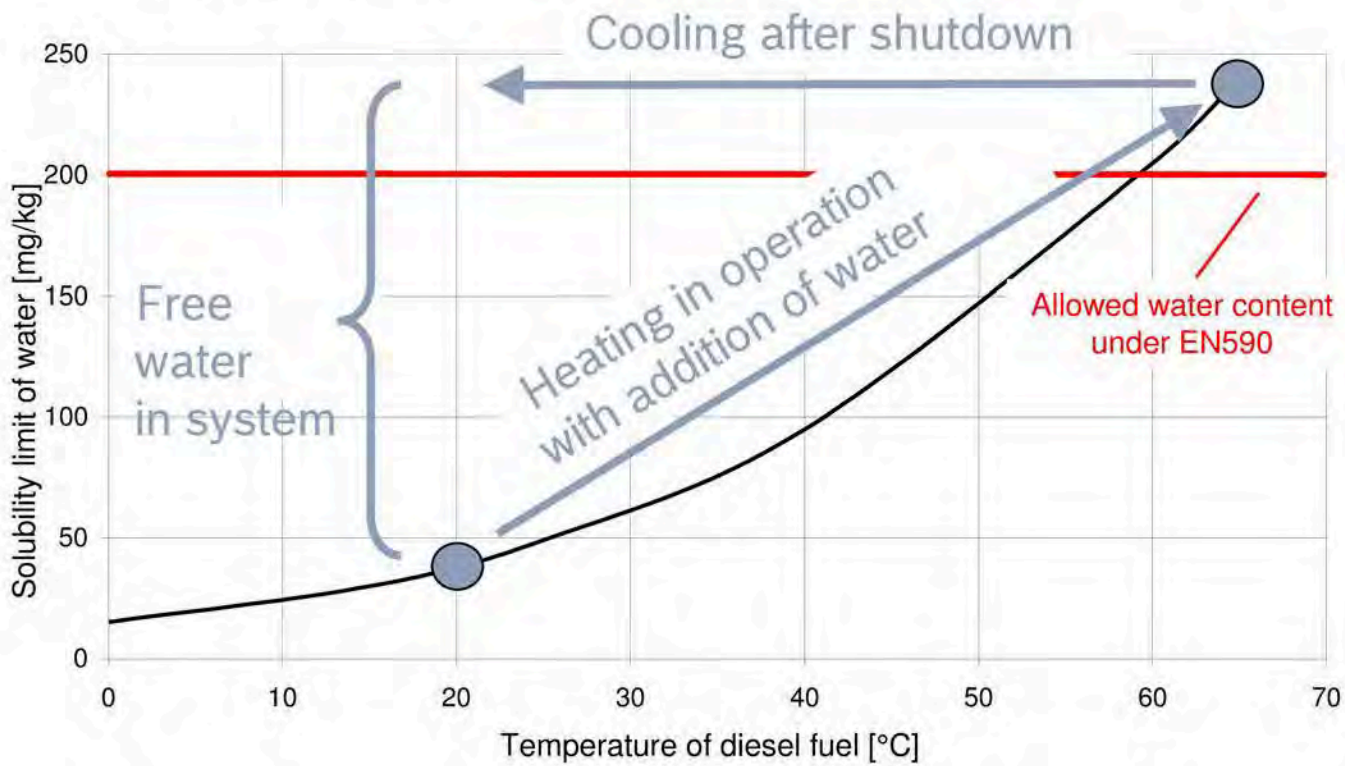
BOSCH

ENTIRE PAGE CONFIDENTIAL

Water-caused damage mechanisms

➔ **Corrosion**

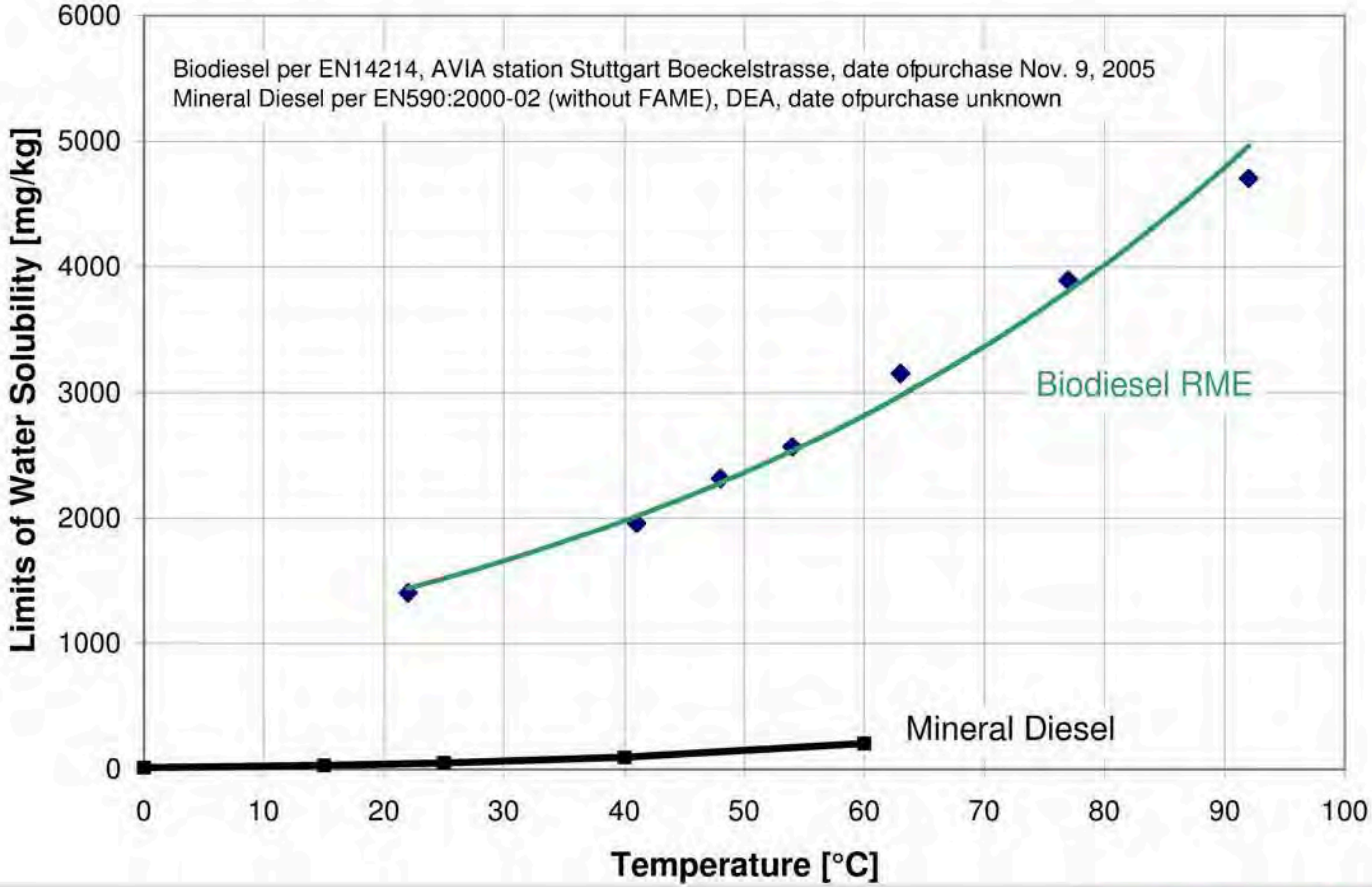
Mechanism for creating free water in field



BOSCH

Filter Presentation AUDI, NSU, 01/22/2007

Dissolving Power of Water in Mineral Diesel & RME



BOSCH

Water separation in pressure/inlet systems

- Under DIN ISO 4020 and ISO TS 16332, only pressure systems in the standard are implemented.

- Water droplet size in pressure system depends on delivery pump:
- 10 – 15 µm Jet Pump (Venturi System)
- 40 – 60 µm EFP
- 60 µm under ISO TS 16332 (setting from panel)

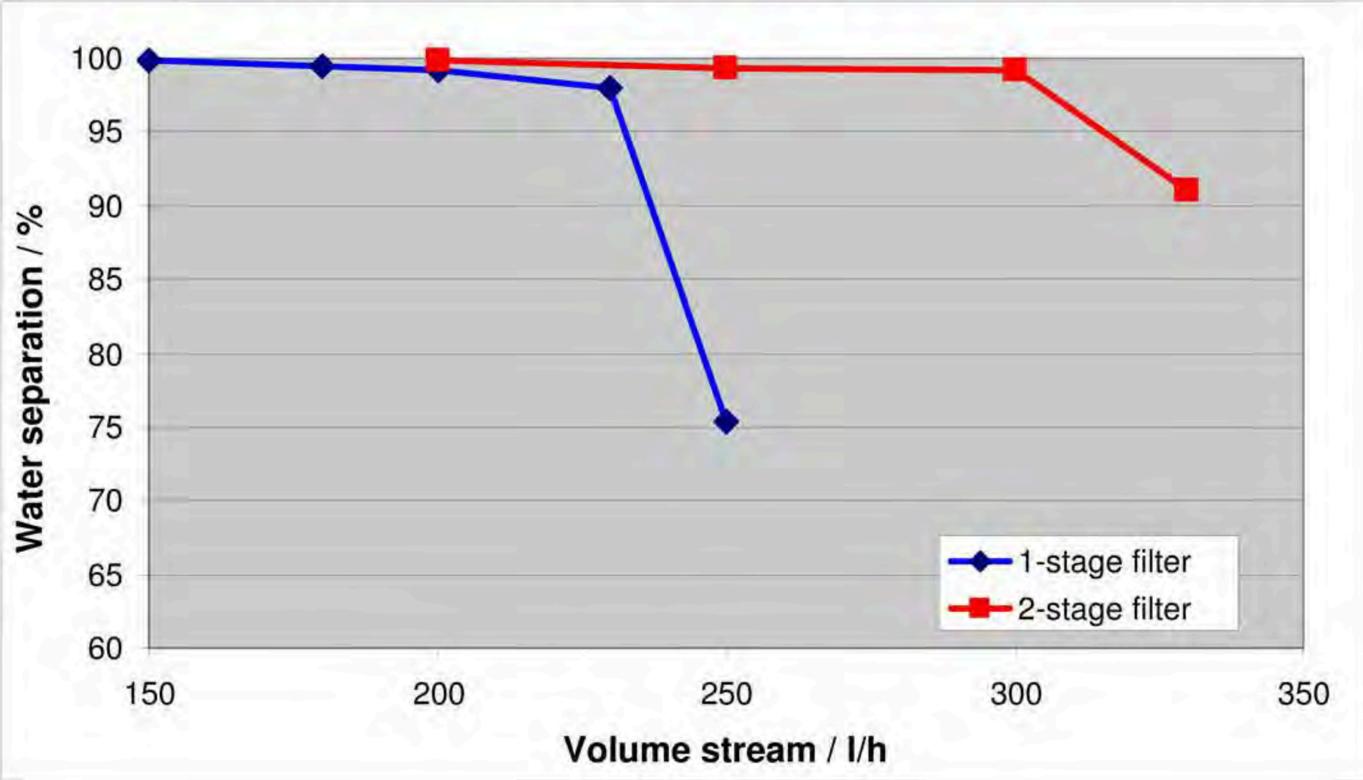
- Water droplet size in inlet systems (gear pump) dependent on delivery volume under ISO TS 16332:
- 300 µm at 150 l/h (droplet size specified under ISO TS 16332)
- 125 µm at 200 l/h

- **The smaller the droplets, the more difficult the water separation**

Filter Presentation AUDI, NSU, 01/22/2007

Dependency on volume stream

- Water separation for various filter types under ISO 4020 with reference diesel and droplet size of approx. 60µm



BOSCH

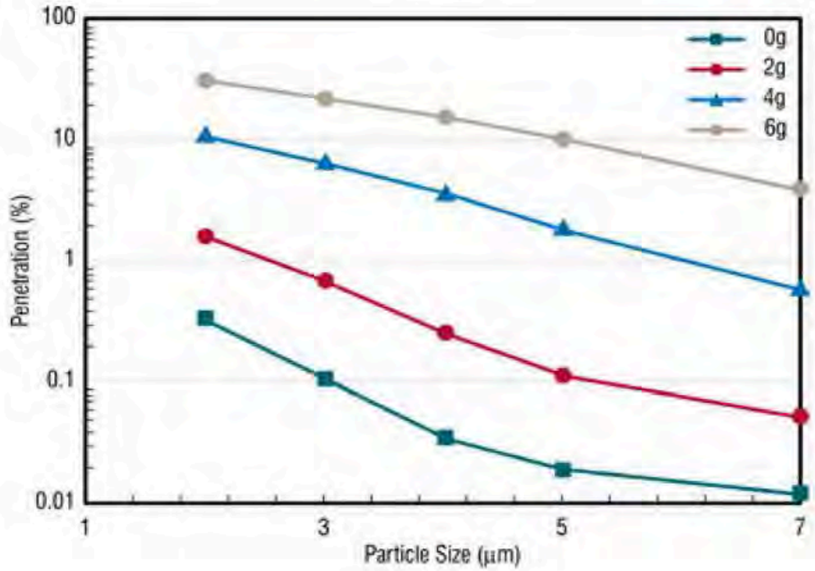
Filter Presentation AUDI, NSU, 01/22/2007

Vibration impact on water separation

- Oscillation movements prevent coalescence effect
- (Use of melt-blown fibers and growing water droplets on these fibers) lower water separation
- Start of tests in Alcalá in 2007

BOSCH

Vibration impact on particle separation



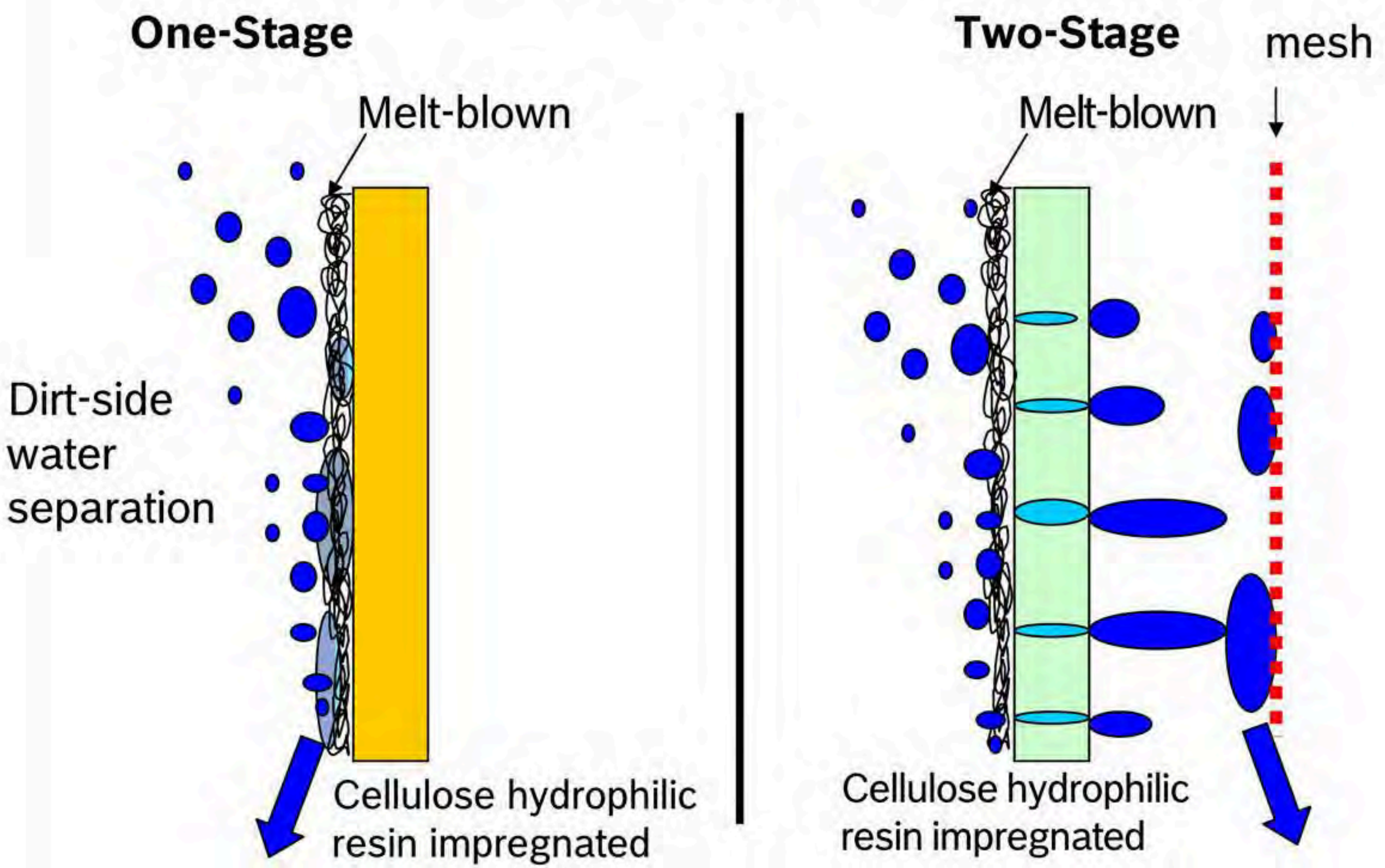
Particle separation for various vibration accelerations, 0g to 6g. Measured with Viscor fluid at 15 Hz

From Gregory LaVallee and Phillip Johnson, Donaldson Company, Inc., "How Flow and Vibration Affect Filter Performance - Inside and Outside the Laboratory". *Machinery Lubrication* Magazine. May 2003

ENTIRE PAGE CONFIDENTIAL

EA11003EN-00341[30]

Water separation techniques



Filter Presentation AUDI, NSU, 01/22/2007

Bosch 2-stage filter

- Water separation depends on flow velocity at filter media surface
- Normally (one-stage filtration) the water will be separated by hydrophobic resins in the cellulose fibers
- Water separation is limited to flow rates of 160 l/h with a typical filter size of 1700 cm2
- With a two-stage concept water separation at flow rates of more than 200 l/h is possible

BOSCH

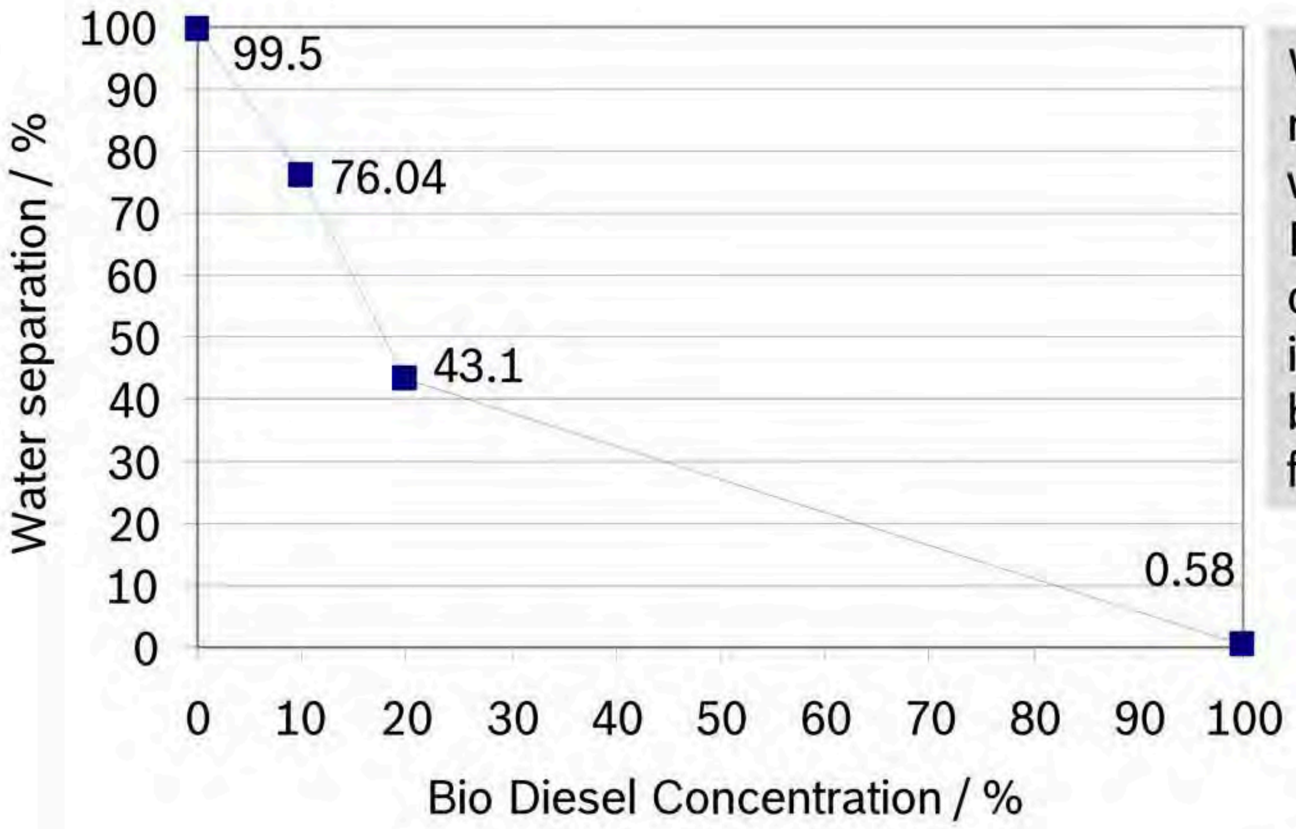
Filter Presentation AUDI, NSU, 01/22/2007

2-stage filter: benchmark

	DS Requirements PC (severe cond.)	Racor Double Pleat	M&H	Mahle	Bosch "2-Step Filtration" (B)
					
Life Time ISO TR 13353		?	?	8.5 g	16 g
Efficiency ISO TR 13353	94.5% (3-5 µm)	*99% (3-5 µm)*	*?*	*<90% (3-5 µm)*	*98% (3-5 µm)*
Water separation ISO 4020	> 93% (Max-Flow-Rate)	*<80% (230 l/h)*	*<36% (260l/h)*	*99% (230 l/h)*	*99% (230 l/h)*

*measured with jet pump

Impact of biodiesel on water separation



Water separability reduces significantly with increasing Bio Diesel concentration due to reduction of interfacial tension between water and fuel.

*measured with jet pump

Filter Presentation AUDI, NSU, 01/22/2007

Water separation and corrosion with biodiesel

Table 3: Corrosion protection impact of diesel / biodiesel blends

DK-Blend	NACE_mod-Rating	NACE-Rating
EN 590 DK Blend 2005	C	B++
B5	B – C	A
B10	B	A
B20	B	A
B30	B+	A
Biodiesel SB tank	B+	A

In the NACE_mod rating, synthetic seawater is used instead of water; assessment is made visually based on degree of rust on steel rods.
As blend rate of fresh biodiesel increases, the degree of corrosion improves

BOSCH

Summary

- Water separation can be improved through favorable system design (rougher emulsions and lowest possible volume streams)
- Greater filter surface improves water separation (construction space!!!)
- Biodiesel(additive) may result in higher water content and poorer water separation, but lower corrosion susceptibility as well
- With the same space, 2-stage filtration can provide for water separation even at higher volume streams

Outlook for 2007

- Tests on impact of vibration on water and particle separation
- Further improvement of filter media
  - More hydrophilic cellulose/resin systems
  - Variation of hydrophobic nets with regard to coating and mesh size
- Quantification of impact of various emulsion sizes on water separation
- Examination of different biodiesel and biodiesel blends on water separation, dependence on IFT

Water Separation - Diesel Fuel System

Reasons for Water Separator in Fuel System

- Warranty from HPP manufacturer (Bosch)

  Even with a water separator, warranty coverage for corrosion and wear caused by water is excluded.

- Customer satisfaction/quality increase through water separator

  How many field complaints involving water damage to the HPP system are known at Audi? No usable figures are available yet.

  Can these cases of damage be reduced by using a water separator?

  There is no statement on the critical water quantity in the system, therefore no estimate on the reduction of cases of damage can be made!

  Independent of this, water in the system is unavoidable (see technical explanation in attachment from P. 4).

What does Audi and the customer get from using a water separator?

The additional part costs and development costs cannot be justified through either quality nor warranty cost optimization!

Requirements by HPP on water separator in fuel system

– Excerpt from Bosch TCD 0449D00005

- General **demand** for water separators for magnetic valve-controlled injection systems when fuel quality cannot be guaranteed under DIN EN 590
- eparation level according to DS requirements (>=93 % from 2 % emulsion at max. flow quantity, other through DIN ISO 4020, part 1; increased requirements in critical regions)

The TCD from Bosch does not limit the permissible water quantity in the SP system! It merely documents requirements for the separation level. This means there are no quantity limits for water in the HP system!

Example: (consumption 7l/100km, journey length 10,000km)

	2% Emulsion	max. values according to EN 590
separated water quantity:	13l	0.13l
Water quantity remaining in system:	1l	0.001l

Both water quantities (13l & 1l) in the system are allowed according to the Bosch TCD.

Water Separation - Diesel Fuel System

Audi

Bosch TCD

BOSCH	Diesel Systems Technical Customer Documentation COMMON RAIL Inspection Method Sheet	0 445 D00 005 Page 1 of 2 Date 11/13/2006

System Requirements for Water Separator

1. General

Some CR system components are sensitive to fuels with water content, because these fuels can result in corrosion damage and excessive wear due to reduced lubricity. The use of efficient, properly maintained water separations can largely remove water from the fuel, preventing damage to CR system components.

2 Definition of Water Separator

Requirement for water separation level for magnetic valve-controlled diesel high-pressure injection systems.

Water separation level >=93 % from 2 % emulsion at max flow quantity. Otherwise DIN ISO 4020, part 1; Increased requirements in critical regions

DIN ISO 4020, part 1 describes the procedure, test equipment, test medium, and analysis procedure of the water separation test for determining the separation level of water separators.

The test medium consists of an emulsion produced with a defined membrane pump from suitable diesel fuel (RB uses non-additive reference diesel CEC RF-73-A-93 from supplier CLH, for example) and distilled water in a ratio of 50:1.

The delivery quantity for each membrane pump is 50 l/h; or multiples with several pumps, to get a standard state of water droplet size.

For practical reasons, RB uses a comparable emulsion, created with a peristaltic pump (hose pump) and EFP4 (rolled cellulose pump) with adjustable delivery stream.

Water separators that achieve a separation level of at least 93 % according to DIN ISO 4020, part 1 largely protect magnetic valve-controlled diesel high-pressure injection systems against corrosion and wear damage, according to RB field experience!

The actual efficiency of water separators achieved with additive filling station fuels is usually less than the efficiency measured under DIN ISO 4020, part 1.

No.	Seite	Arrangement	Date	Responsible Abteilung	Signature
0	1-2	Layout, TCD Renumbering	11/13/2006	DS/ECP	[redacted]

BOSCH	Diesel Systems Technical Customer Documentation COMMON RAIL Inspection Method Sheet	0 445 D00 005 Page 2 of 2 Date 11/13/2006

System Requirements for Water Separator

3. Water Separator Strategy

- General recommendation for water separators for magnetic valve-controlled injection systems
- General demand for water separators for magnetic valve-controlled injection systems when fuel quality cannot be guaranteed under DIN EN 590
- Separation level according to DS requirements (>=93 % from 2 % emulsion at max. flow quantity, other through DIN ISO 4020, part 1; increased requirements in critical regions)
- Arrangement before delivery pump if possible, possibly separate from fuel filter
- Add existing requirements to file of affected hydraulic components
- Storage volume is consumption-dependent and country-specific, at least 200 ml
- Water level sensor with warning lamp and error recording in error memory
- Activation threshold for water level sensor at half-filled water storage reservoir
- Rejection of warranty for corrosion damage
- Rejection of warranty for wear damage traced to fuel with water content

No.	Seite	Arrangement	Date	Responsible Abteilung	Signature
0	1-2	Layout, TCD Renumbering (ersetzt TKU KM45110005)	11/13/2006	DS/ECP	[redacted]

Critical:
- Water is allowed, but warranty for water is rejected.
- Water level with warning lamp and fault storage is an equivalent requirement for separator.

No.	Seite	Arrangement	Date	Responsible Abteilung	Signature
0	1-2	Layout, TCD Renumbering	11/13/2006	DS/ECP	[redacted]

Water Separation - Diesel Fuel System

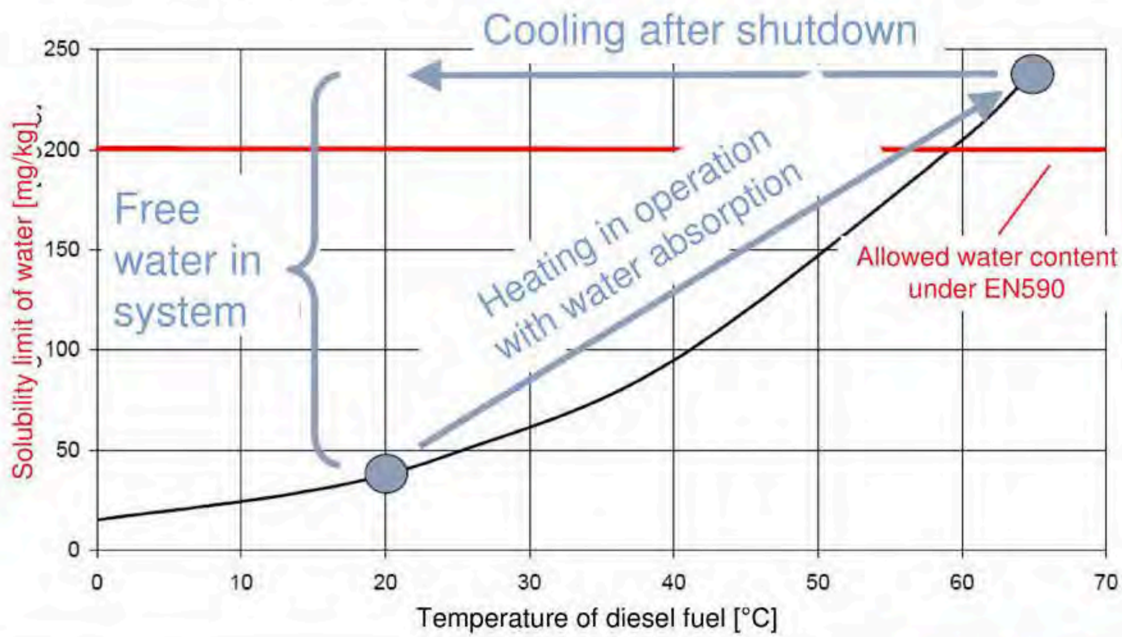
Systematic free water despite separation

Filter Presentation AUDI, NSU, 01/22/2007

Water-caused damage mechanisms

→ Corrosion

Mechanism for creating free water in field



BOSCH

Water Separation - Diesel Fuel System

How much water reservoir is required for a separation system?

Assumption:

- Poor-fuel country with high water content (11.7 mg/kg, Argentina 32 mg/ kg) in diesel fuel
- Water separator in fuel system with 93% separation performance

Example:

- With Ø consumption of 7l for 100km, approx. 930ml of water is “filtered” from the fuel by the separator every 1,000 km
- With mileage of 30 tkm, this means a water quantity of 27.9l

How much water reservoir is required for a separation system?

Required water reservoir for separation performance of 93% and

Ø consumption of 7l/100km

		Specific water content in fuel [ml/kg]			
		0.2	0.5	11.7	24.4
Mileage [tkm]	10	150 ml	400 ml	9300 ml	13000 ml
	20	300 ml	800 ml	18600 ml	26000 ml
	30	450 ml	1200 ml	27900 ml	
	60	900 ml	2400 ml		
	90	1350 ml	3600 ml		

Example in words:

If water content is 0.5 ml/kg, a water reservoir of 1200ml is required for mileage of 30 tkm

0.2 ml/kg = DIN EN590

0.5 ml/kg = DIN 14214 (biodiesel new)

11.7 ml/kg = 1l water in 70l fuel

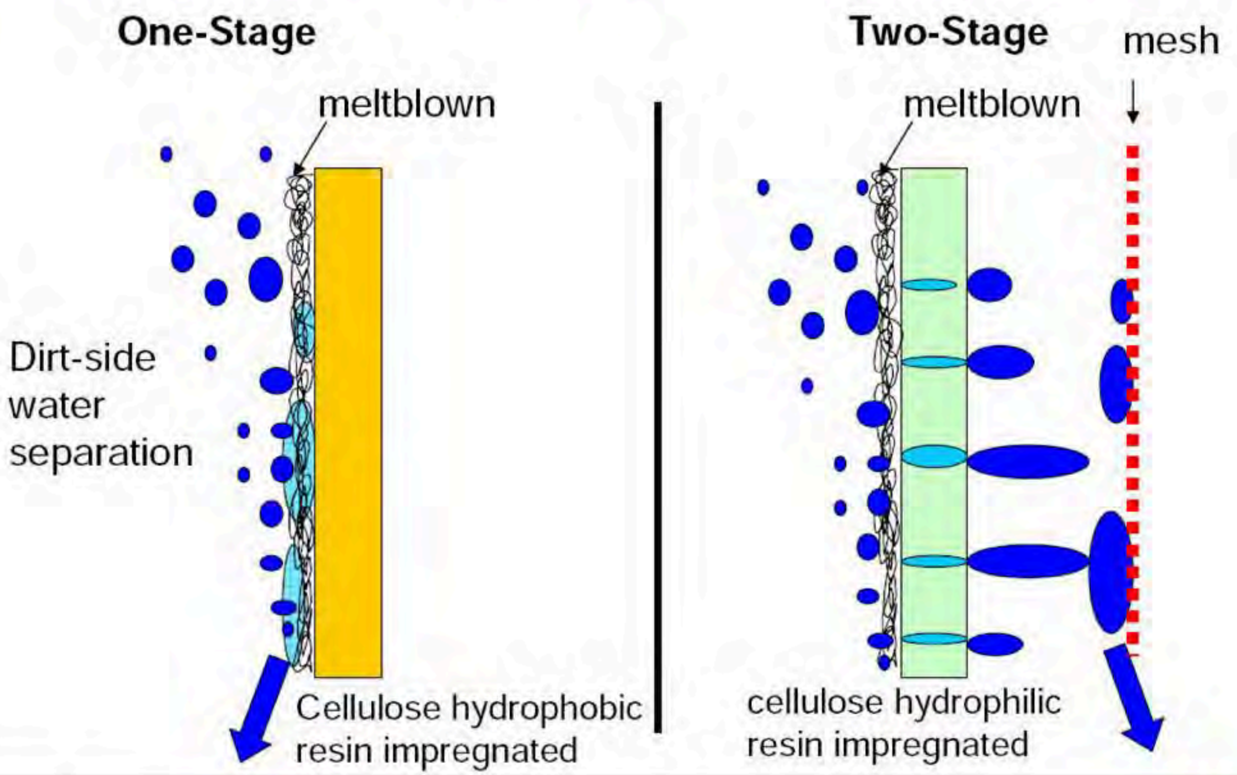
24.4 ml/ kg = 2% emulsion (ISO 4020)

Water Separation - Diesel Fuel System

Water Separation Function

Filter Presentation AUDI, NSU, 01/22/2007

Water separation techniques



Automotive Aftermarket

31 [redacted]

BOSCH

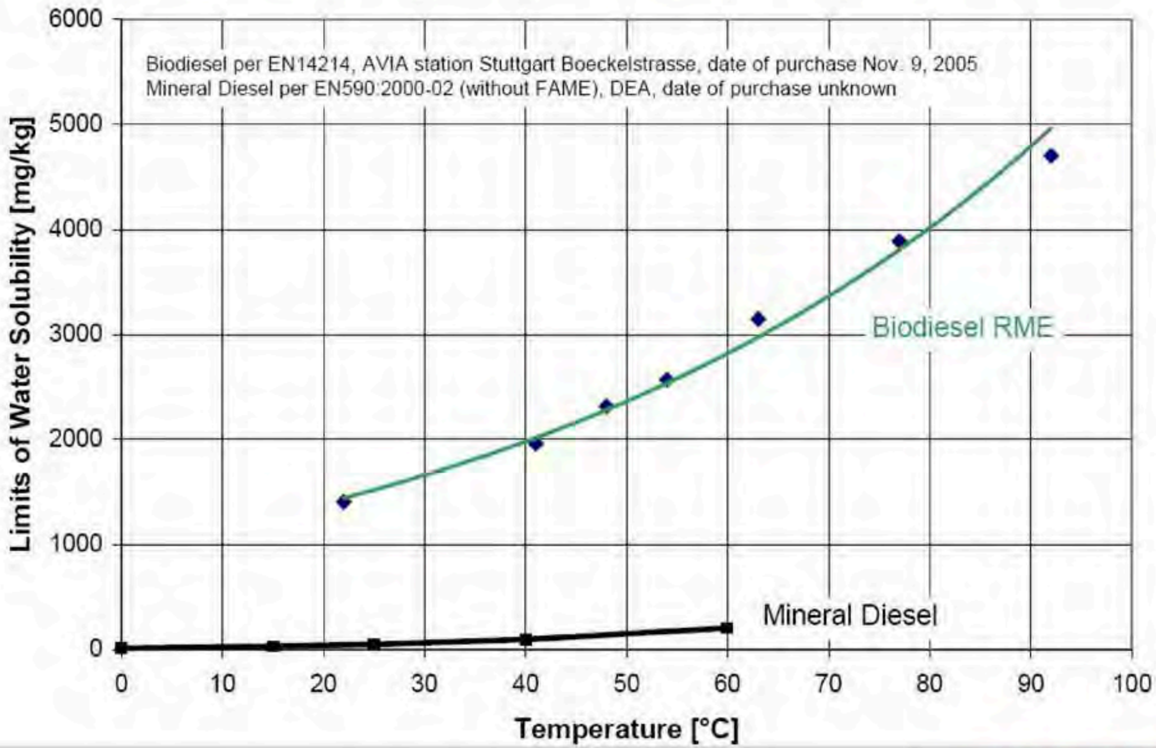
Water Separation - Diesel Fuel System

Audi

Water absorption ability of fuel

Filter Presentation AUDI, NSU, 01/22/2007

Dissolving Power of Water in Mineral Diesel & RME



BOSCH

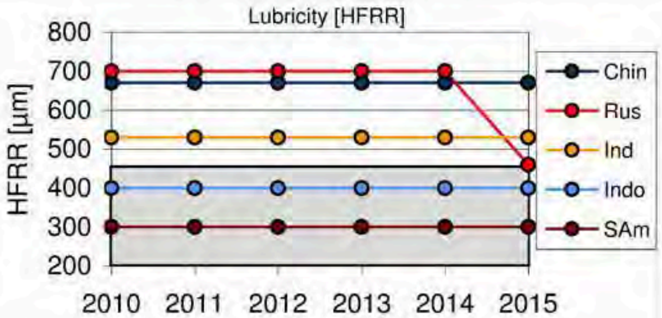
Non-responsive content removed

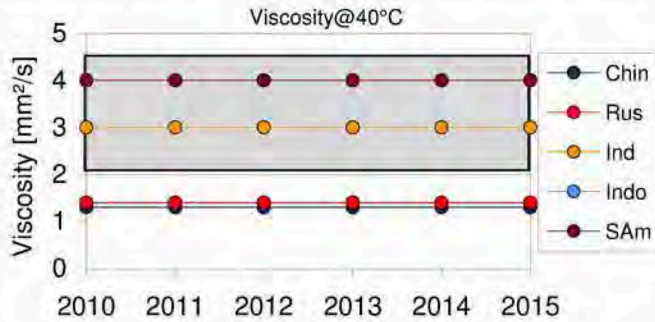
Use of Diesel Engines in emerging markets (BRIC)

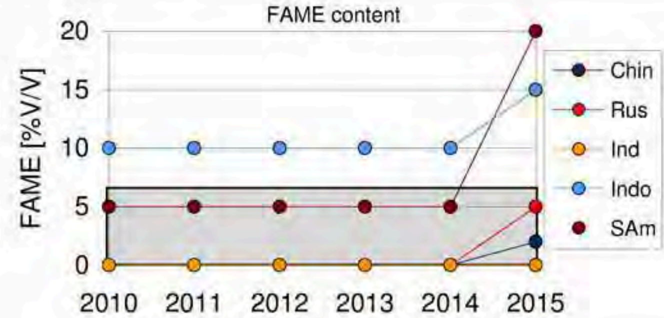
Agenda

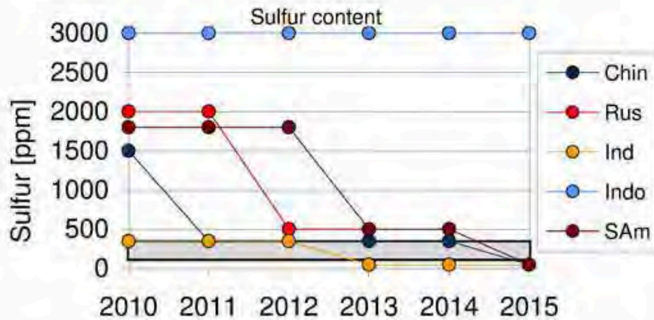
- Framework condition in BRIC countries
  - Fuel standards and mandates
  - Non-standardized fuel characteristics
  - other conditions
- Critical components
  - Approaches to harden engines to deal with conditions
  - Near-series solutions
  - Far-series solutions
- Implementation of measures in current series
  - Selected components
  - Test method
  - Critical items
- Future engine concepts
  - Basic observations
  - Necessary steps

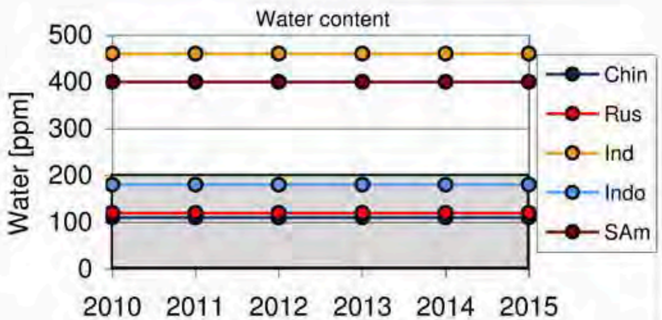
Conditions:
Development of fuel standards + mandates







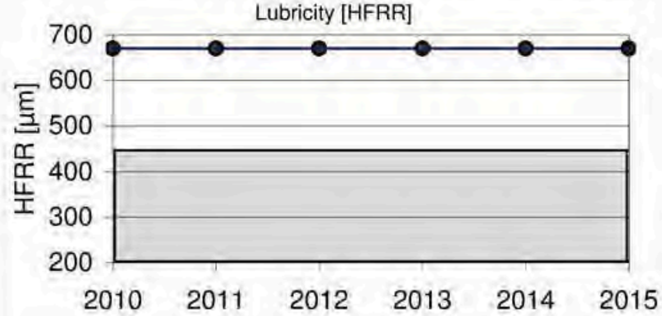


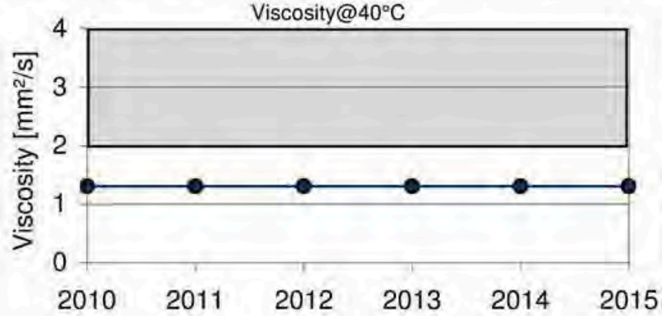


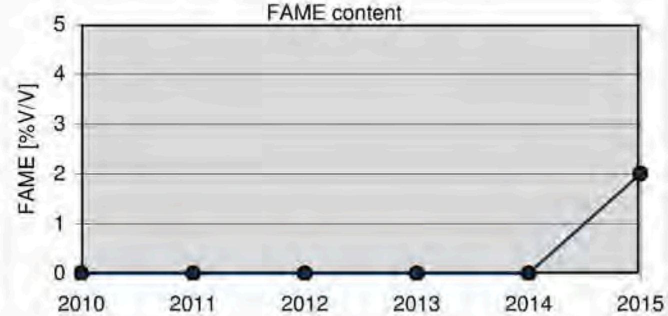
- **Sulfur content will drop in coming years to 50 ppm or 500 ppm [redacted] (exception: [redacted] (applies to main grade). If the correct additives are not added, this can have a negative impact on lubricity.**
- **Lubricity will continue to be at a critical level. The blending of biodiesel will alleviate the situation.**
- **Due to the blending of kerosene and gasoline in winter, viscosities in [redacted] will remain troublesomely low.**
- **Increasing FAME blends must be expected in the coming years. The blend quantity is highly dependent on availability, production costs, and state subsidies in the individual markets.**
- **In some countries [redacted] increased water content and free water are found repeatedly. The blending of FAME could also result in higher water content.**

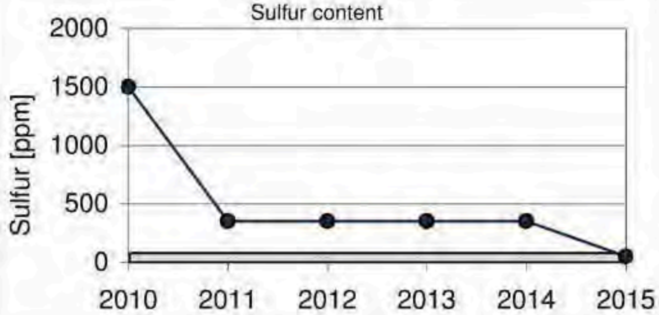
* Highlighted gray: EN590

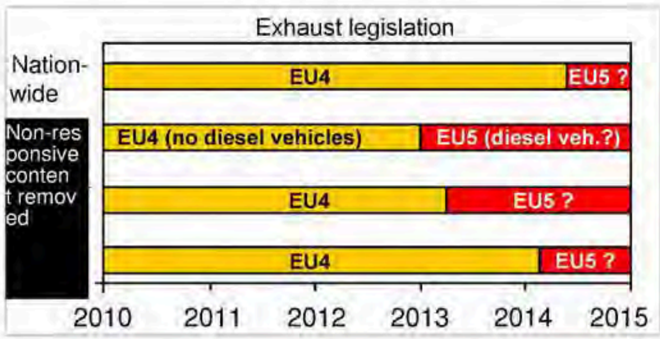
Conditions:
Fuel standardization and exhaust laws in Non-responsive content removed











- In major cities Non-responsive content removed, fuels with sulfur contents of max. 50 ppm are available. A nationwide reduction of sulfur content to max. 350 ppm will take place on July 1, 2011.
- Lubricity will continue to be at a critical level. The potential for blending biodiesel in four to five years could alleviate the situation
- Due to the blending of kerosene and gasoline in winter, viscosities will remain troublesomely low.
- FAME blends must be expected in the coming years. The blend quantity is highly dependent on availability, production costs, and state subsidies. B5 is already required in Hainan

* Highlighted gray: EN590

Conditions: Non-standard fuel properties

Measurement methods established

• NACE (corrosiveness)	In fuel atlas in future
• Surface tension	Initial data available
• Dissolved water	Initial data available
• Metal content	Contained in fuel atlas
• Chlorine content	In fuel atlas in future

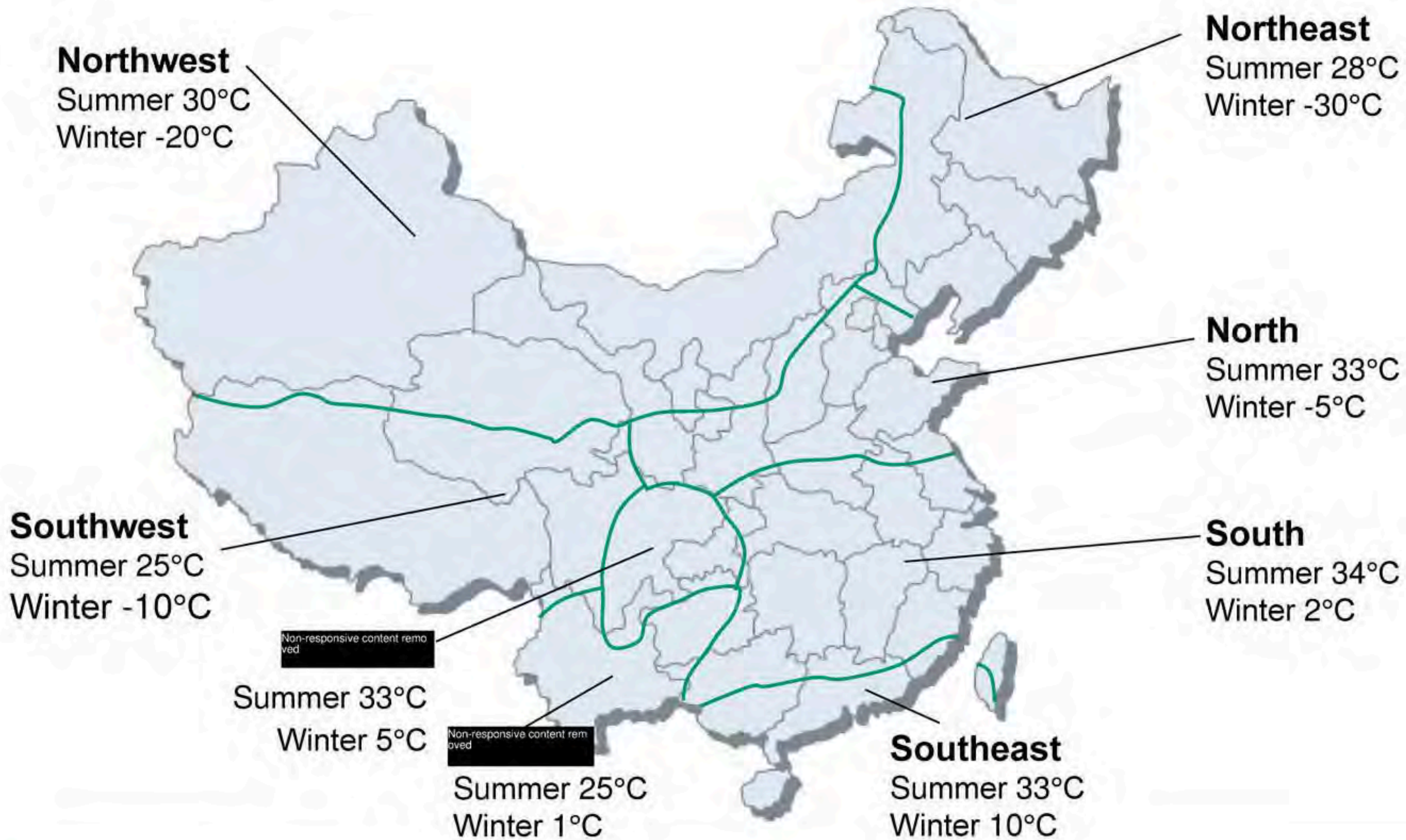
No measurement methods

• Additive content	Methods under development
• Seizure behavior	Methods under assessment
• Waste	"Ad hoc – analytics"

Other conditions:
Climate, altitude, road quality (excerpt from list of countries)

	Poor roads	Flooding	Dust	Additional heating	Hot climate	Super hot climate	Cold climate	Megacity	Drivable altitude
Non-responsive content removed [redacted]	X	X	X	X	X			X	Pico de Neblina – 2994 m
[redacted]	X		X	X			X	X	Roki Pass – 2995 m
[redacted]	X	X			X			X	Kardung La – 5602 m
[redacted]	X	X	X			X	X	X	Gyantso La (Tibet) – 5200 m
[redacted]					X				Puncak Pass – 1500 m

Other conditions Climate conditions in Non-responsive content removed

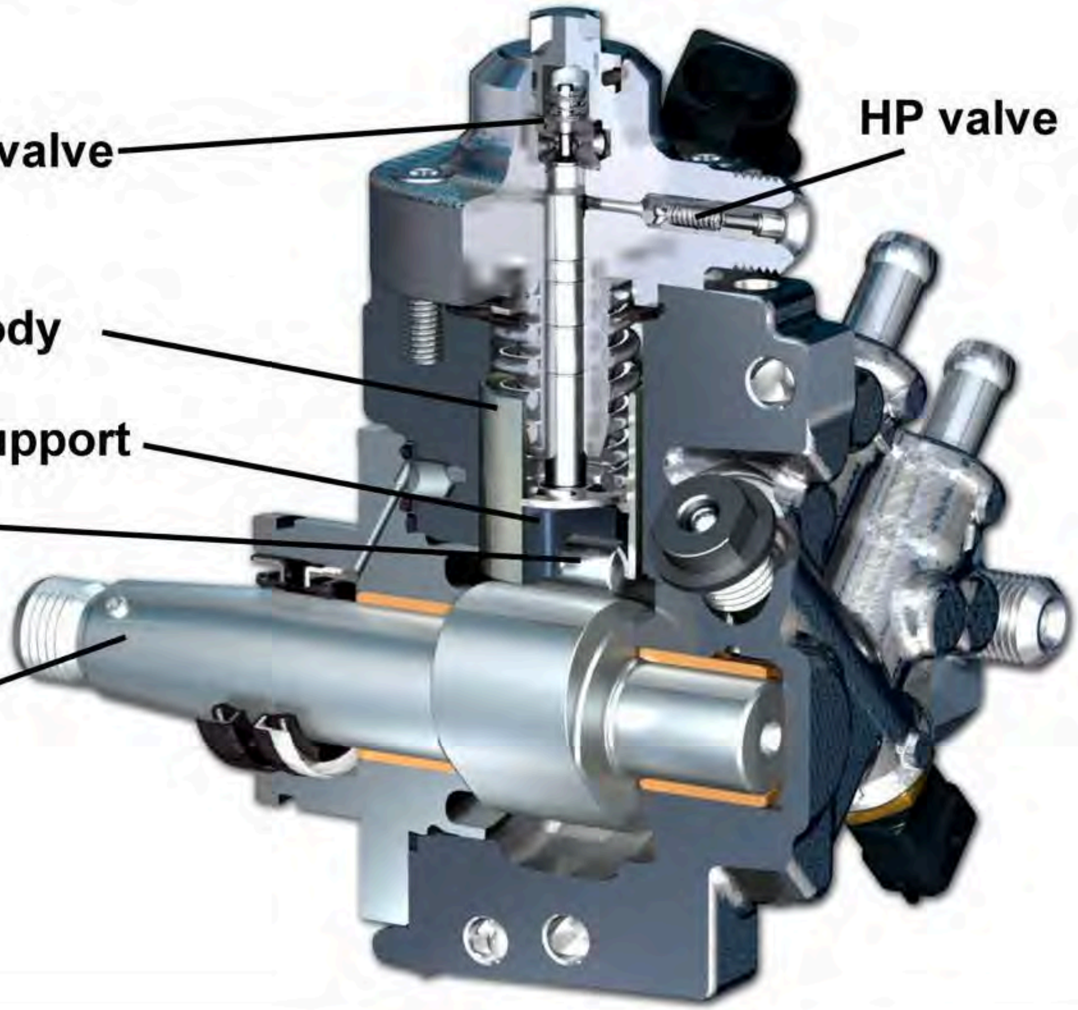


Critical components: Approaches for hardening

part / component	Problem	Near-series measure	Measure in development
HP pump	Wear (HFRR, evaporation curve)	Anti-wear packages RP 0, RP 1	6 bar low-pressure system, filtered tank venting
	Corrosion (NACE, water)	Water separation	Additive - dosing
Injector	Deposits (metals, additives)	Optimization of tolerances (series)	Additive - dosing
	Quantity variances (thickness, visco)	-	Quantity correction (sensor)
Exhaust treatment	White smoke, DPF blocking (sulfur)	S-resistant coating Country-specific regeneration	Fuel-specific regeneration (sensor)
Engine oil	Hyperacidity, aging (sulfur)	Use of 505 01 shortened oil change intervals	Oils TBN 11 Other oils
EGR	Corrosion, pitting (sulfur, chlorine)	-	Deactivate EGR (sensor) Ni – high-alloyed steel

Selected components: High-pressure pump

Bosch CP4.1



Selected components: High-pressure pump

Anti wear package 0

Task/impact

- Reduce wear, avoid piston seizures

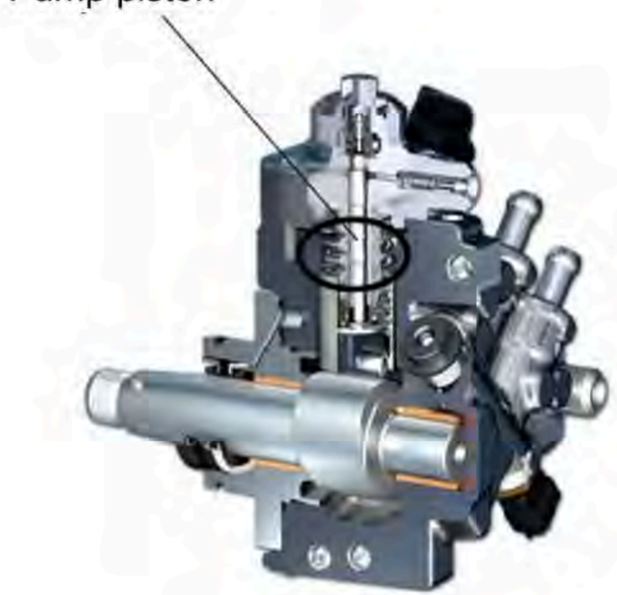
Measures

- C layer on pump piston

Result

- Improved resistance to wear, reduced wear

Affected drive unit/ components



Selected components: High-pressure pump

Anti wear package RP1 / RP1+

Task/impact

- Increase lubricating film between roller support and roller for low-viscosity fuels, to reduce mixed friction share and thus temperature

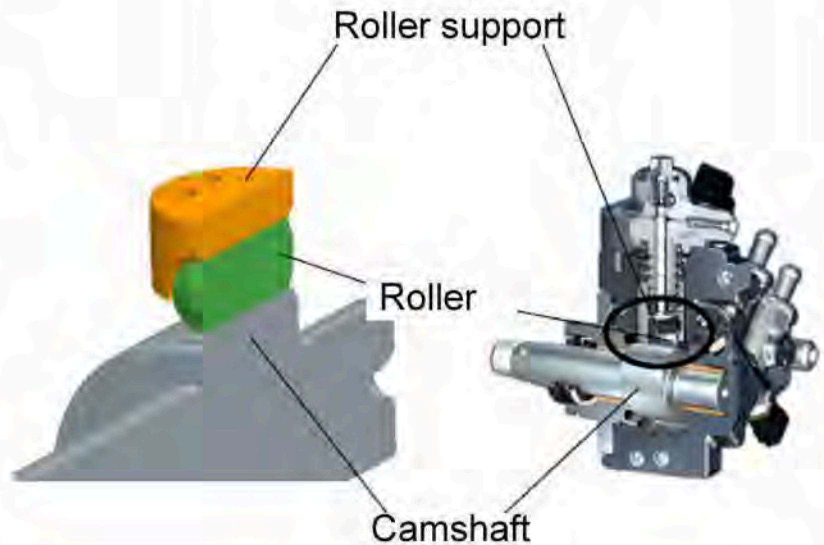
Measures

- C2 coating to reduce friction on roller support surface and avoid metal spraying (for RP1+ 3.1)
- Lower gap/tolerance between roller and RS through reduced roller support bore
- Reduced roughness of roller surface
- Optimized roller end

Result

- Increase of lubricating film thickness (approx. factor of 2), proven by test results

Affected drive unit/ components

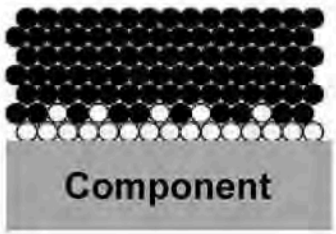


Selected components: High-pressure pump

Comparison of layer systems for roller support

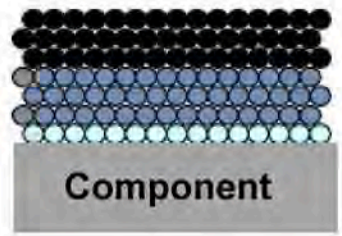
Schematic diagram: Layer structure for friction-reducing anti-wear layer

C2.1 layer (RP1)



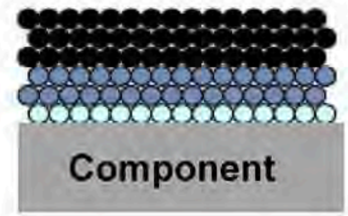
K1 layer
Transition K1 adhesive layer
Adhesive layer

C3 layer standard



K1 layer
K2 layer (thick)
Adhesive layer 2 (smoother, thinner)

C3.1 layer RP1+



K1 layer opti.
K2 layer opti. (thinner)
Adhesive layer 2 (smoother)

- ● **Carbon layer type 1 (K1)**
- ● **Carbon layer type 2 (K2)**
- ○ **Adhesive layer type 1**
- ○ **Adhesive layer type 2**

Selected components: High-pressure pump

Pump housing / roller tappet

Objective

- Reduced tilting of roller tappet
- Increased robustness against wear in tappet guide
- Reduction of cavitation erosion

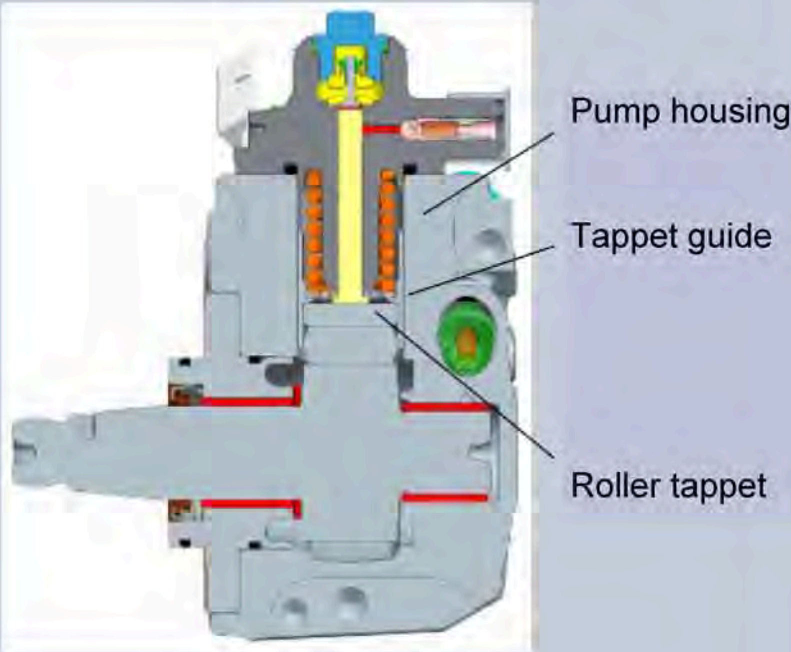
Measure

- Reduction of play in roller-tappet guide in pump housing

Impact

- Reduced wear depths
- Reduced cavitation erosion zones in tappet guide

Affected components



Selected components: High-pressure pump

Overflow valve

Task

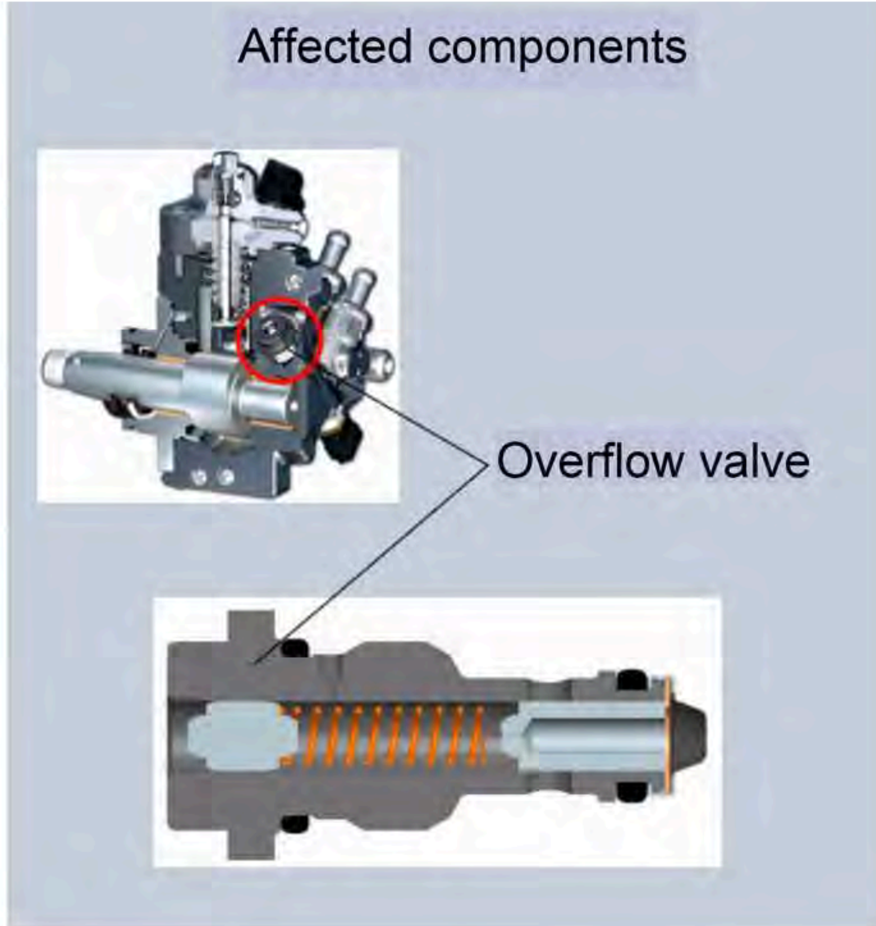
➔ Avoid nucleation in cam area.

Measure

➔ Increase opening pressure of overflow valve.

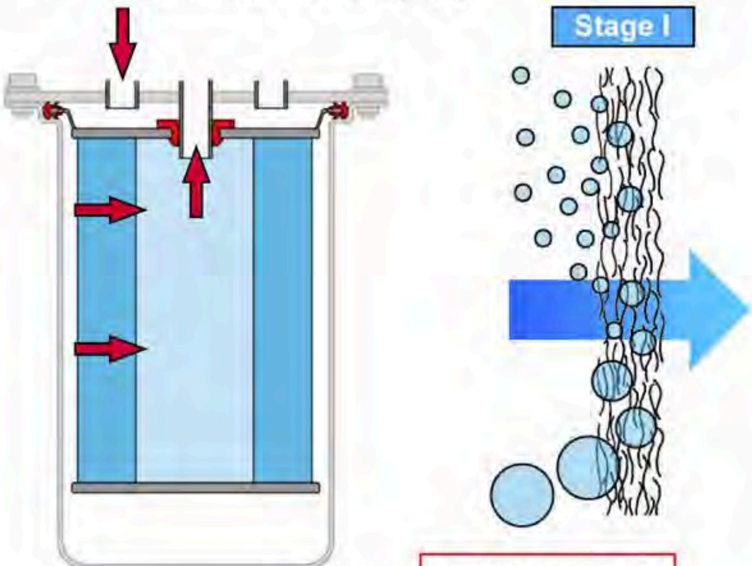
Effect

➔ Increased fuel pressure level in cam area.



Selected components: One/two-stage water separator

Old platforms / series:
- One-stagewater separator
- No sensor or display

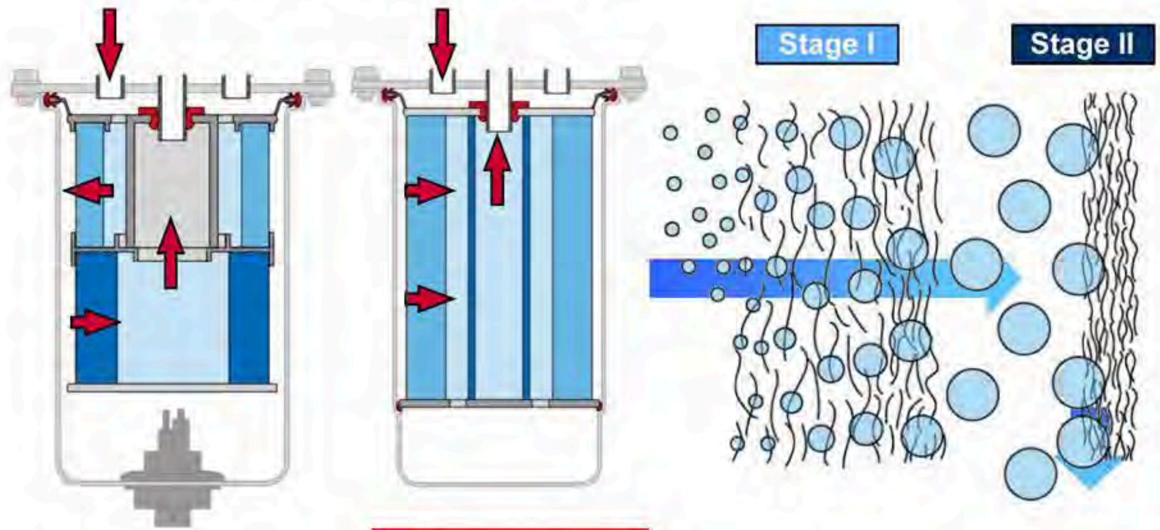


ΔEK approx. €2

Function:
Water droplets are blocked by hydrophobic surface and sink to the filter floor.

For fuels:
With higher surface tension, large water droplets

From MQB
- Two-stagewater separator
- With sensor and display



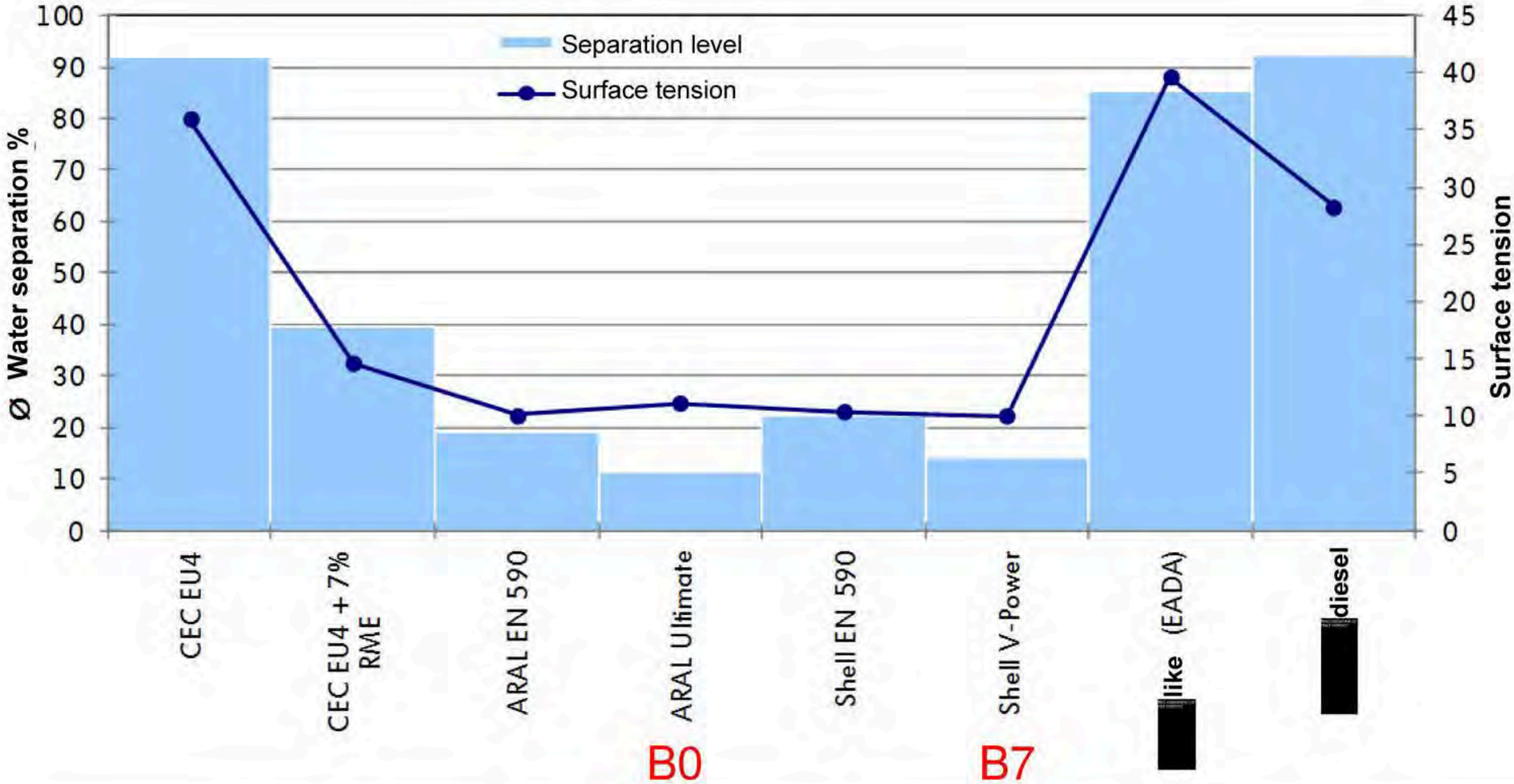
ΔEK approx. €11

Function:
Water droplets are enlarged at the first hydrophilic stage; enlarged droplets are blocked at the second hydrophobic stage

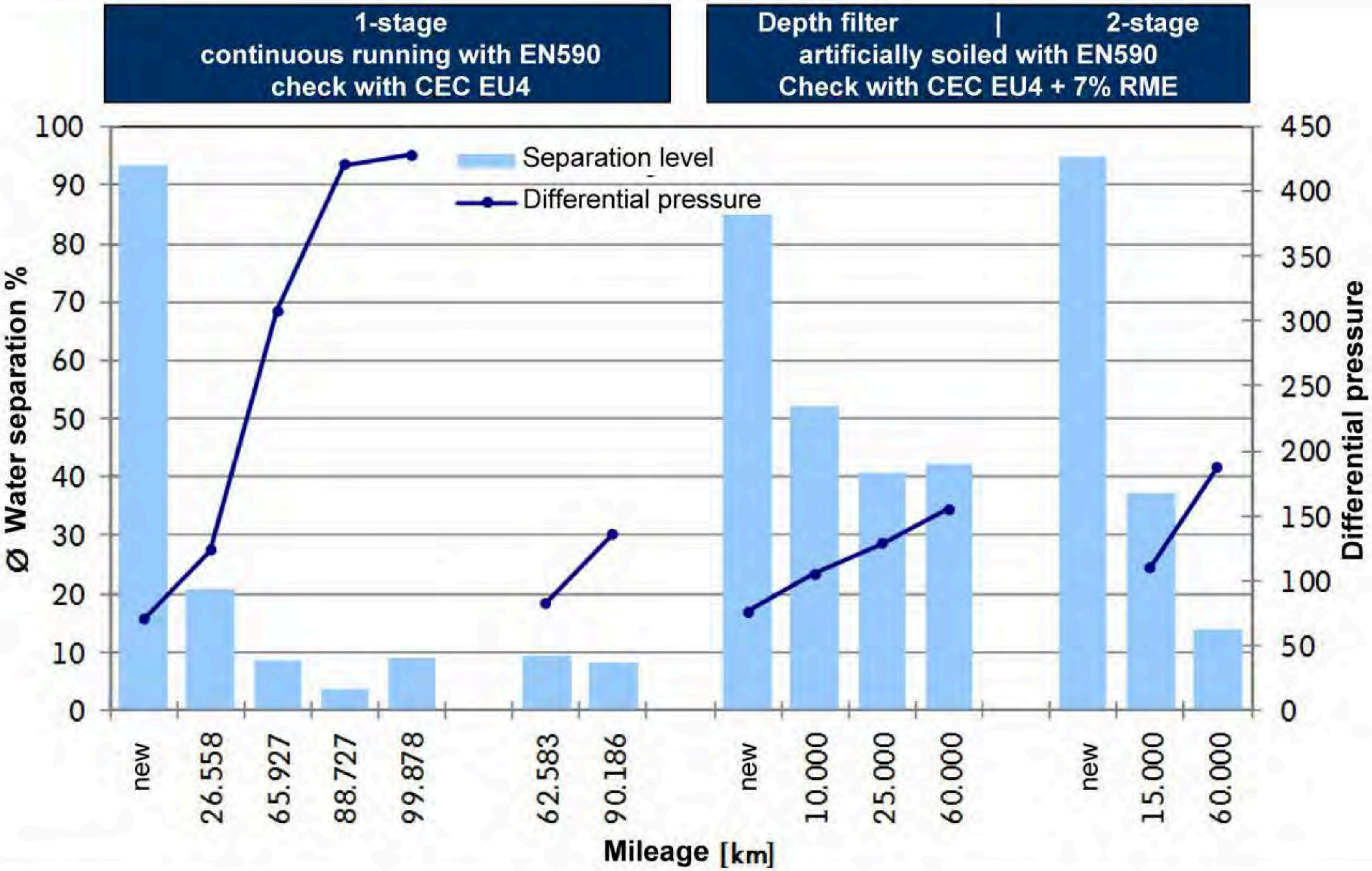
For fuels:
With lower surface tension, small water droplets

Investigation results - Fuels

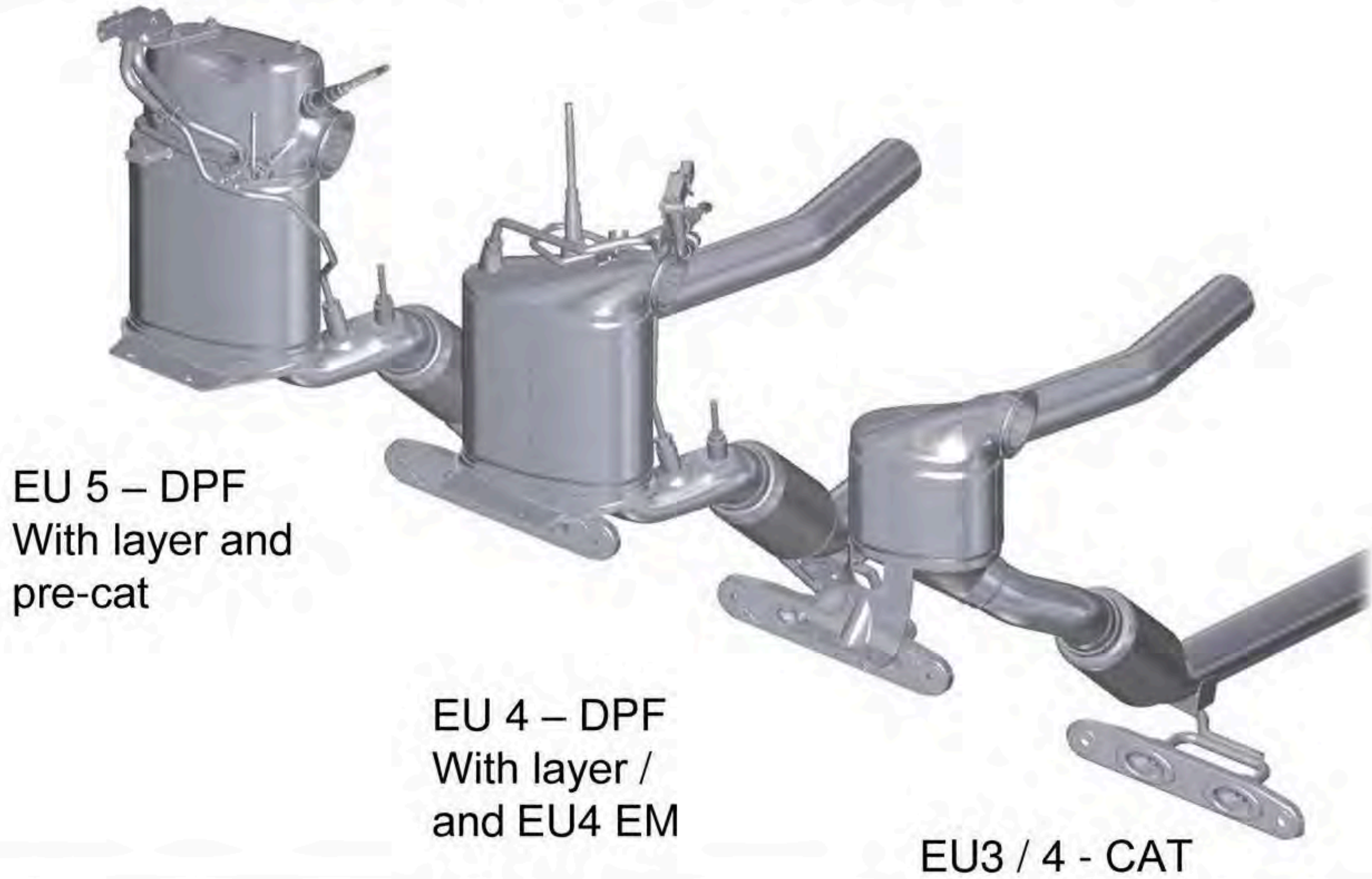
with one-stage water separators



Investigation results - Run filter elements



Selected components: Exhaust equipment for emerging markets



Selected components: Development of robust DPF (EADA)

- Development for countries with sulfur content up to 500 ppm
  - Up to 500 ppm sulfur currently realistic
  - Special case: Brazil PL 6 up to 2000 mg/kg
- Development includes:
  - More sulfur-resistant coating (platinum only)
  - Modified desulfurization strategy
    - Desulfurization is carried out before DPF regeneration
    - Coding possible to adapt regeneration strategy to sulfur content in fuel (in future: controlled by fuel sensor)
- Impact of higher sulfur content on drivetrain is being investigating (e.g. gray corrosion)
- Use of engine oil with higher TBN, but also with higher sulfate axes
  - Modified oil change interval due to higher oil dilution
  - Possibly reduced DPF change intervals dependent on engine oil used

Selected components:
Exhaust equipment for EU4 Emerging Markets

1) Other conditions

Fuel and emission requirements (example: Non-responsive content removed [redacted]
climate and geographical conditions

2) Target conflict

No self-contained DPF due to fuel quality, no

EU4 with DOC due to particle non-compliance

3) Technical solution

DOC with particle reduction system (PRS)

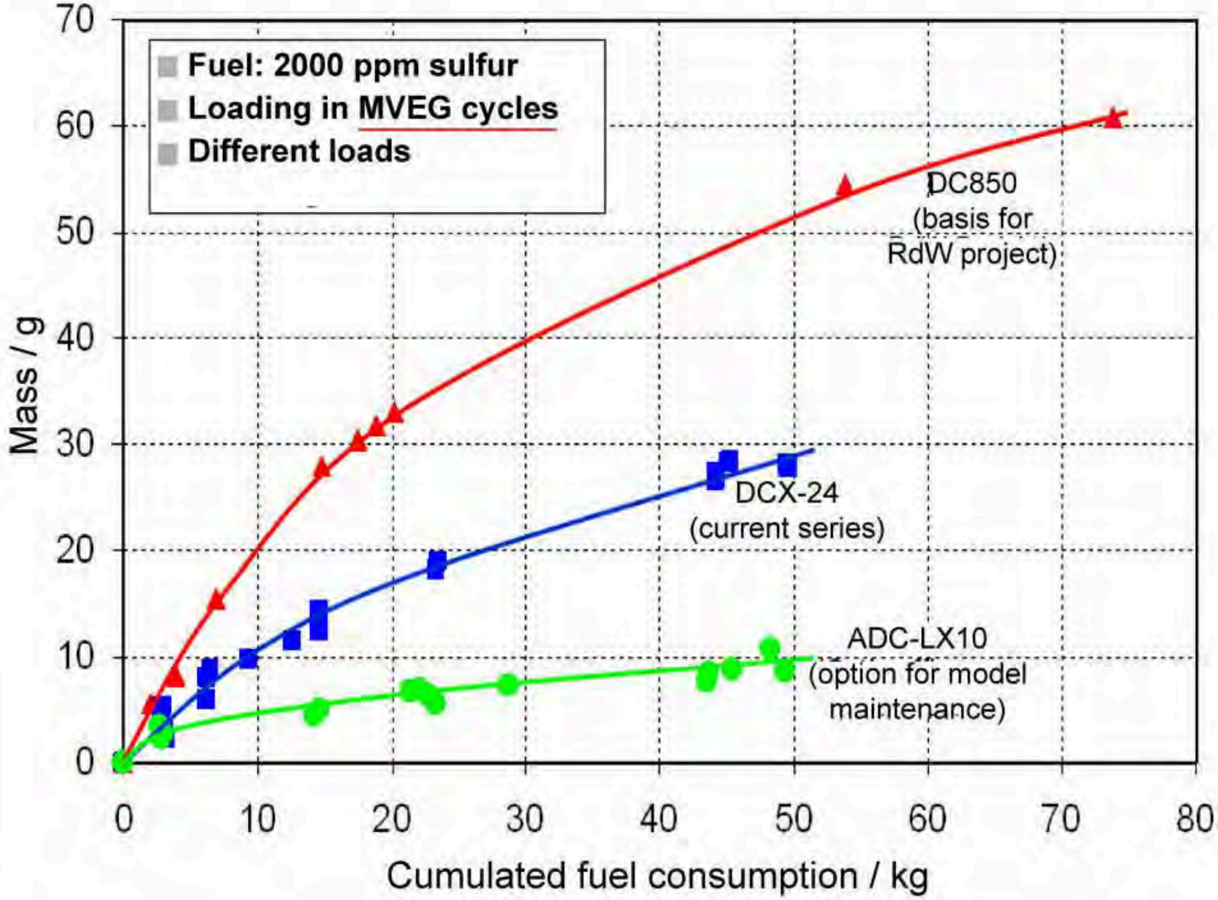
-> 30% particle reduction

4) Costs

Δ to self-contained DPF ~ €90

Catalytic converter development for emerging markets

Development of S-resistant coating for EU4 (DOC+PRS) systems

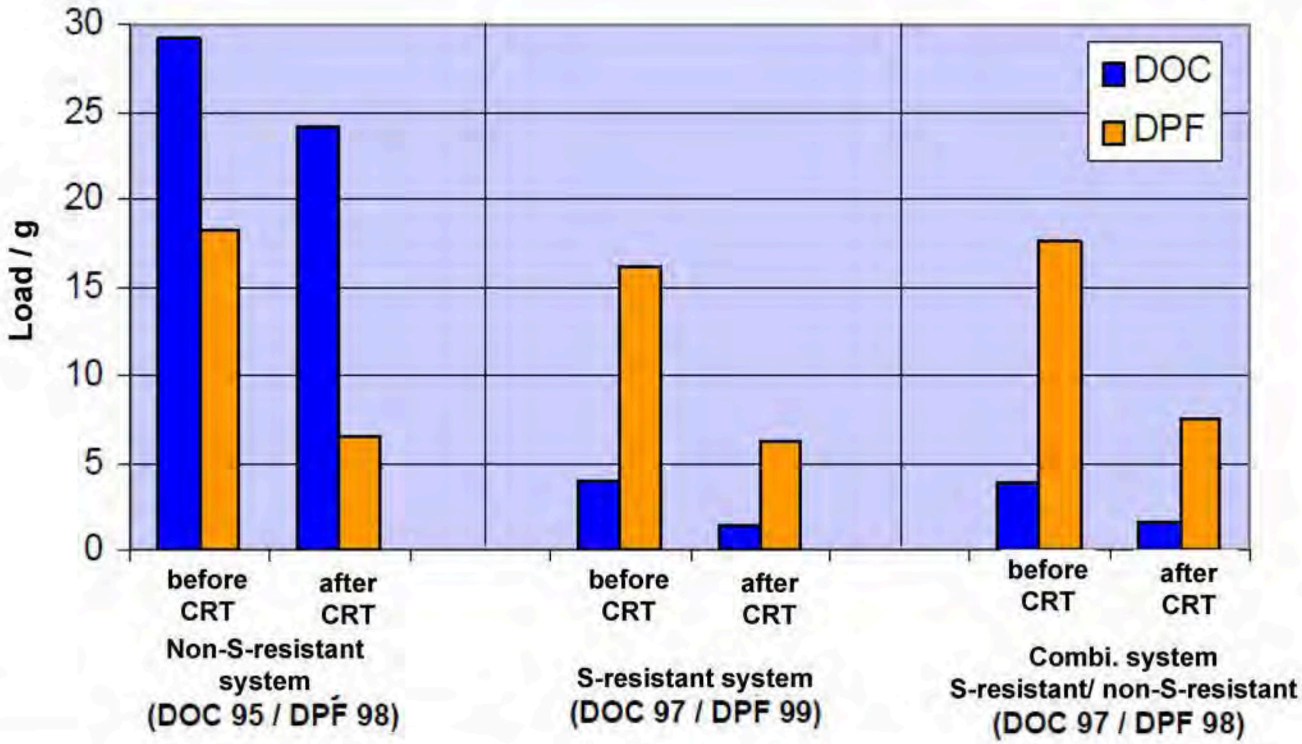


Catalytic converter development RDW markets

Development of S-resistant coating for EU5 (DOC+DPF) systems

Comparison of different sulfurized systems
Loading with ***sulfur fuel***

DOC 95: 105 g/ft³, Pt:Pd (3:2), Non-S-resistant
DPF 98: 10 g/ft³, Pt:Pd (1.1:1), Non-S-resistant
DOC 97: 105 g/ft³, Pt only, S-resistant
DPF 99: 10 g/ft³, Pt:Pd (3:2), S-resistant
DOC 55: 105 g/ft³, Pt:Pd (2:1), S-resistant

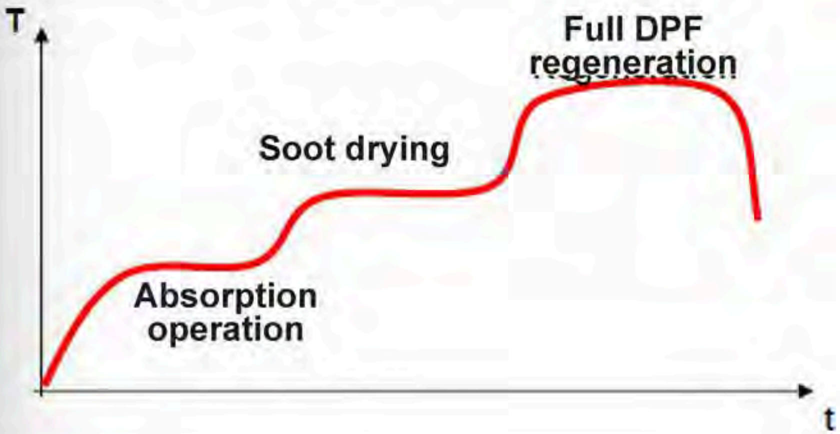


Regeneration strategy for PRS

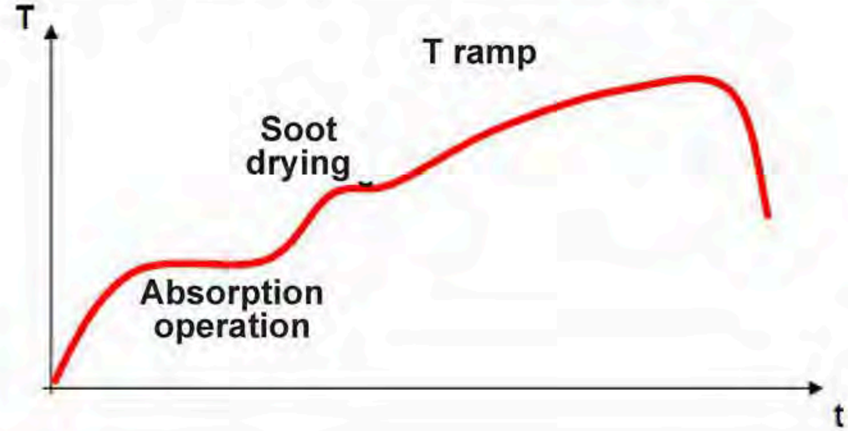
Influencing parameters for white smoke formation

- Temperature
- Sulfur quantity
- Exhaust mass stream

Original target concept:
2-stage regeneration strategy



Alternative concept:
Ramped regeneration strategy



Regeneration strategy for PRS

Premises:

- **Maximum utilization of EU5 regeneration parameters**
- **Regeneration trigger after kilometer threshold (1000km) for 10 minutes**

Implementation:

- The outer exhaust temperature circuit is deactivated. To enable active regeneration of the PRS, the Pol1 is operated under control. This reduces the basic volumes at Pol1.
- The trigger of regeneration through a kilometer threshold was implemented as follows: The kilometer threshold initializes the soot loading to 24.1 g. This is followed by the regeneration command via load, in line with the EU5 parameters.
- Regeneration takes place in 2 stages, soot drying and DPF regeneration; the latter is ramped between 2 sets of variables depending on the current soot load.
- To achieve the slowest possible temperature increase starting from the soot drying, the SotHigh parameters were shifted to lower temperatures (T3 target temperature reduced and Pol1 characteristic set to 1 mg/lift).

Regeneration strategy for PRS

- The regeneration command dependent on the load status from soot mass simulated and determined from differential pressure sensor has been deactivated.
- The missing temperature sensors have been switched to the corresponding model values. The corresponding models (ASMod_TempTrbn, ASMod_TempPipe, ASMod_TempCatMod) must be adjusted.
- Service regeneration in stand status is not parameterized, because the verification effort for this is very high (temperature emissions of standing components) and in no relation to benefit.
- If a T3 sensor is defective, a permanent regeneration command may arise, since it may no longer be possible to achieve a regeneration stage in which the regeneration timer counts down. A corresponding maximum time limit will **be implemented**.

Vehicle use - robust AGA

Vehicle		Performance	Gearbox	SOP	AGW	PRS	Oxi cat.	Non-responsive content removed			MKB	Remark	Control through
SK351/2	Octavia	2,0l 81kW	MQ250-5F	Wk 13/10			X	yes	no	no	CLCA	PQ35	11V551C
SK351/2	Octavia	2,0l 103kW	DQ250-6F	Wk 13/10		X		yes	no	no	CLCB	PQ35	11V551C
SK316	Yeti	2,0l 81kW	MQ250-5F	Wk 45/10		X		yes	no	no	CLCA	PQ35	Committee passage
SK316	Yeti	2,0l 103kW	MQ350-6A	Wk 22/10		X		yes	no	no	CLCB	PQ35	11V551C
AU350/3/5	Audi A3	2,0l 103kW	DQ250-6F	Wk 22/10	X	X		no	no	yes	CLJA	PQ35	11V551C
VW360/9	Golf, Golf Plus	2,0l 81kW	MQ250-5F	Wk 22/10			X	no	no	no	CLCA	PQ35	11V551C
VW362	Golf Variant	2,0l 81kW	MQ250-5F	Wk 27/10			X	no	no	yes	CLCA	PQ35	11V551C
VW351	Jetta	2,0l 81kW	MQ250-5F	Wk 13/10			X	yes	no	no	CLCA	PQ35	11V551C
VW368	Touran	2,0l 81kW	MQ250-6F	Wk 45/10		X		no	no	no	CLCA	PQ35 comp.	11V551C1
VW368	Touran	2,0l 81kW	DQ250-6F	Wk 45/10		X		no	no	no	CLCA	PQ35 comp.	11V551C1
VN337/0/1 GP	Caddy	2,0l 81kW	MQ250-5F	Wk 45/10			X	no	no	yes	CLCA	PQ35 comp.	11V555A
SK461	Superb	2,0l 103kW	DQ250-6F	Wk 13/10	X	X		yes	no	no	CLJA	PQ35 comp.	11V551C
VW361	Jetta NF	2,0l 81kW	MQ250-5F	Wk 41/10			X	no	no	yes	CLCA	PQ 35 LC	Vehicle Dev.
VW361	Jetta NF	2,0l 103kW	MQ350-6F	Wk 41/10			X	no	no	yes	CLCB	PQ 35 LC	Vehicle Dev.
VW361	Jetta NF	2,0l 103kW	DQ250-6F	Wk 41/10		X		no	no	yes	CLCB	PQ 35 LC	Vehicle Dev.
VW316	Tiguan	2,0l 103kW	AQ450-6A	Wk 45/10	X	X		no	no	yes	CLJA	PQ Mix	11V551C2
VW471/2	*Passat NF*	*2,0l 103kW*	*MQ350-6F*	*Wk 45/10*	*X*	*X*		*yes*	*no*	*no*		*PQ46*	
VW471/2	Passat NF	2,0l 125kW	MQ350-6F	Wk 45/10	X	X		yes	no	yes	CLLA	PQ46	11V552E
VW471/2	Passat NF	2,0l 125kW	DQ250-6F	Wk 45/10	X	X		yes	no	yes	CLLA	PQ46	11V552E
AU48X	Audi B8	2,0l 105kW	VL381-F	Wk 22/10	X	X		yes	yes	yes	CMEA	PL	11P553N

Oil change interval CAR and CV

Dependent on sulfur content in diesel fuel (coordinated with EADA, EADK, EADL)

Diesel fuel [ppm S]	EN 590	< 500	500 - 2000	2000 - 4000	> 4000
Engine oil	VW 50700	VW 50700 VW 50601 VW 50501	VW 50601 VW 50501	VW 50601 or Engine oil w/ min. TBN 10	VW 50601 or Engine oil w/ min. TBN 10
Change interval [km]	WIV				
CAR		15,000	7,500	7,500	5,000
CV		20,000	10,000	10,000	5,000

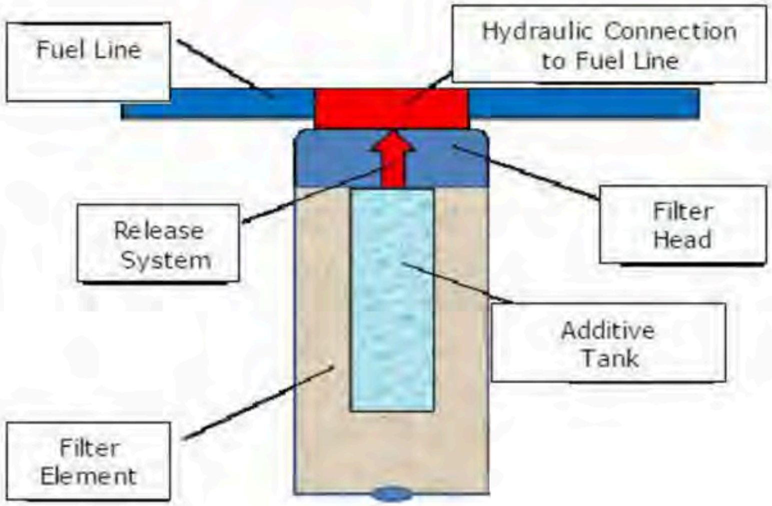
Current status of fuel sensor

- Following SP3H and Conti concepts

SP3H:

- Investigations in lab are completed
  - Fuel recognition for various fuels and fuel blends could be proven
    - Detection of FAME, mishandling, evaporation fractions, individual components
    - Proof of sulfur not currently possible
- Vehicle set up for demonstrator test
- Sensor for demonstrator is being delivered

Selected components: Additive dosing system



- The additive package is integrated in the fuel filter
- The quantity of the additive is adjusted to the service life of the fuel filter (system is completely swapped out; no refilling)
- Delivery of additive is possible either continuously or controlled
- Dosing possible both in the inlet and return

Time track for additive dosing system

	Dosing device – Rhodia / Sogefi	Additives – Lubrizol / Rhodia	Status
2011			
Jan	3 D concept (CAD) – completed for A sample (venture to be fine tuned for additive)	Define different requirements / demands (FBC, CFPP, 2-EHN). Agree to base on Easyflex (detergent and lubricity agent)	✓
Feb		Test and if necessary fine tune additive in critical fuel. Deliver current Easyflex additive to straight away and estimate target dosing concentration	✓
March	Meet with VW to define car and hardware details		✓
Apr		Additive Samples delivered	
May		VW: Performance and no harm testing	
June	A-Sample for demonstration with fuel line		
July	Integrate into engine fuel system	Select appropriate additive variants	
Aug			
Sept			
Oct			
Nov	Demonstration for car		
Dec	Demonstration car running		
2012	run under bad local conditions (hot test, cold test, high wear test, poor cetane test etc)		

Implementation of measures in current series Test method

Release of FIE Components

Step 4 necessary to confirm relevance of steps 1… 3 with respect to not foreseeable market specific risks.

Step	Test Type	Fuel	alte Ez	neue Ez
④ CRS RoW user	active field surveillance (e.g. 1k veh. 1 year)	BRIC		X
③ CRS Vehicle @ OEM	Test Fleet (10 veh.) per Region	BRIC	(X)	X
② CRS Engine Tests @ OEM	Engine TB RP1-RP2-RP3	RoW & GDK	(X)	X
① CRI-CP-CRR Component Tests @ ETC	Component TB RP1-RP2-RP3	RoW & GDK	(X)	X

SOP

Step

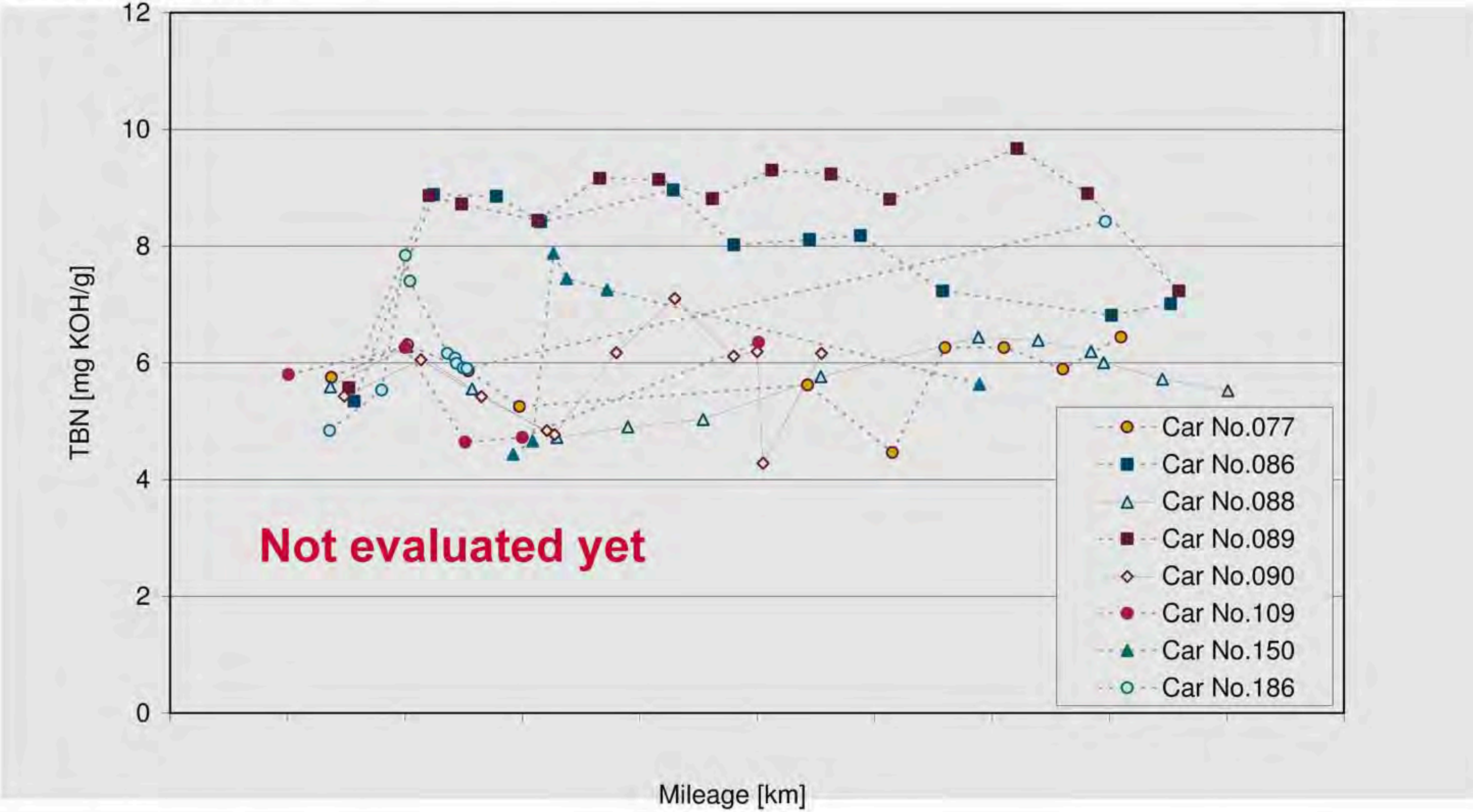
Schedule

Step 2: Properties of test fuels for applications outside CEN system

	Unit	US – worst case TL XXX - B	GRV (Bosch) TL XXX - F	SME B 20 TL XXX - E	Nato F 34 TL XXX - D	EU 3 – DK TL XXX - A	EU 2 – DK TL XXX - B	CEC RF 91 – A 81 TL XXX - I
CZ		41 to 45	45 to 50	42 to 47	-	45 to 48	44 to 47	45 to 47
CFPP		-	-	-	< -47	-	< -24	0 to -9
CP		Report	-	-	-	-	-	-
Density	kg/m³	855 to 865	Report	855 to 865	775 to 840	Report	800 to 820	820 to 855
Evaporation point		report	120 to 140	report	Report	120 to 140	-	-
50% evap		report	-	report	Report	-	-	< 300
95% evap		report	Report	report	≤300	360 to 370	report	< 350
FAME content		0	0	20	0	0	0	0
Flash point		-	Report	-	≥38	Report	report	≥55
HFRR		520 to 620	550 to 650	-	< 650	550 to 650	550 to 650	report
NACE		E	E	-	-	E	E	-
Sulfur content	mg/kg	10 to 20	< 10	10 to 20	≤2000	400 to 600	1900 to 2100	9500 …10500
Viscosity (40° C)		-	-	-	-	-	1.5 to 2	1.8 to 6
Viscosity (-24°C)		-	-	-	< 8	-	-	-
Surface tension		-	-	-	-	-	-	-
DSEP		-	-	-	-	-	-	-

Step 3:
Engine oil qualities in Non-responsive content removed 2010/2011

- **Results: TBN**



Implementation of measures in current series: Critical items

- Individual measures
  to be implemented at various times

- Large number of variants

- High verification requirements (Non-responsive content removed ….),
  Non-standardized road tests

- Low prioritization for capacity reasons:
  e.g. engine oil development

- “Hitching” on to European concepts:
  Optimum solution with regard to costs, development effort
  will be missed

Future engine concepts: Basic observations

- EU IV engine for "poor-fuel markets" → Engines for the different exhaust categories in emerging markets
- Use of individual measures → Basic concepts "developed from the foundation"
- Reaction in field should unexpected problems occur → Improved, systematic field observation

Future engine concepts: necessary steps

- Continue the regular BRIC meetings
- Select a suitable project
- Create a TPB "MDB – EU 4/5/6 for BRIC"
- Provide the necessary start-up capacity
- Committee passage

BACKUP

Real diesel qualities in [redacted] 2010/2011

- **Fuel standard is valid nationwide, but largely not met**
  - **Increased HFRR > 460 µm (23%)**
  - **Significantly increased sulfur content > 350 ppm (63%)**
  - **CFPP of specified degree not standard-compliant (25%)**
  - **Significant shortfall in flash point (blending of gasoline) (30%)**
- **Blends of gasoline and/or kerosene found in 55% of samples**
  - **Low viscosities**
  - **Low flash points**
  - **Early evaporation begin and flat evaporation curve**
- **Poor warehouse situation and handling in some areas (Na, Mn, Zn, Fe, ...)**

Outlook for emerging markets

- Current problems:
  - Lubricity (HFRR)
  - Low viscosities
  - Low evaporation point
  - Water (dissolved & free)

} Impact on lubrication

- Future challenges:
  - Markets are growing very quickly
  - High energy requirements
  - new fuel components are expected
  - "Unconventional" crude oils

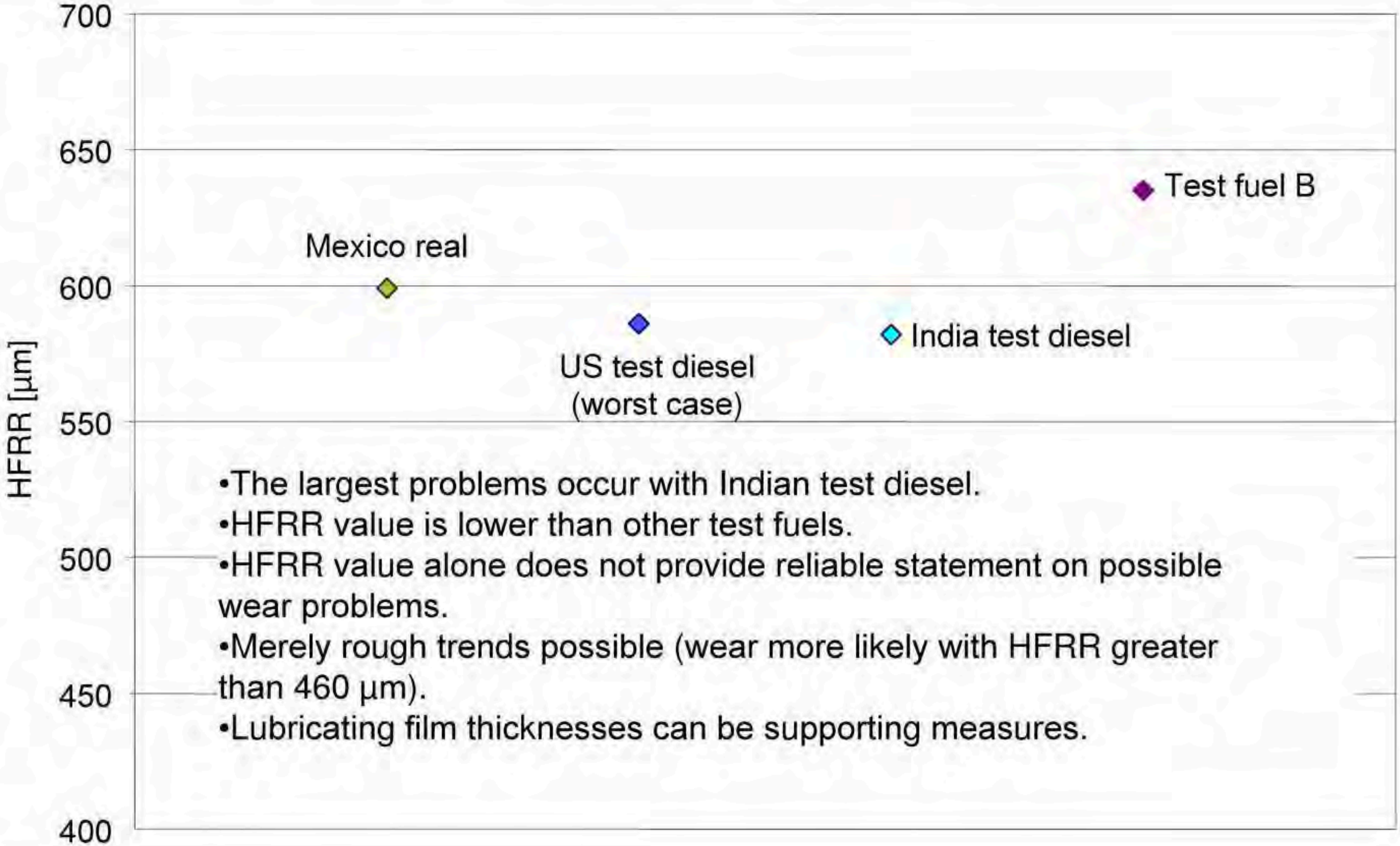
} Description through conventional fuel parameters?

Methods to determine lubricity

- High Frequency Reciprocating Rig (HFRR):
  - Current standard method
  - Large tolerance ranges (± 136 µm for ASTM D 6079; ± 120 µm for EN ISO 12156-1)
  - Correlation between HFRR value and damage symptoms in injection system not perfect
- Scuffing Load Ball on Cylinder Lubricity Evaluator (SLBOCLE):
  - ASTM Standard for middle distillates (ASTM D6078)
  - Not widely used in Europe
  - Large tolerance ranges (± 1500 g)
  - Correlation between lubricity and damage symptoms in injection system not perfect
- Four-Ball Apparatus (VKA):
  - Standard test method for oils
  - Not optimized for diesel fuels

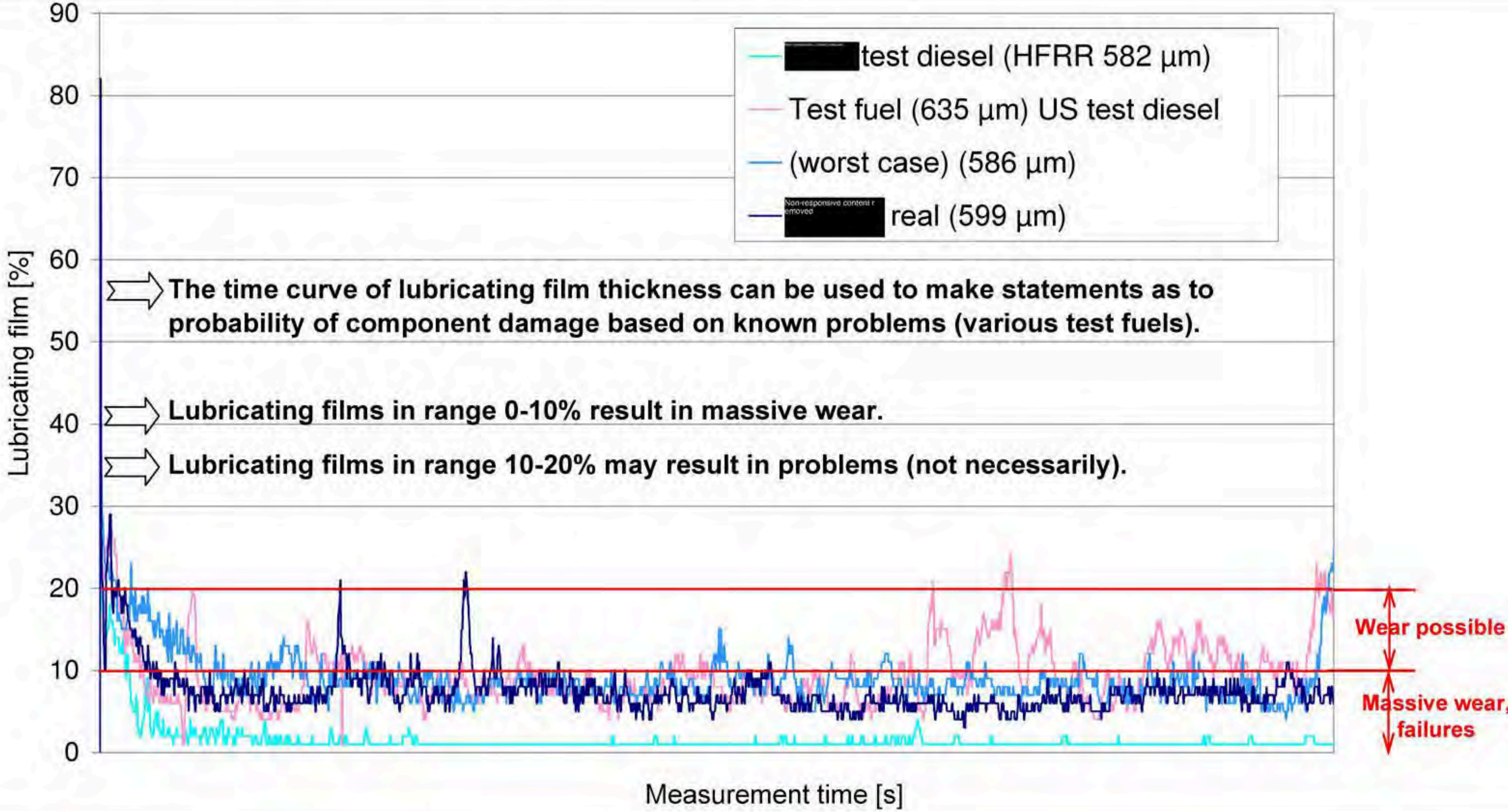
Source: SGS

HFRR values of various diesel fuels



- The largest problems occur with Indian test diesel.
- HFRR value is lower than other test fuels.
- HFRR value alone does not provide reliable statement on possible wear problems.
- Merely rough trends possible (wear more likely with HFRR greater than 460 µm).
- Lubricating film thicknesses can be supporting measures.

Lubricating film thicknesses



Current status of additive dosing system

- Definition of vehicles for test program:
  - 2.0 L CR Golf with start/stop (EWP durability test)
  - 2.0L CR Caddy (investigations at FH [redacted]
- Provision of critical fuels to Lubrizol
  - Corrosion
  - Lubricity
- A samples will be provided by SOGEFI by late June
  - Investigations on two vehicles
  - Investigations on engine test bench

Decision proposal on "Further development of tools"

1. Joint assessment of existing (not specified in standard) parameters 9/2011
2. Develop joint assessment system 10/2011
3. If necessary, modify test fuels 11/2011
4. **No restriction to releases and/or liability**

Niche fuels are expected worldwide

Bosch - position

- FAME blends
  - B 20
  - B 30

Released for fresh fuels

- Paraffinic fuels/components
  - GtL
  - (BtL)
  - HVO

Currently no release

=> Process after GRV completion
e.g. test
Assessment of overall system: Standard - Infrastructure - Vehicle
Split old stock/new concepts -> Analyze, develop solution
=> Solution for USA

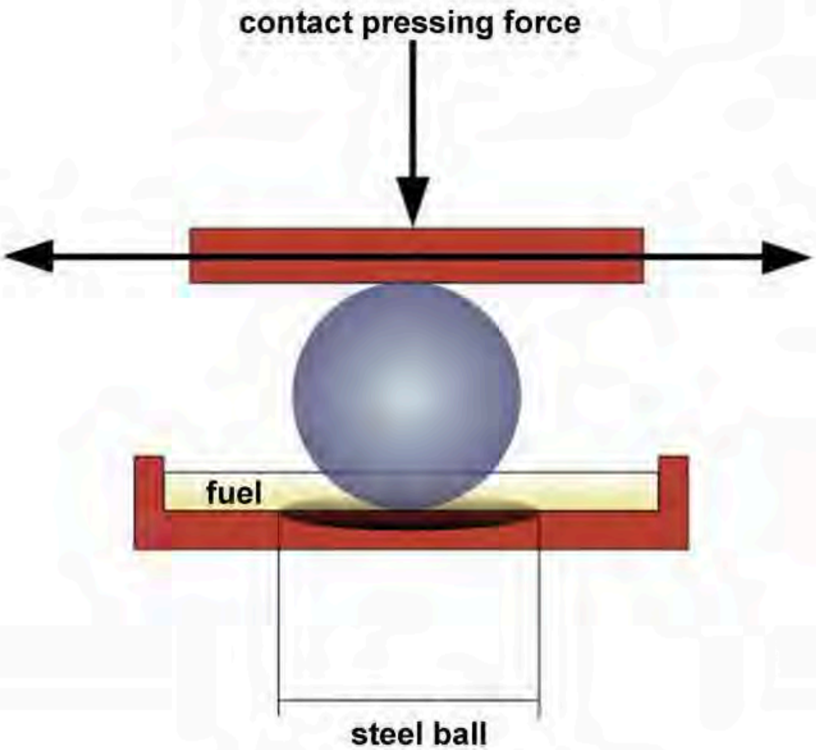
Properties of test fuels for applications within CEN system

	Unit	TL 788 A	TL 788 B	TL XXX – G	Arctic: TL XXX – H		
Cetane number	CZ	≥51	≥51	≥51	Arctic Diesel like typical at VW, compliant EN 590 Arctic Class		
CFPP	°C	0 to -20	0 to -20	-19 to -21			
CP	°C			-6 to -8			
Density	kg/m³	820 to 845	820 to 845	820 to 845			
Evaporation start	°C	report	report	report			
50% evap	°C	report	report	report			
95% evap	°C	≤360	≤360	≤360			
FAME content	Vol.%	< 0.2	≤7	≤7			
Flash point	°C	> 55	> 55	> 55			
HFRR	µm	≤460	≤460	≤460			
NACE							
sulfur content	mg/kg	≤10	≤10	≤10			
Viscosity (40° C)	mm²/s	2 to 4.5	2 to 4.5	2 to 4.5			
Viscosity (-24°C)	mm²/s	-	-	-			
Surface tension		to report	to report	to report	to report		
DSEP		to report	to report	to report	to report		

Properties of test fuels for applications outside CEN system

	Unit	US – worst case TL XXX - B	GRV (Bosch) TL XXX - F	SME B 20 TL XXX - E	Nato F 34 TL XXX - D	EU 3 – DK TL XXX - A	EU 2 – DK TL XXX - B	CEC RF 91 – A 81 TL XXX - I
CZ		41 to 45	45 to 50	42 to 47	-	45 to 48	44 to 47	45 to 47
CFPP		-	-	-	< -47	-	< -24	0 to -9
CP		Report	-	-	-	-	-	-
Density	kg/m³	855 to 865	Report	855 to 865	775 to 840	Report	800 to 820	820 to 855
Evaporation point		report	120 to 140	report	Report	120 to 140	-	-
50% evap		report	-	report	Report	-	-	< 300
95% evap		report	Report	report	≤300	360 to 370	report	< 350
FAME content		0	0	20	0	0	0	0
Flash point		-	Report	-	≥38	Report	report	≥55
HFRR		520 to 620	550 to 650	-	< 650	550 to 650	550 to 650	report
NACE		E	E	-	-	E	E	-
Sulfur content	mg/kg	10 to 20	< 10	10 to 20	≤2000	400 to 600	1900 to 2100	9500 …10500
Viscosity (40° C)		-	-	-	-	-	1.5 to 2	1.8 to 6
Viscosity (-24°C)		-	-	-	< 8	-	-	-
Surface tension		-	-	-	-	-	-	-
DSEP		-	-	-	-	-	-	-

High Frequency Reciprocating Rig (HFRR)



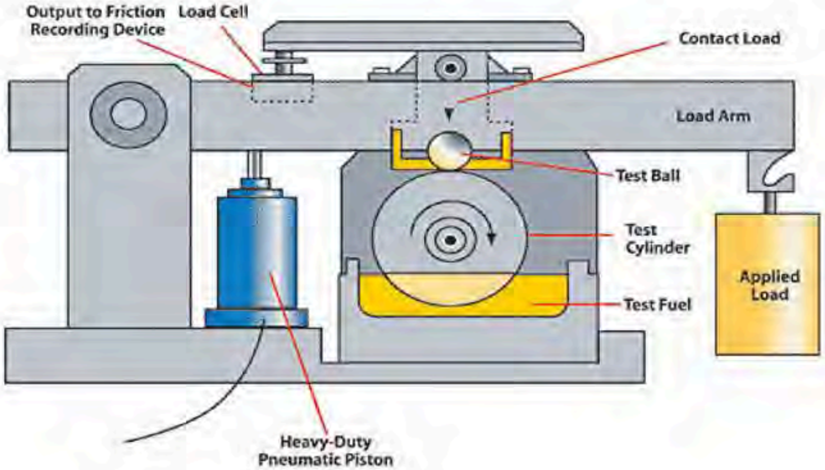
- Standard method to determine lubricity
- Wide spread (ASTM D 6079: ± 136 µm; EN ISO 12156-1: ± 120 µm)
- Wear problems do not always correlate with HFRR values.
- Alternative: Follow timeline of lubricating film thickness as well (not average value).
  - Better correlation with damage symptoms (VW tests)
  - Early disintegration of lubricating film and/or thin lubricating film (≤10%)

    <u>often massive damage</u>
  - Lubricating film (10-20%)

    <u>Wear possible</u>

Source: ASTM D 975-09b; SGS

Scuffing Load Ball on Cylinder Lubricity Evaluator (SLBOCLE)

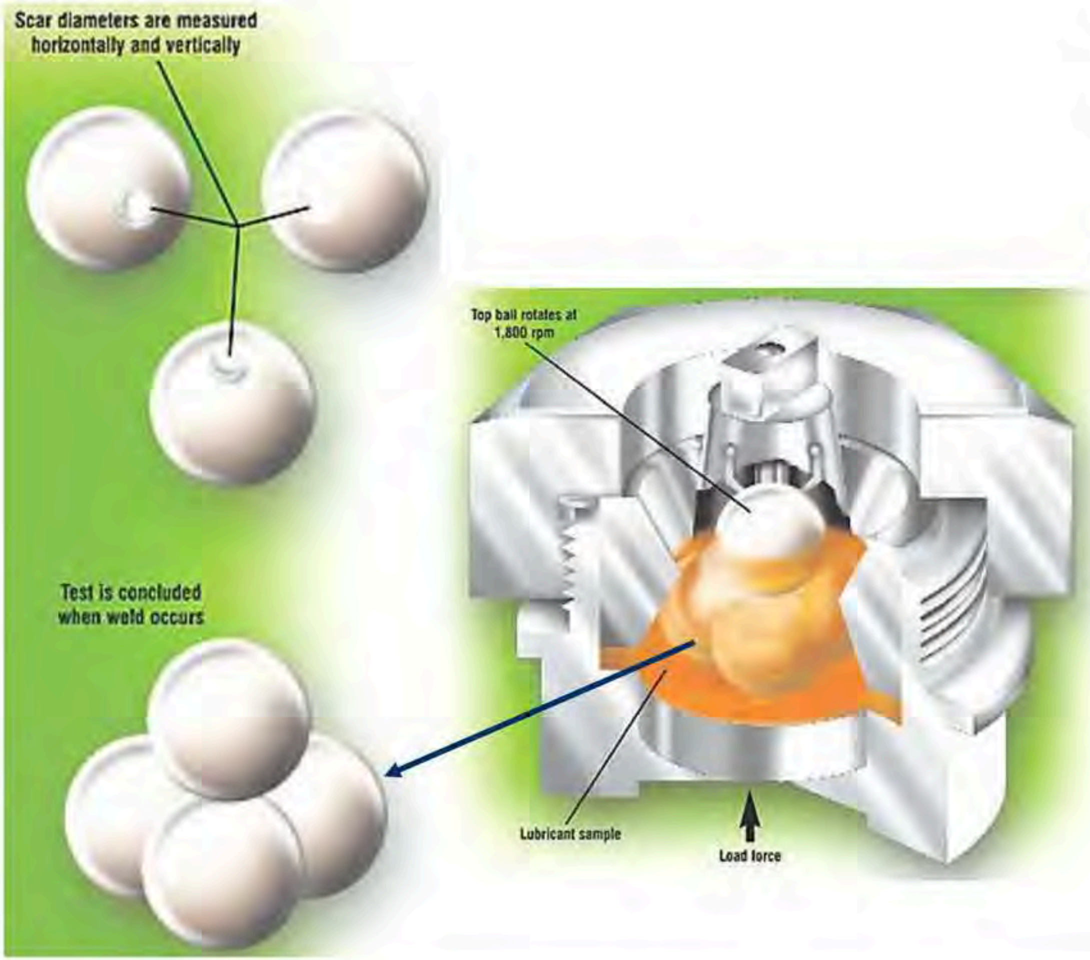


- **ASTM standard for middle distillates**
- **Hardly known in Europe (only a few labs)**
- **Large spread (ASTM D6078: 1500 g)**
  - **"SLBOCLE < 2000 g can result in massive wear"**
  - **"SLBOCLE > 3100 g should prevent massive wear"**

Due to the spread size allowed by the standard, damage symptoms do not always have to correlate to SLBOCLE

Source: ASTM D 975-09b

Four-ball apparatus (VKA)



- Standard method for oils
- Precision data comparable to HFRR data
- Correlation with damage symptoms unknown (hardly any measurements with Diesel)
- Method must be modified for diesel fuel first:
  - Constant temperature required (prevention of fuel evaporation) (not currently available in oil method-ology)
  - Load variation results in evaporation (conditioning required)
  - Setting of humidity necessary (not currently available)

Measurement of lubricating film thickness

- Measurement made through potential drop of resistance bridge at a voltage of 15 mV and a standard resistance of 10 Ohm
- Potential drop over test body is a measurement of film resistance compared to comparison resistance
  - If lubricating film is too small / non-existent, the potential loss (low resistance) will be high
    - Metal-metal contact
    - High friction / abrasion
  - A thick film has less metal-metal contact and thus less friction as a consequence

Additive Dosing System Project

- Contents: Develop an additive dosing system that will help improvefuel quantity in fuel-critical countries.
- Involved parties:
  - Volkswagen: The vehicles are to be sold worldwide. In fuel-critical markets, adaptation to market quality is needed (such as AWP, additives, ...)
  - SOGEFI/Rhodia: Manufacturer of fuel filter systems and dosing units for additives
  - Lubrizol: Delivery of various additive packages tailored to the needs in these markets (lubricity, corrosion protection, detergents; ...)

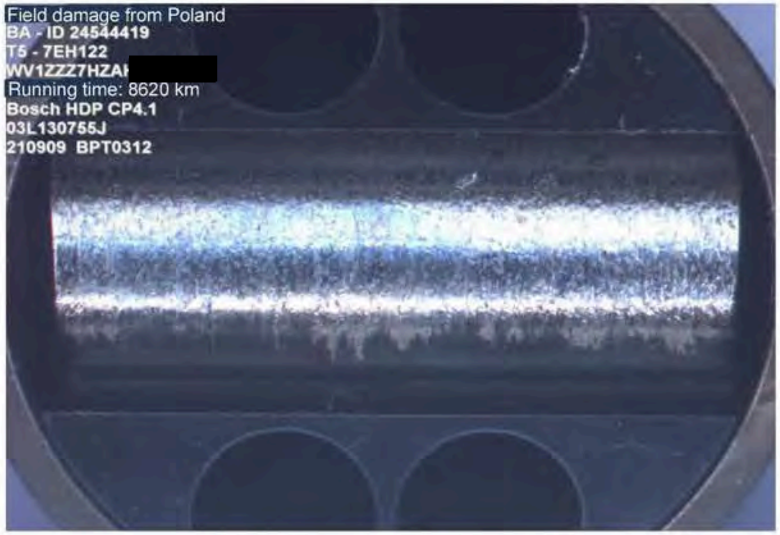
- **General cause for CP4 drivetrain damage:**

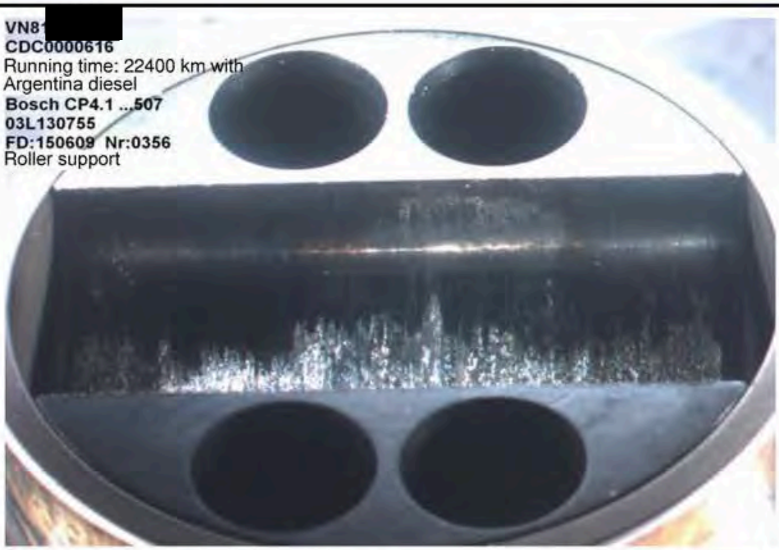
- Intolerably high mixed friction during roller and roller support results in local contact during operation.
- The C layer of the roller support is destroyed (wear and abrasion of C layer), the friction coefficient between roller and roller support increases.
- Sluggish roller ⇒Wear ⇒Particle formation ⇒Drivetrain damage
- Amplifying factors: Fuel with low viscosity; elevated spots on roller (fusing) &amp and on on roller support (metal spatters); surface of roller/roller support

- **Consequences of HPP drivetrain damage:**

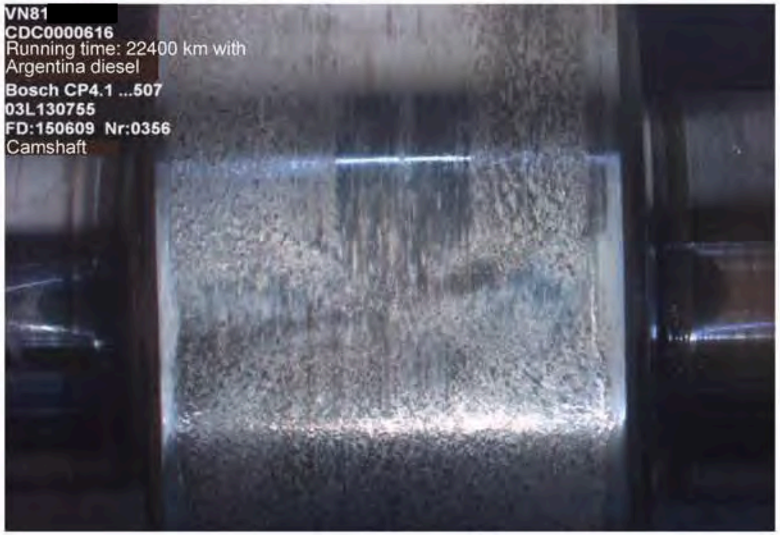
  - Shavings created in high-pressure fuel pump drivetrain
  - Shavings distributed through entire fuel system
  - Malfunctions of HPP, PCV, RDS, injectors, DHV

⇒ Breakdowns


Field damage from Poland
BA - ID 24544419
T5 - 7EH122
WV1ZZZ7HZA[redacted]
Running time: 8620 km
Bosch HDP CP4.1
03L130755J
210909 BPT0312


VN81[redacted]
CDC0000616
Running time: 22400 km with
Argentina diesel
Bosch CP4.1 ...507
03L130755
FD:150609 Nr:0356
Roller support


Field damage from Poland
BA - ID 24544419
T5 - 7EH122
WV1ZZZ7HZAH[redacted]
Running time: 8620 km
Bosch HDP CP4.1
03L130755J
210909 BPT0312


VN81[redacted]
CDC0000616
Running time: 22400 km with
Argentina diesel
Bosch CP4.1 ...507
03L130755
FD:150609 Nr:0356
Camshaft

Vehicle-side measures

- Fuel filter with water separation
- Water sensors
- 6 bar low-pressure system (ITP)
- Filtered tank venting (under clarification)

Release of FIE Components

Step 4 necessary to confirm relevance of steps 1… 3 with respect to not foreseeable market specific risks.

Step	Test Type	Fuel	alte Ez	neue Ez
④ CRS RoW user	active field surveillance (e.g. 1k veh. 1 year)	BRIC		X
③ CRS Vehicle @ OEM	Test Fleet (10 veh.) per Region	BRIC	(X)	X
② CRS Engine Tests @ OEM	Engine TB RP1-RP2-RP3	RoW & GDK	(X)	X
① CRI-CP-CRR Component Tests @ ETC	Component TB RP1-RP2-RP3	RoW & GDK	(X)	X

SOP

Step

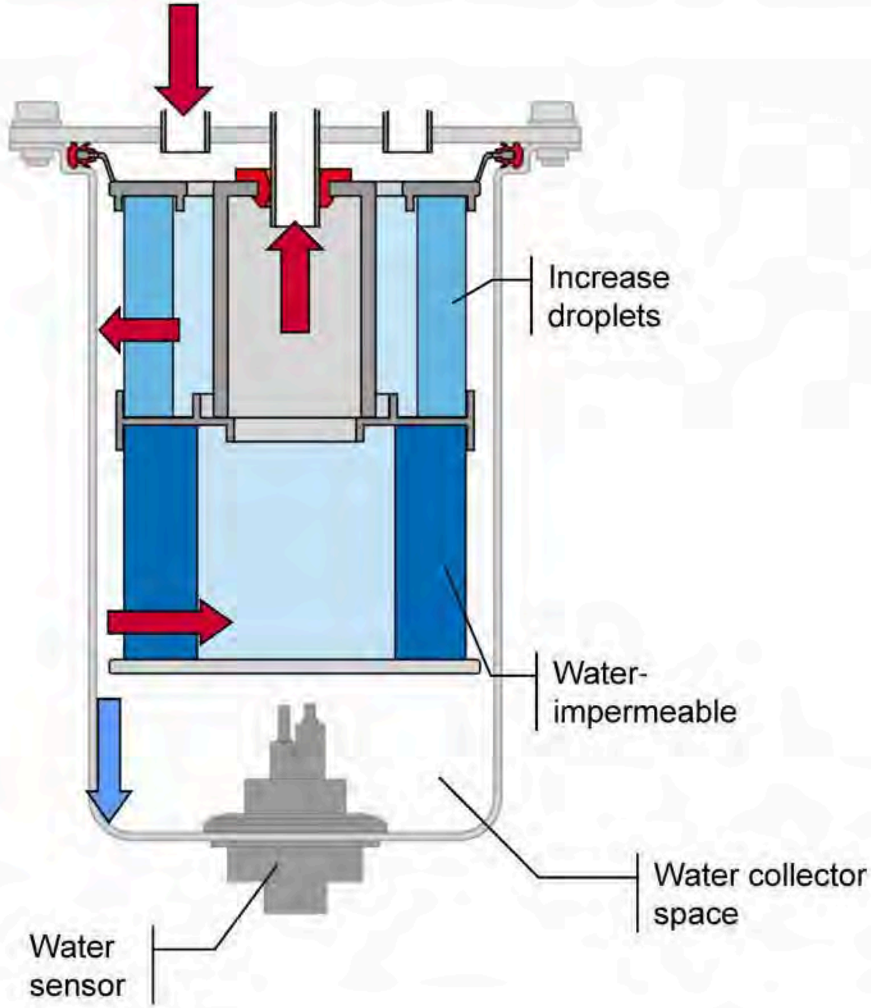
Schedule

Backup

MQB Fuel Filter incl. Water Separation

2-stage concept

First parts to PVS WK45/11



EA11003EN-00578[0]

Vacuum in the LPC

Non-responsive content removed

BOSCH
Invented for life

Vacuum in the LPC

Fact

A vacuum may exist caused by

- Vacuum in the tank (extraction of injection quantity, …)
- Differences in height installation height pump CRS vs. tank level(filling level, type of tank,…)

Estimate: Vacuum in the LPC ~ -100mbar_rel

If LPC are not air tight (vs. service life, aging plastic,…) then air can enter the LPC and in the worst case also drain it partially.

Problem / Risk

If the high-pressure fuel pump is drained & but not refilled prior to starting the motor then the risks of damaging the roller exists at initial restart.

Vacuum in the LPC

Factors which influence dry-running of the LPC

- Vacuum in the tank = f(tank volume, filling level, bleed valve,…
- Hight difference return flow vs. tank (return flow connection to the upper edge of the swirl pot)
- Fuel (viscosity-> temperature)
- Low pressure circuit & components (number of LPC sealing points,..)
- Leakage protection (with or without tongues)

Vacuum in the LPC

Open points

Can a vacuum be produced in the tank and if so how much? V. Audi (query started)

Answer Audi: Yes. Vacuum of several mmbar can be measured.

Is leakage prevented with a spring-loaded valve (leak tightness?) V. Audi (query started)

Answer Audi: No

The valve is not spring-loaded (elastomer mushroom valve)

Does diagram of LPC correspond with reality V. Audi/ VW

Vacuum in the LPC

Latest findings

- Abnormality: Preliminary results have indicated that the pump was not completely filled with fuel when attempting to start the vehicle with kerosene.
- A Plexiglas pump was rinsed with GDK570 @ 40°C on the test bench (Audi 2 bar LPC). Result: The pump runs dry up to the lower bearing shell

Task: Where does the air come from? Low pressure circuit was built-up with transparent hoses. Air leaks on the components could not be observed.

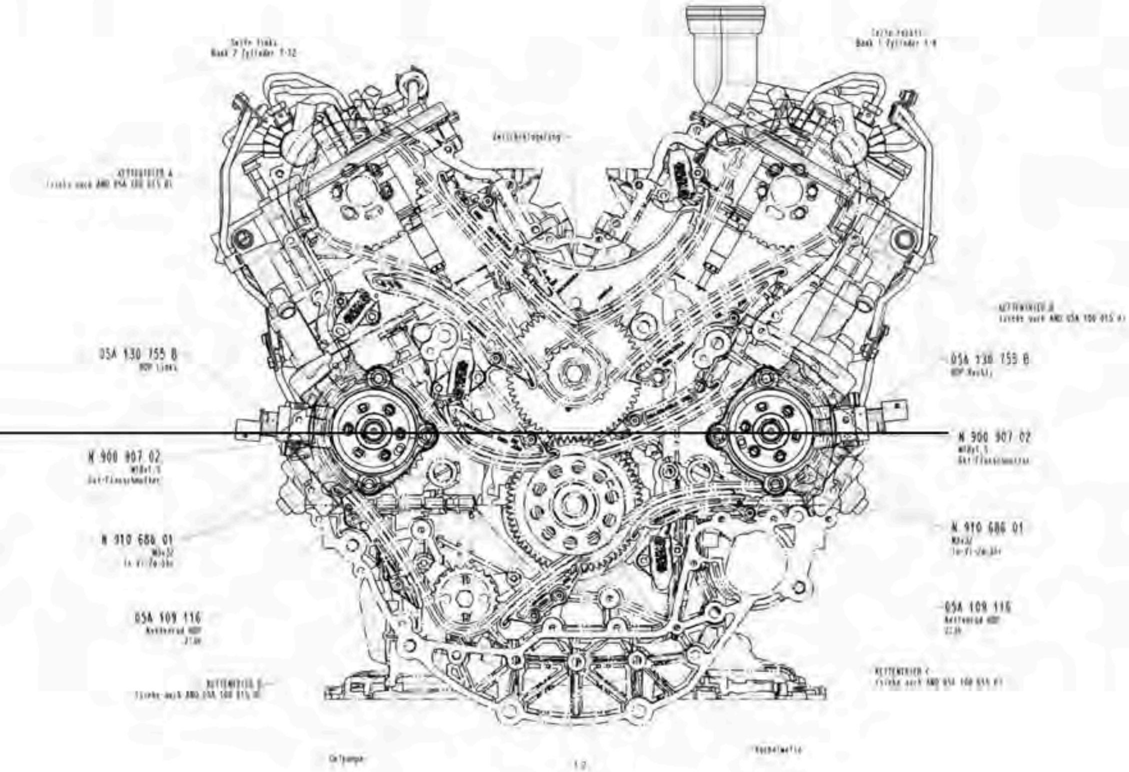
Vacuum in the LPC

Suggestions for next steps

• Determination of w.c. Vacuum in the LPC	V. Audi
• Determination of height difference assembly position pump vs. tank	V. Audi
• Test with "partially filled" pump for producing braking flats	V. RB

Vacuum in the LPC

Example on W26: Comparison of the installation height vs. Tank



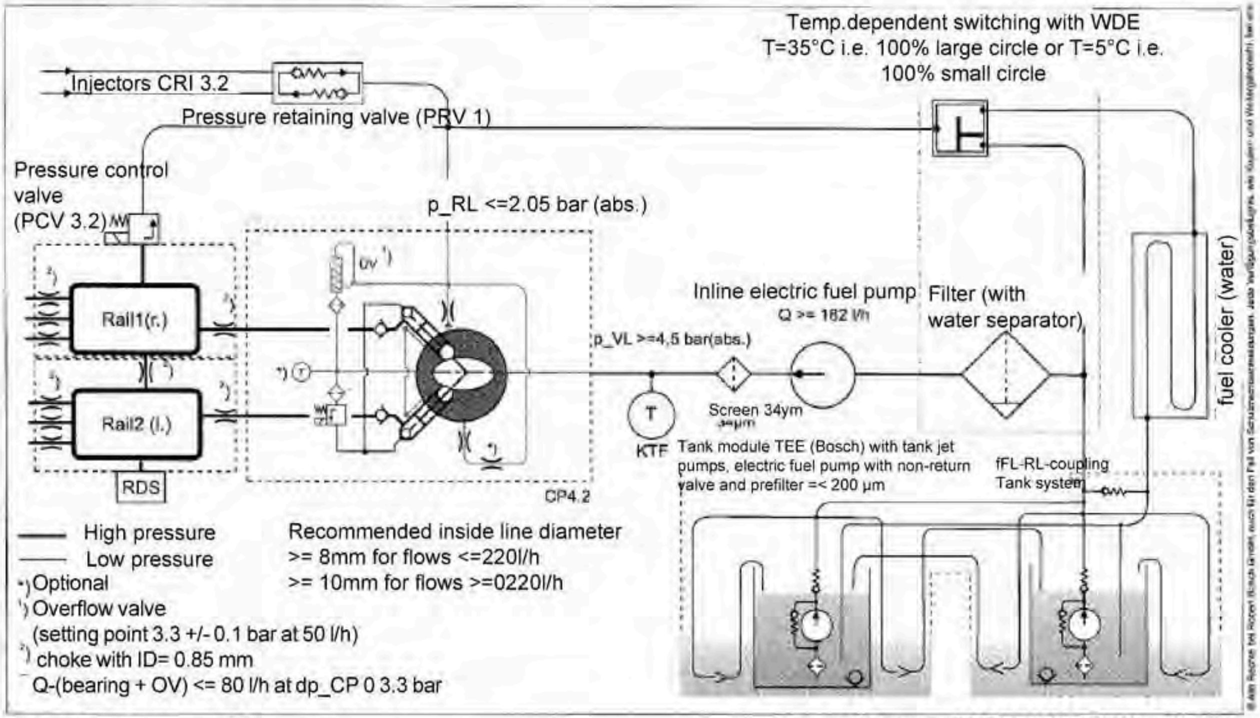
Height difference?

Tank

Vacuum in the LPC

Audi LPC W19 with Q7 (CP4.2 with EFP)

Common Rail System (CRS3.2) - 1800 bar
Audi V6 3.0l TDI EU5 in Q7/Touareg



BOSCH

Status: 5/2/2007 DS/ECC 7840340d_Wo_000** Audi

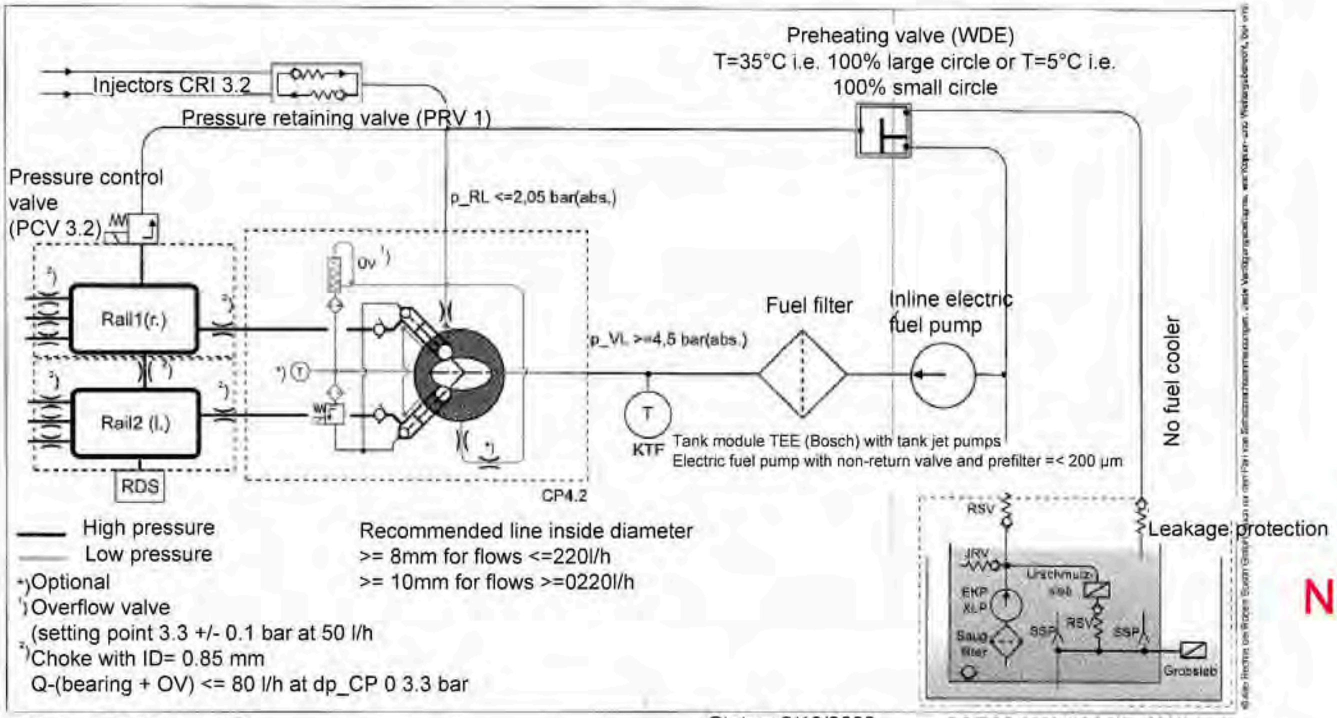
Saddle tank

BOSCH

Vacuum in the LPC

Audi NDK W19 in B8 (CP4.2 with EFP)

Common Rail System (CRS3.2) - 1800 bar
Audi V6 3.0l and 2.7l TDI EU5 / EU5 CO2 in B8



No saddle tank

BOSCH

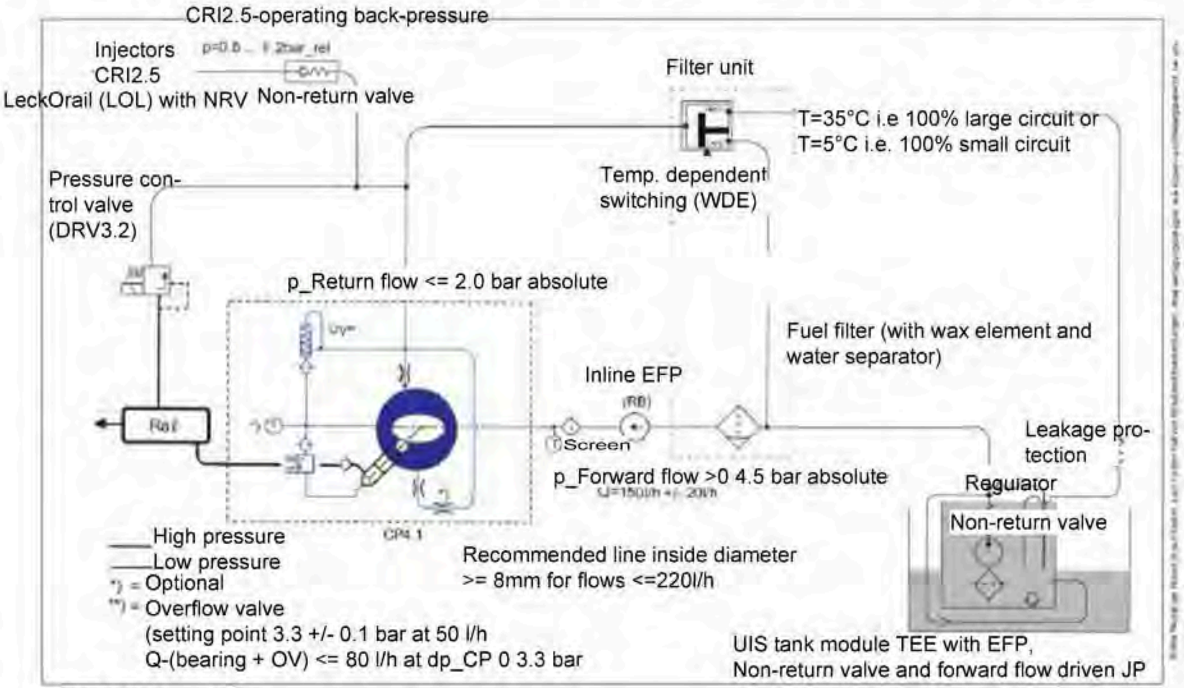
Status: 2/18/2008 DS/ECC 8820148d_Wo_000** Audi

BOSCH

VW Group (CP4.1 with EFP)

Vehicles: PQ 36 (Golf, Skoda, Tiguan, Audi-A3)

Common Rail System (CRS2.5) - 1800 bar with CRI2.5, CP4.1 with tank- and Inline- electric fuel pump after filter
Low pressure circuit VW_R4_2.0l_plus_EA189_EU5 {125kW/Mono} in PQ36 -temporarily-



BOSCH

DS/ECC3 889 0934d_rev0_Zu_000 VW

No saddle tank! ?

"simplified tank assembly"! ?

BOSCH

Filling of the pump and foam in the tank

Non-responsive content removed

BOSCH
Invented for life

Filling of the pump and foam in the tank

Concern: “filling of the pump”

A camera was use to record the filling process of the pump.

Constraints: 4.5 bar_abs, 40°C, fuel GDK570, 0rpm, / 600rpm / 2000rpm

Result

- If fuel is present on the pump then the pump is full after ~5s (@0rpm).
- Residual air accumulates in the tappet hole & in the upper cylinder.
- This area is ventilated when the speed is increased. No “foam” exists in the drivetrain.

Filling of the pump and foam in the tank

Concern: “foam in the swirl pot”

A camera was use to record the film the swirl pot in the Q7 saddle tank.

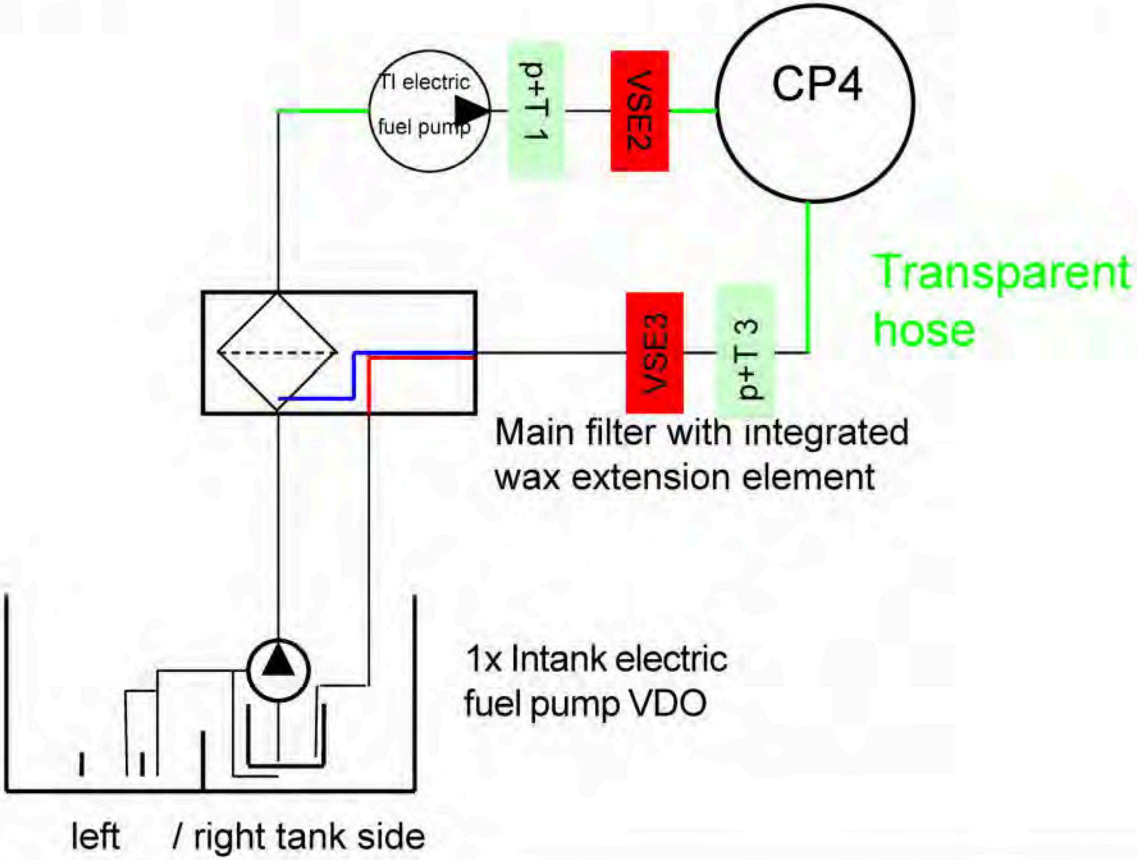
Constraints: 4,5 bar_abs, 40°C, GDK570, tank level 10l / 16l, 0 rev/min

Result

Large amounts of foam can form in the tank when the level of fuel in the tank is low (> 16l !) – this is especially true if the fuel does not contain any defoaming additive (=GDK570).

Filling of the pump and foam in the tank

Q7 system assembly on the test bench (1 Intank electric fuel pump)



Filling of the pump and foam in the tank

Questions

1) How is it possible to recognize if a defoaming additive is present in the fuel?

Indirectly via the the Si content in the fuel. See set of slides H.Non-responsive content removed

2) Is the formation of foam less with return flow driven tank jet pumps?
And what "experience" has been gained by VW/ Audi with fuels that do not contain defoaming additive (Swedish fuel)?

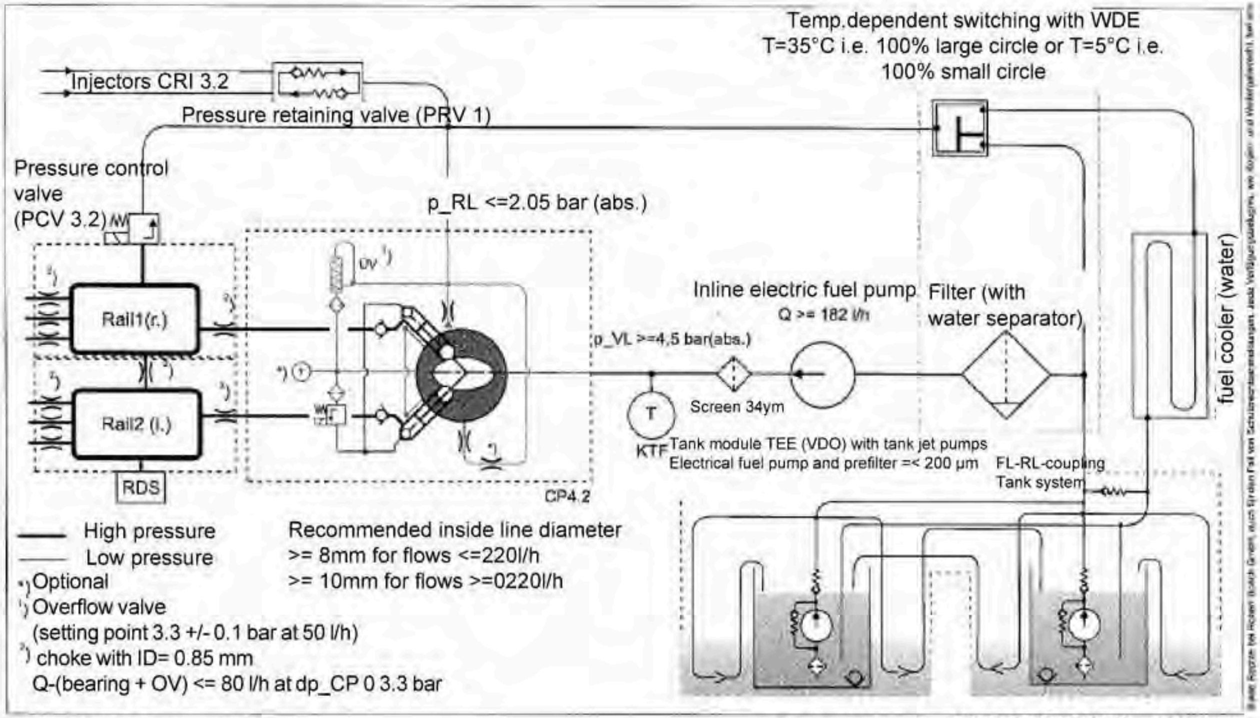
3) Can the pump become damaged through foam or disproportionately high air content?
Specific: Is oxide generated on the roller / cam shaft with excessive foam or disproportionately high air content? Simulation of initial commissioning!

BOSCH

Filling of the pump and foam in the tank

Audi NDKL W19 with Q7 (CP4.2 with EFP)

Common Rail System (CRS3.2) - 1800 bar
Audi V6 3.0l TDI EU5 in Q7/Touareg



Saddle tank

BOSCH

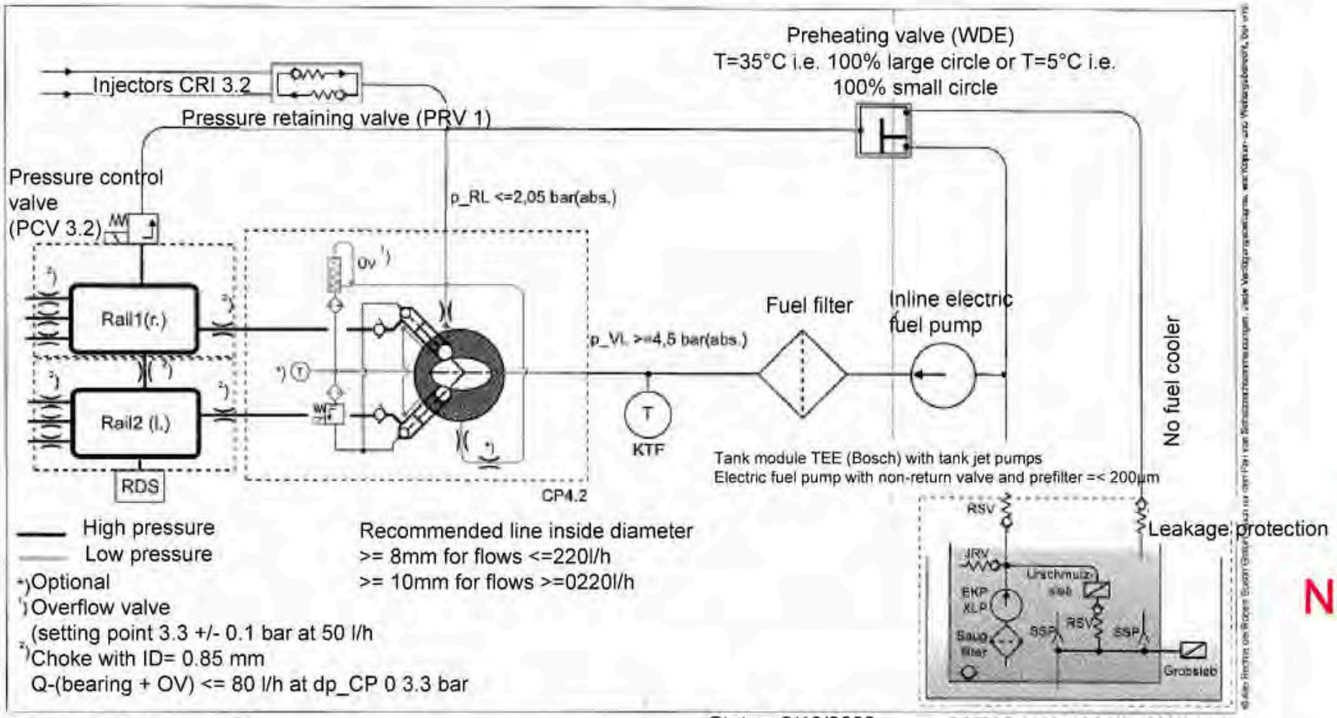
Status: 5/2/2007 DS/ECC 7840340d_Wo_000** Audi

BOSCH

Filling of the pump and foam in the tank

Audi NDK W19 in B8 (CP4.2 with EFP)

Common Rail System (CRS3.2) - 1800 bar
Audi V6 3.0l and 2.7l TDI EU5 / EU5 CO2 in B8



BOSCH

Status: 2/18/2008 DS/ECC 8820148d_Wo_000** Audi

No saddle tank

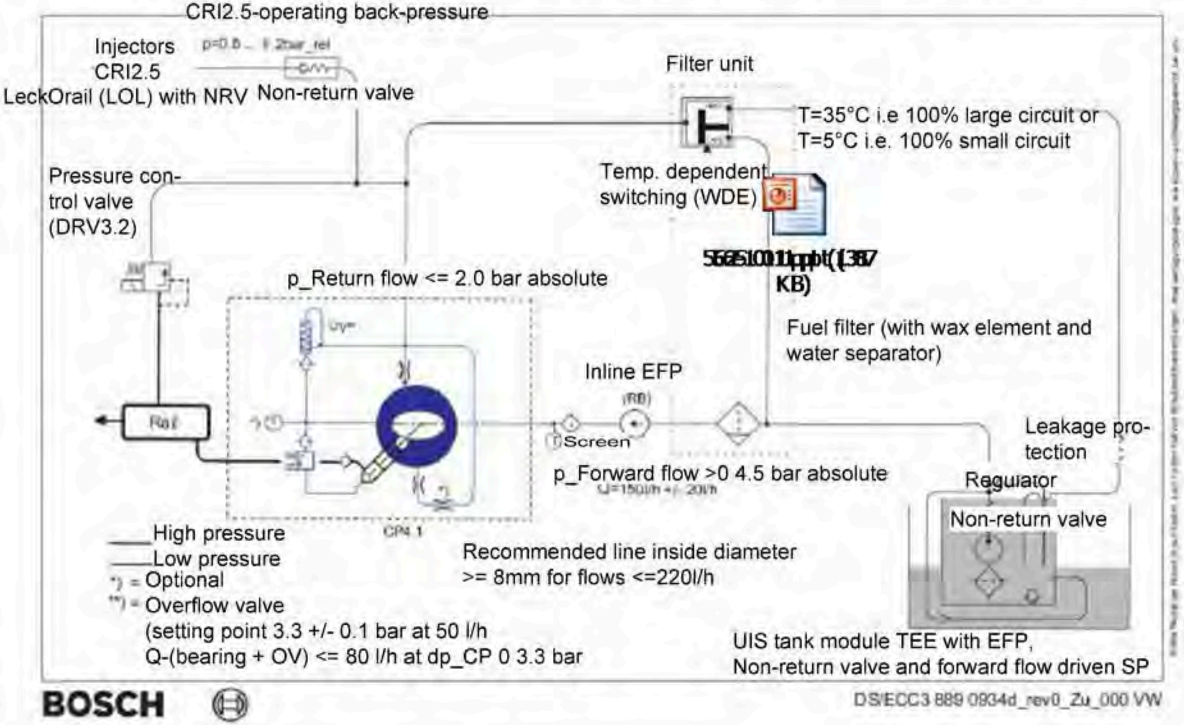
BOSCH

Filling of the pump and foam in the tank

VW Group (CP4.1 with EFP)

Vehicles: PQ 36 (Golf, Skoda, Tiguan, Audi-A3)

Common Rail System (CRS2.5 - 1800 bar with CRI2.5, CP4.1 with tank- and Inline- electric fuel pump after filter)
Low pressure circuit VW_R4_2.0l_plus_EA189_EU5 {125kW/Mono} in PQ36 -temporarily-



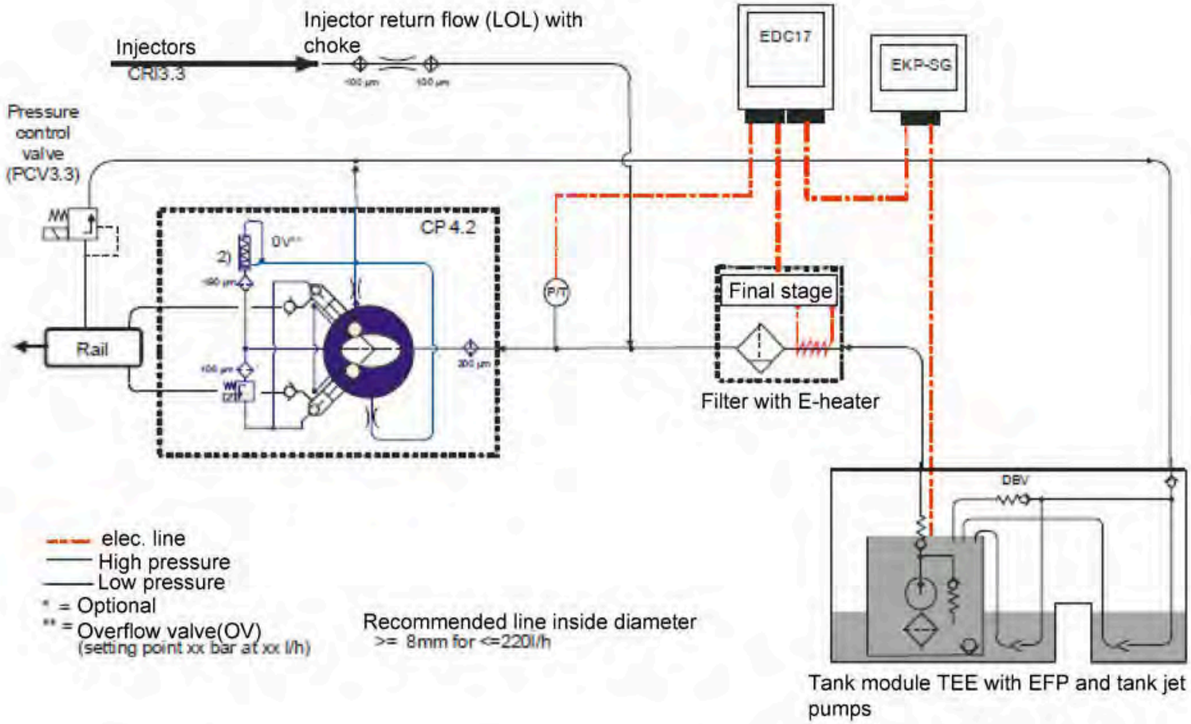
No saddle tank! ?

"simplified tank assembly"! ?

BOSCH

Filling of the pump and foam in the tank

Customer B



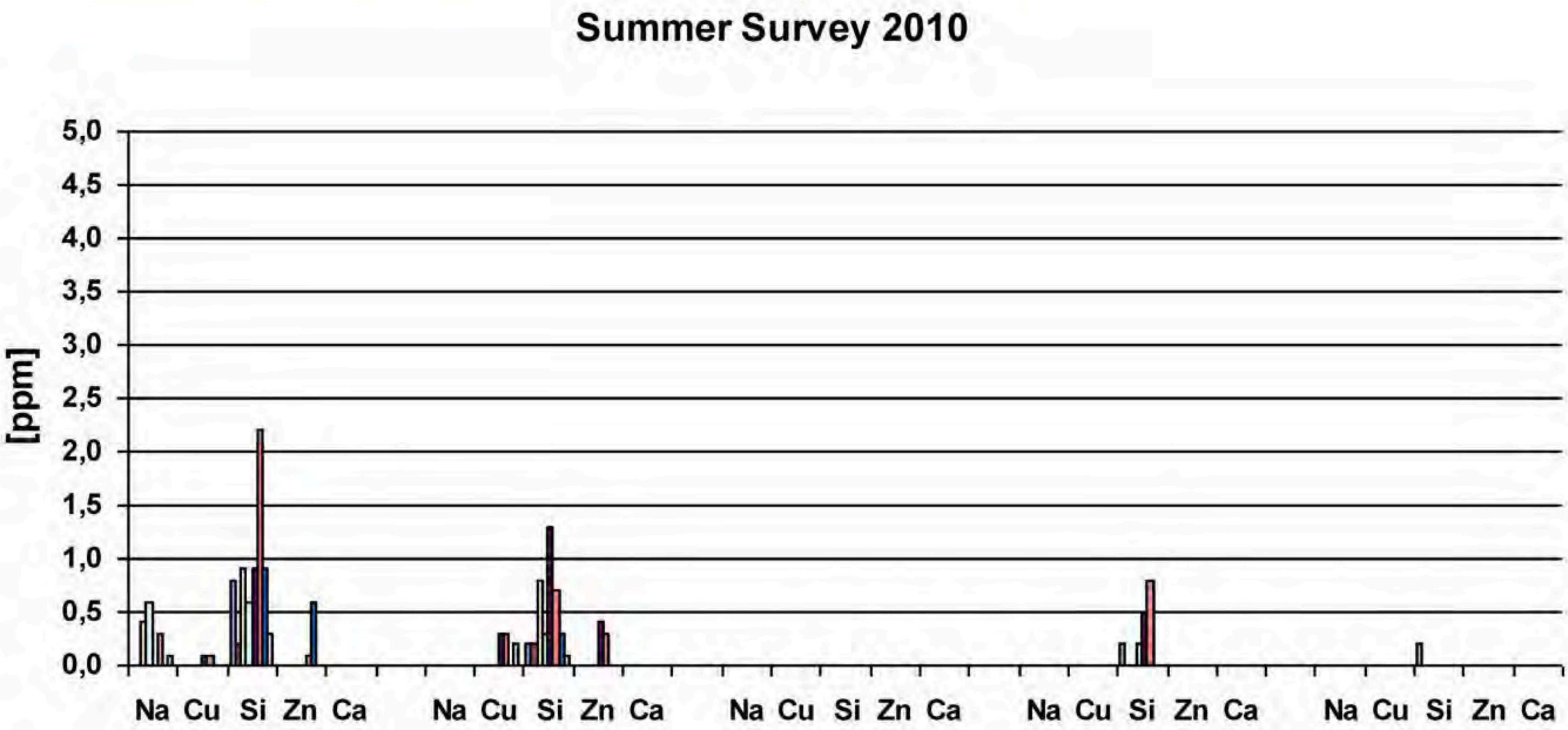
Diesel Fuel Quality
Silicon Content

Status 11.2010

- Silicon (Si) containing additives used as de-foamer
- target of application: avoidance of dispenser shut-off before complete fill of tank to assure maximum fuel quantity sold
- strongly fluctuating regional and local occurrence of Si (and other met-al ion) content, without systematic distribution pattern
- as Si is also part of environmental dust threshold of 0.5 ppm is taken as indication for the application of de-foamer
- under this assumption surveys from 2007 to 2010 indicate:
  - de-foamers found only in portion of fuel samples
  - degree of use of de-foamers different in different countries
    - application at relevant portion of sampled fuels in [redacted] and [redacted] partly also [redacted]
    - no application in [redacted] and [redacted] at least not since Winter 2009)

ENTIRE PAGE CONFIDENTIAL

Diesel Fuel Quality (Metal Ion Content)

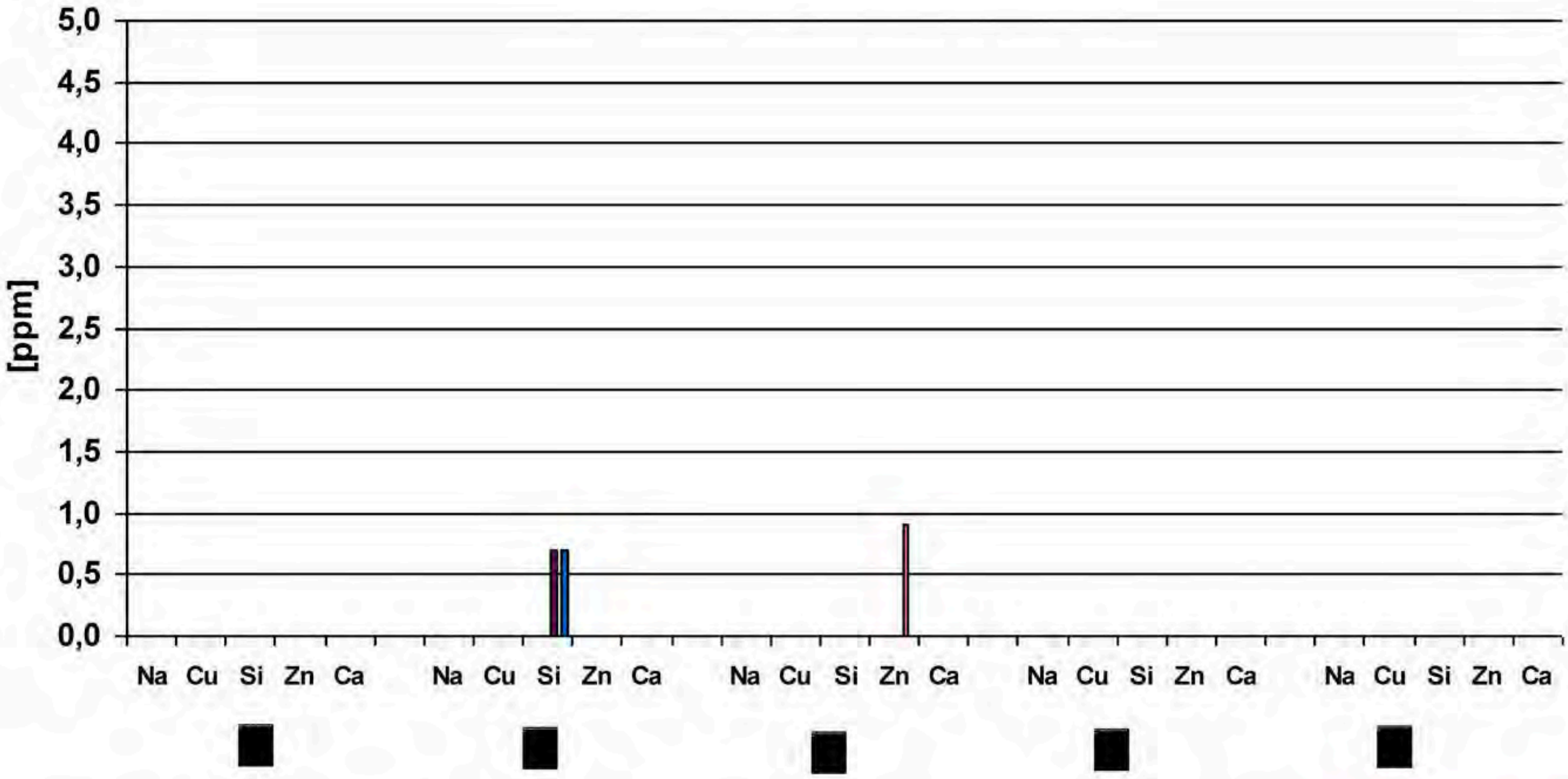


[redacted] [redacted] [redacted] [redacted] [redacted]

BOSCH

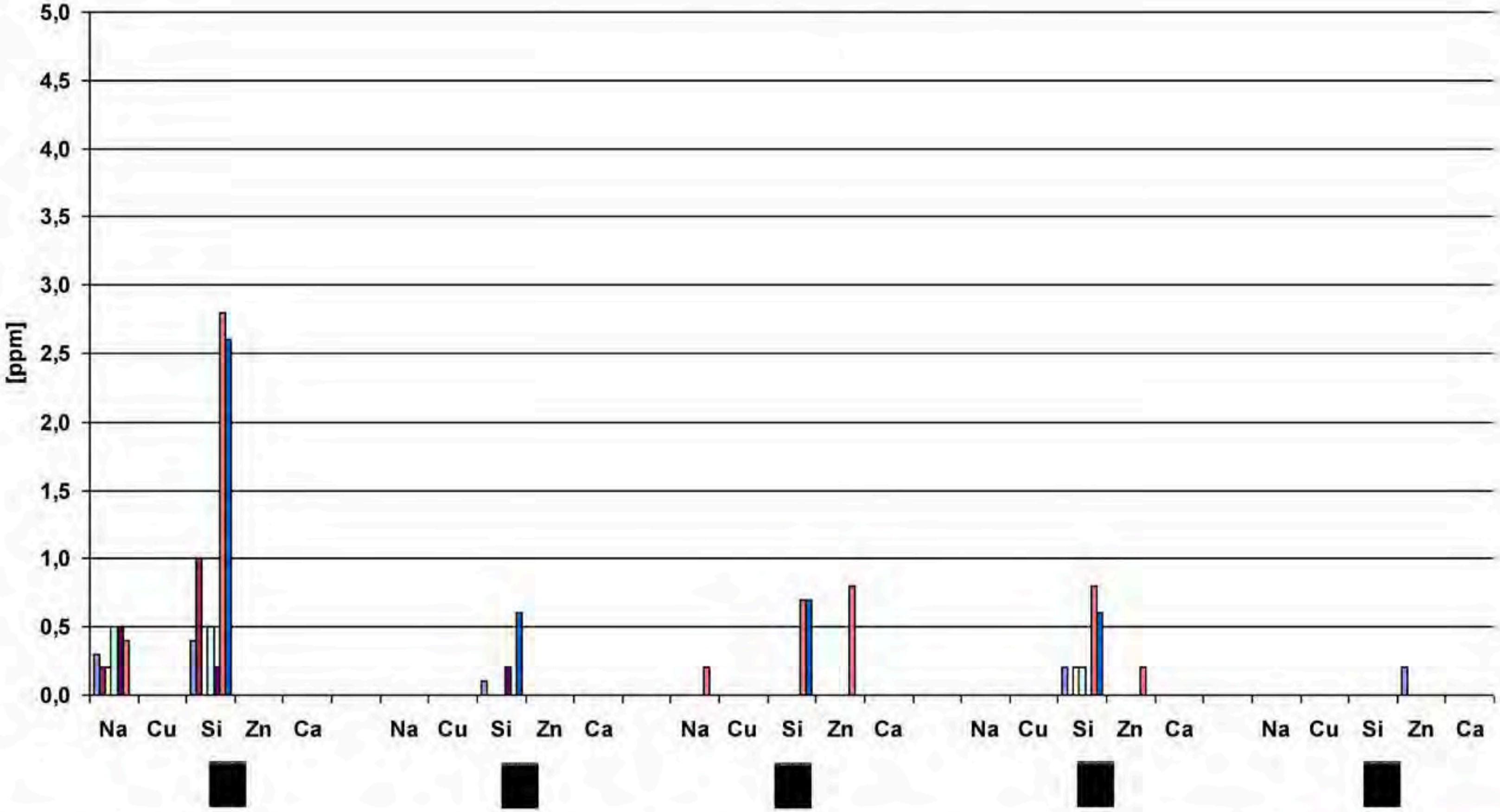
Diesel Fuel Quality (Metal Ion Content)

Winter Survey 2009 / 2010



Diesel Fuel Quality (Metal Ion Content)

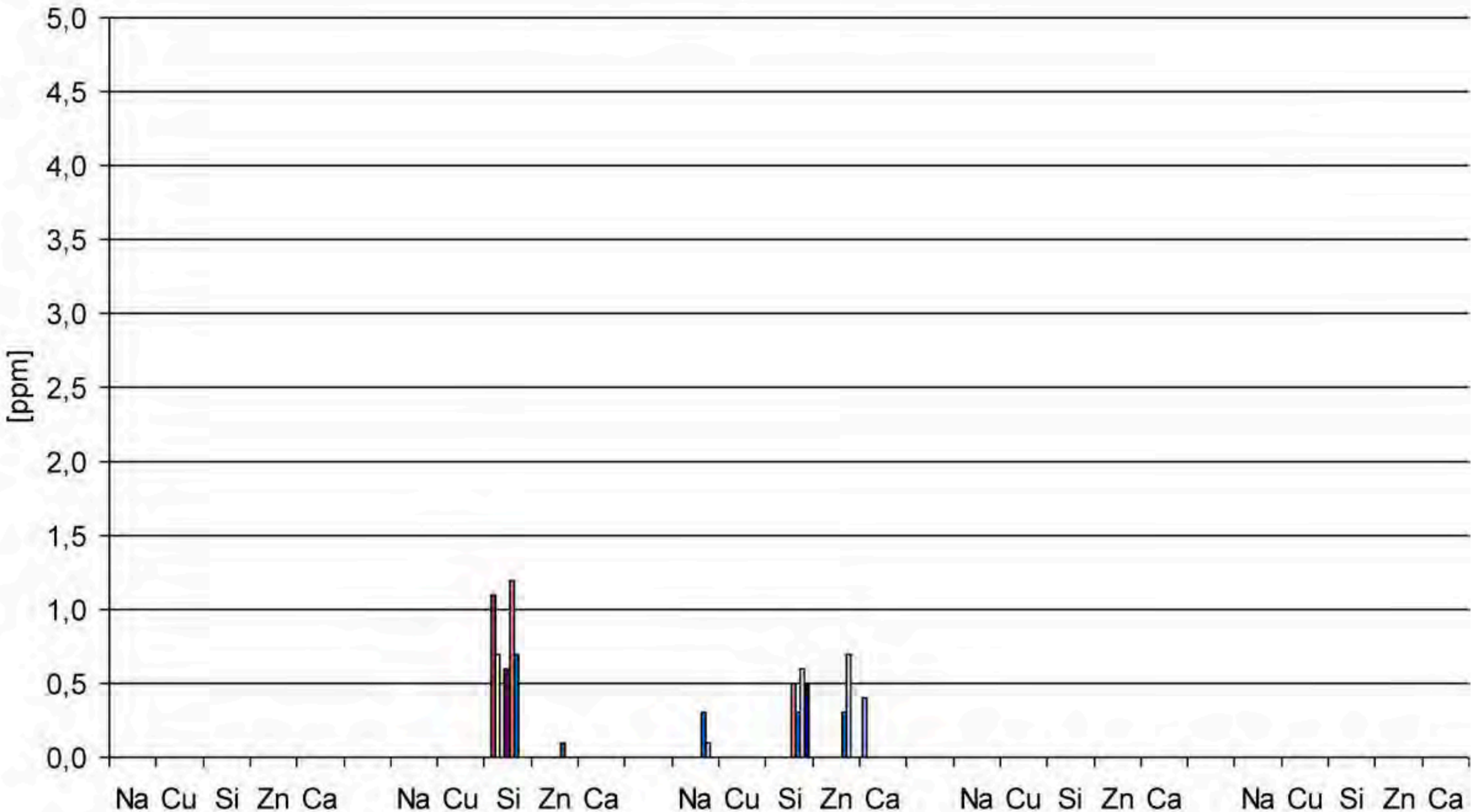
Summer Survey 2009



BOSCH

Diesel Fuel Quality (Metal Ion Content)

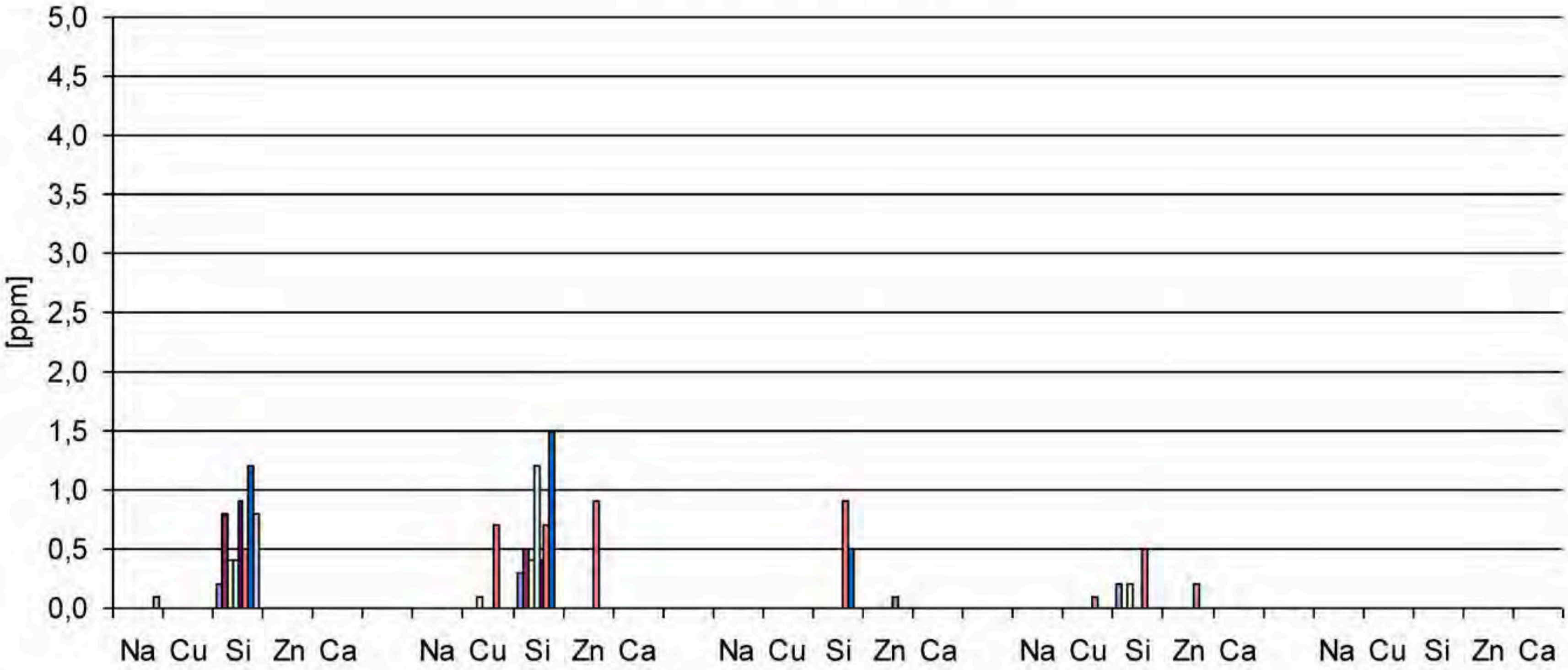
Winter Survey 2008/2009



[redacted] [redacted] [redacted] [redacted] [redacted]

Diesel Fuel Quality (Metal Ion Content)

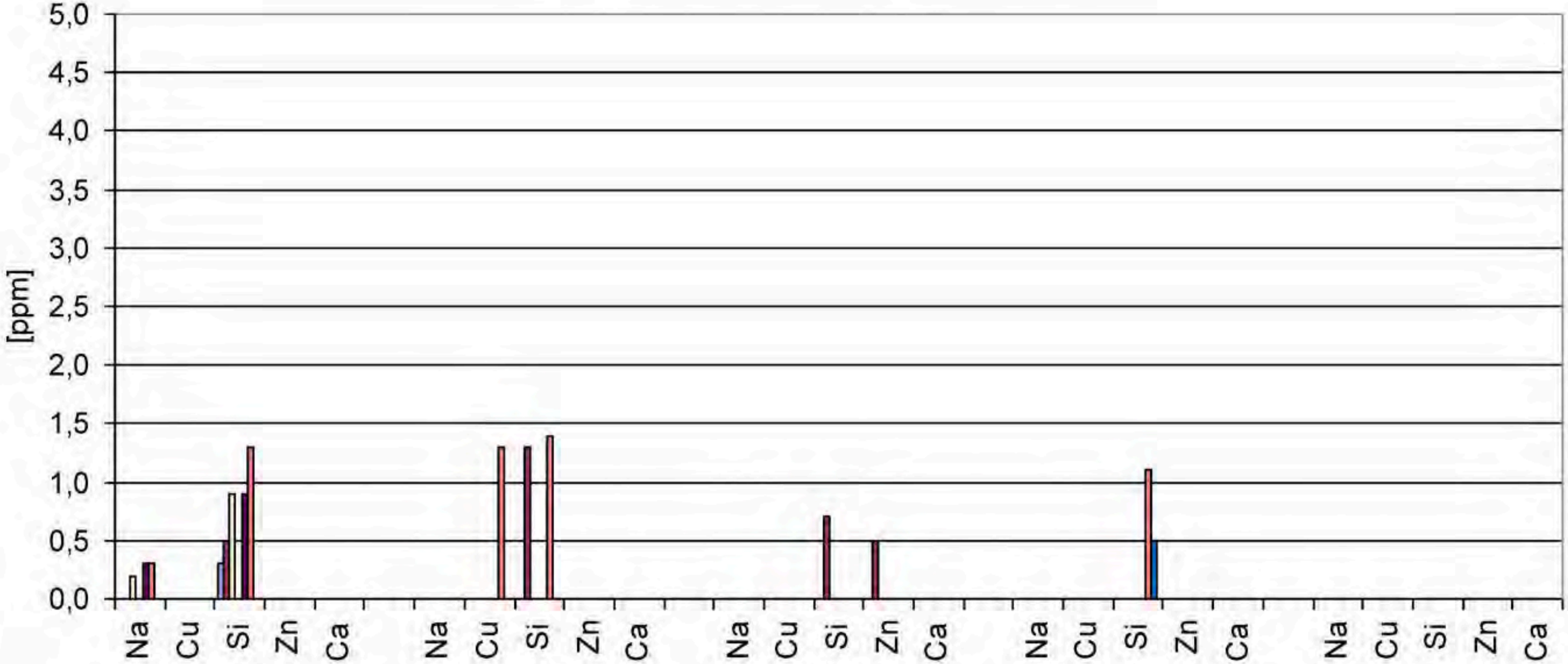
Summer Survey 2008



[redacted] [redacted] [redacted] [redacted] [redacted]

Diesel Fuel Quality (Metal Ion Content)

Winter Survey 2007/2008



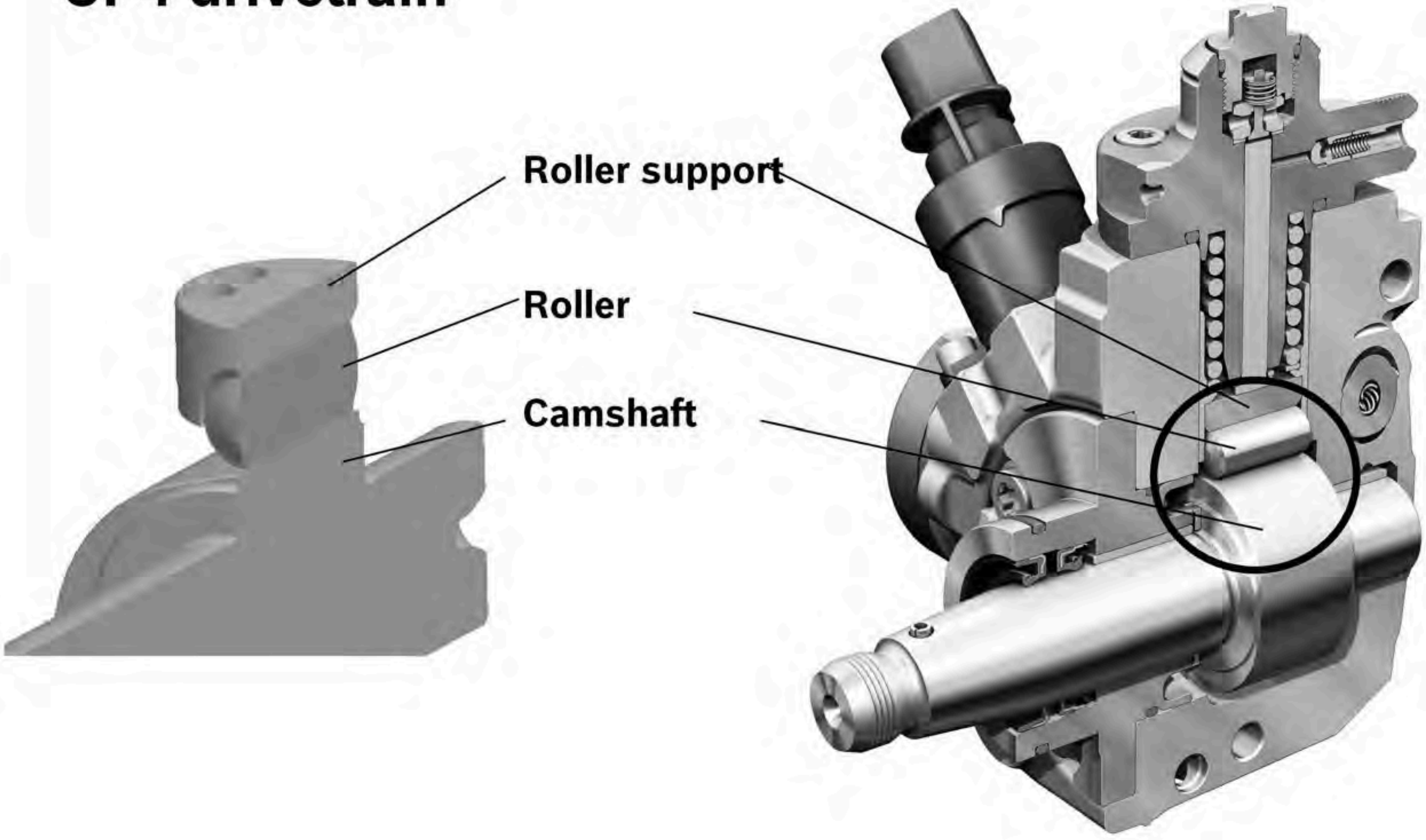
[redacted] [redacted] [redacted] [redacted] [redacted]

RB – Audi Technical Meeting 12.14.2010

BOSCH
Invented for life

Technical Meeting Audi 12.14.2010

CP4 drivetrain



Diesel Systems

BOSCH

Agenda

1.Design hydrodynamic sliding bearing roller/roller support

2.Hypothetical damage profile drivetrain

3.Startup behavior roller

4.Variants for improving lubrication hydrodynamic contact surface

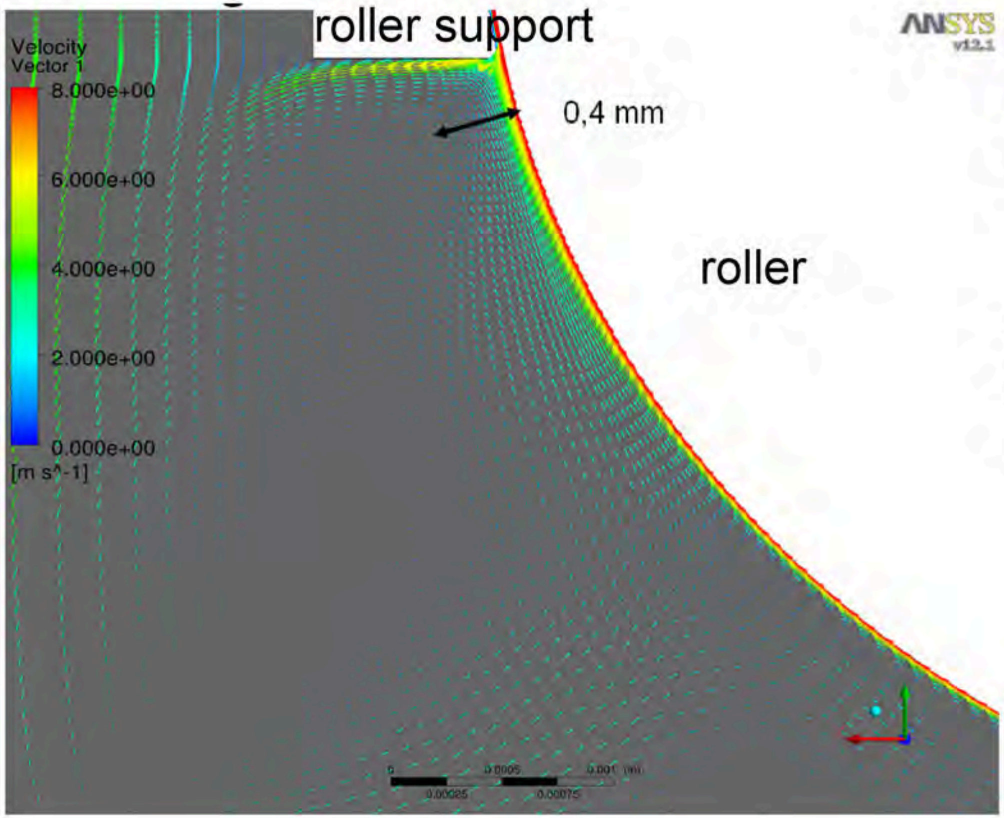
5. Other possible measures for increasing the robustness of WWU

6. Turning angle acceleration, measurements Audi Q7

BOSCH

Design opt. lubricant feeder

Speed vectors:



From the CFX calculation the layer thickness of the lubrication film conveyed by the roller. =>0.4mm

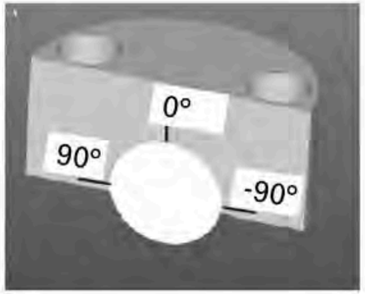
Selected for leading edge: 0.6 mm wide with R1.0 entering into the gap

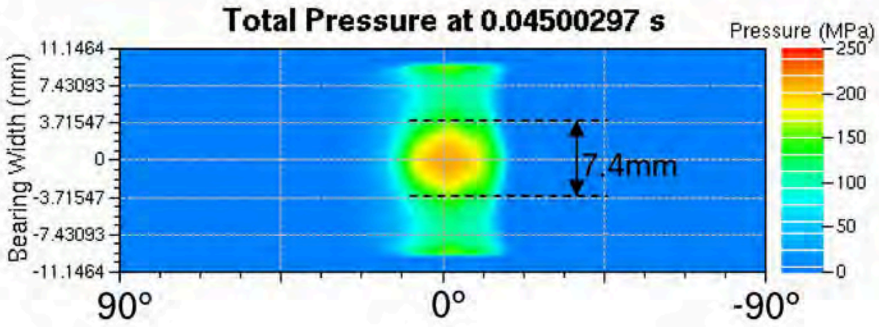
Lifting motion

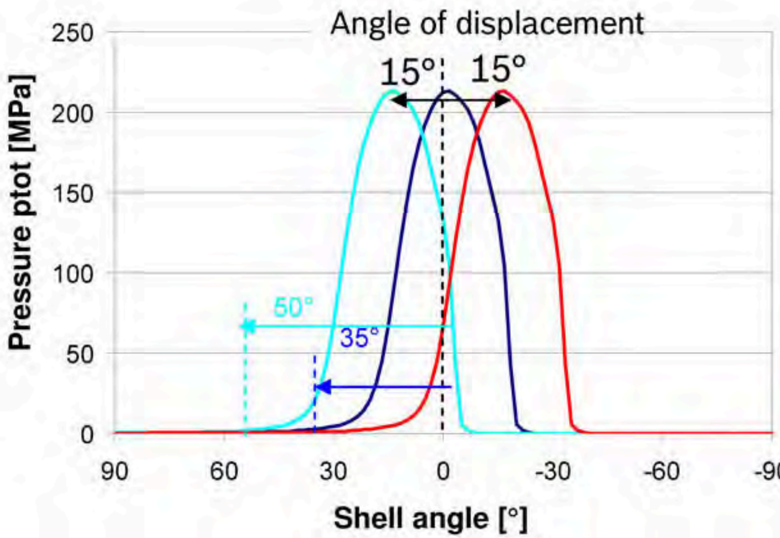
BOSCH

EHD simulation sliding bearing roller and bearing support

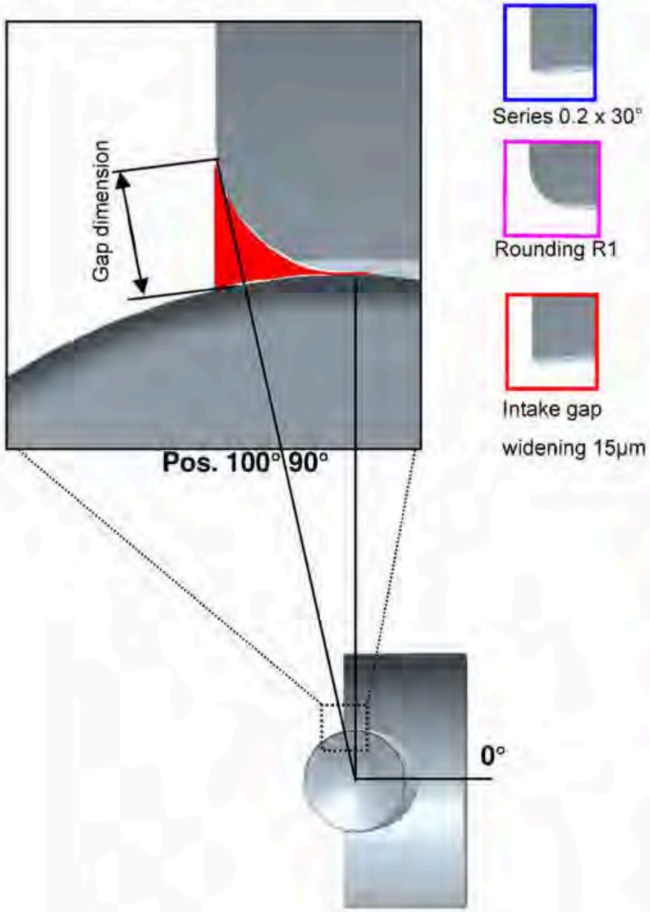
roller support_2863 with Rv=0.3
n_p=1000rpm; p_{Rail}=1800bar
EN590 (@40°) 2.7mm²/s

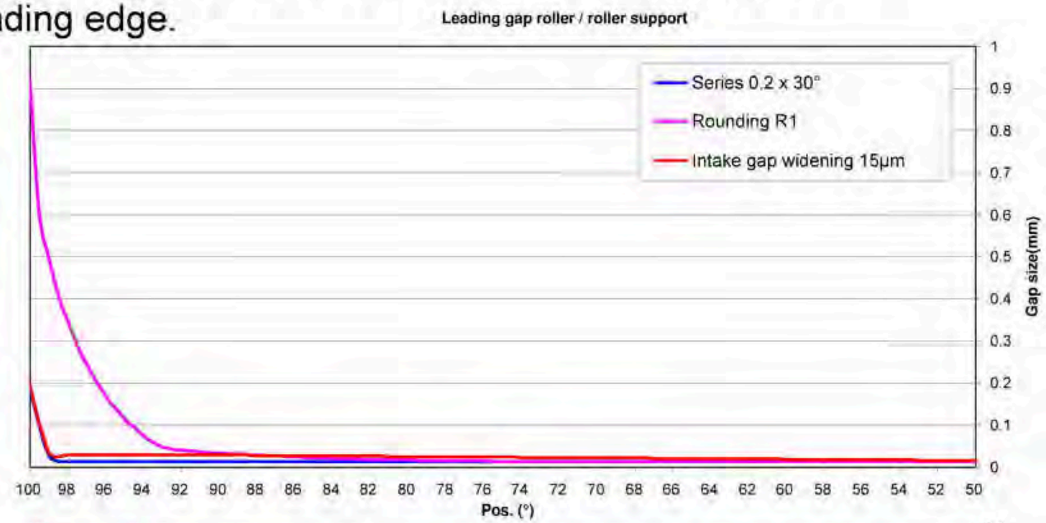


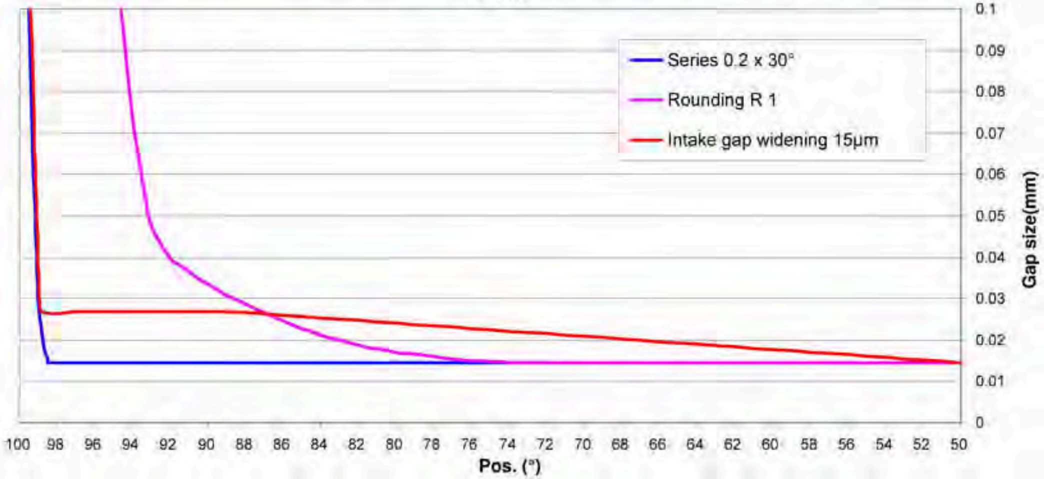




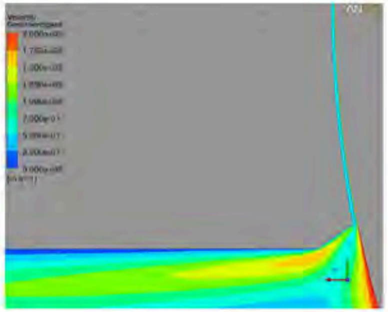
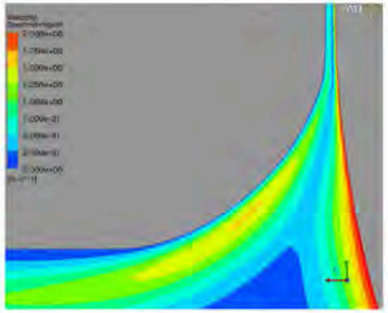
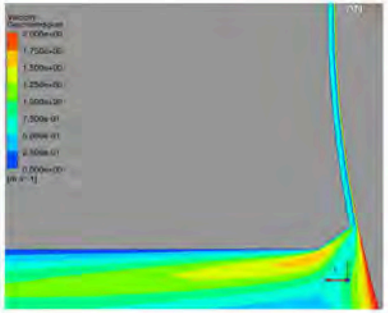
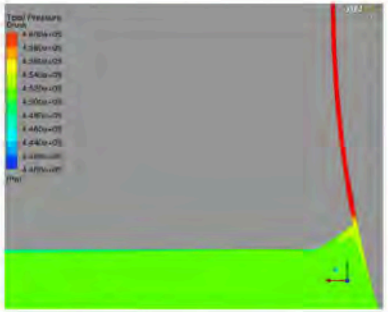
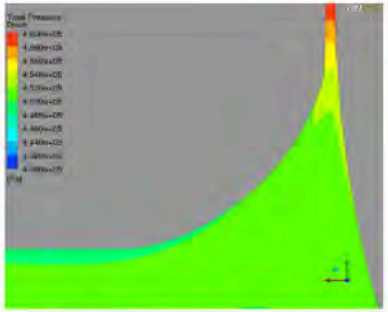
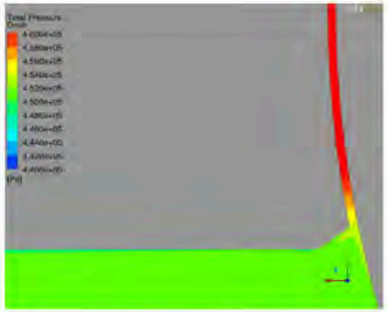
Nominal dimension examination of the leading gap between the roller / roller support with varying designs of the roller support leading edge.







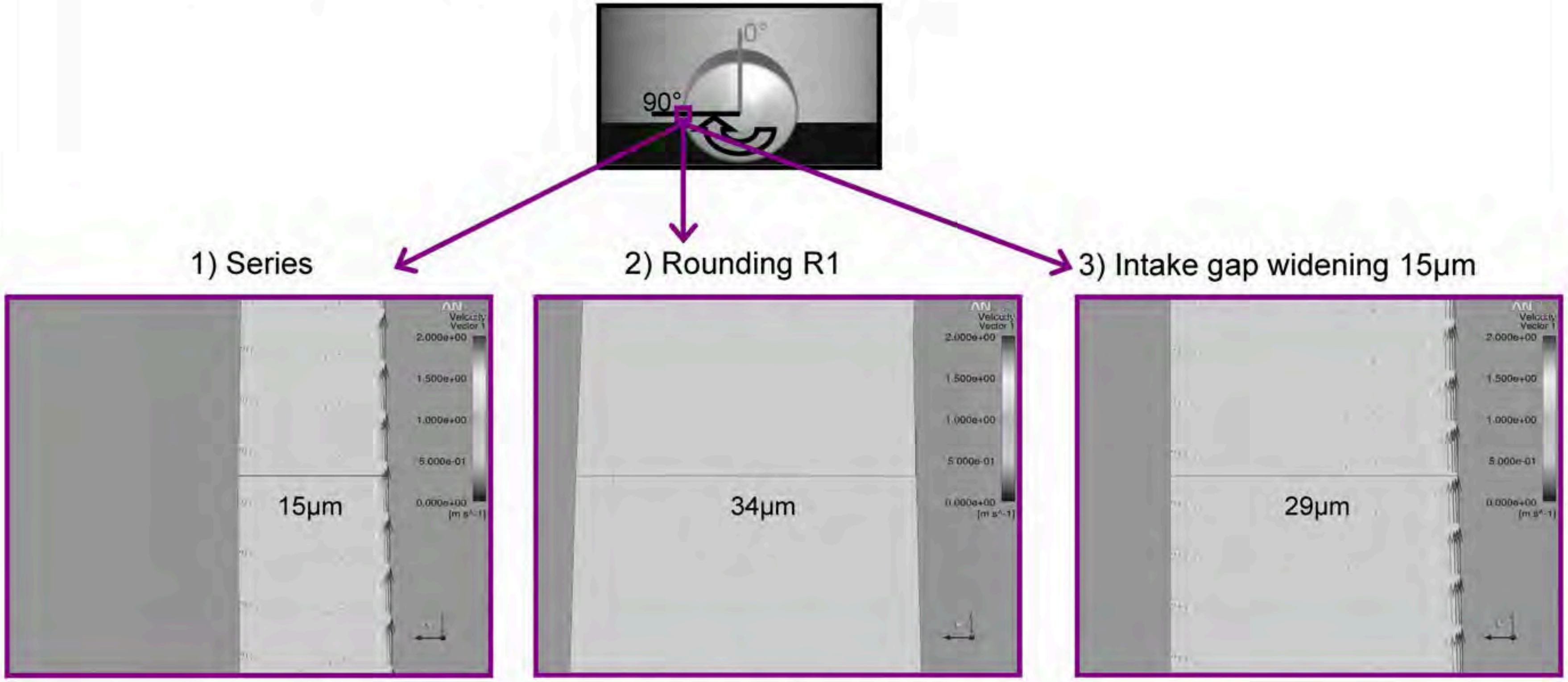
BOSCH

	Series production	Rounding R1	Intake gap widening 15µm
CFD calculations speed n_p=1000rpm			
CFD calculations pressure n_p=1000rpm			
	max. pressure in front of the sliding bearing: 100 % (reference value)	max. pressure: 94 %	max. pressure: 75 %

BOSCH

Design hydrodynamic sliding bearing influence geometry leading edge on the flow field

Speed profile at 90°:

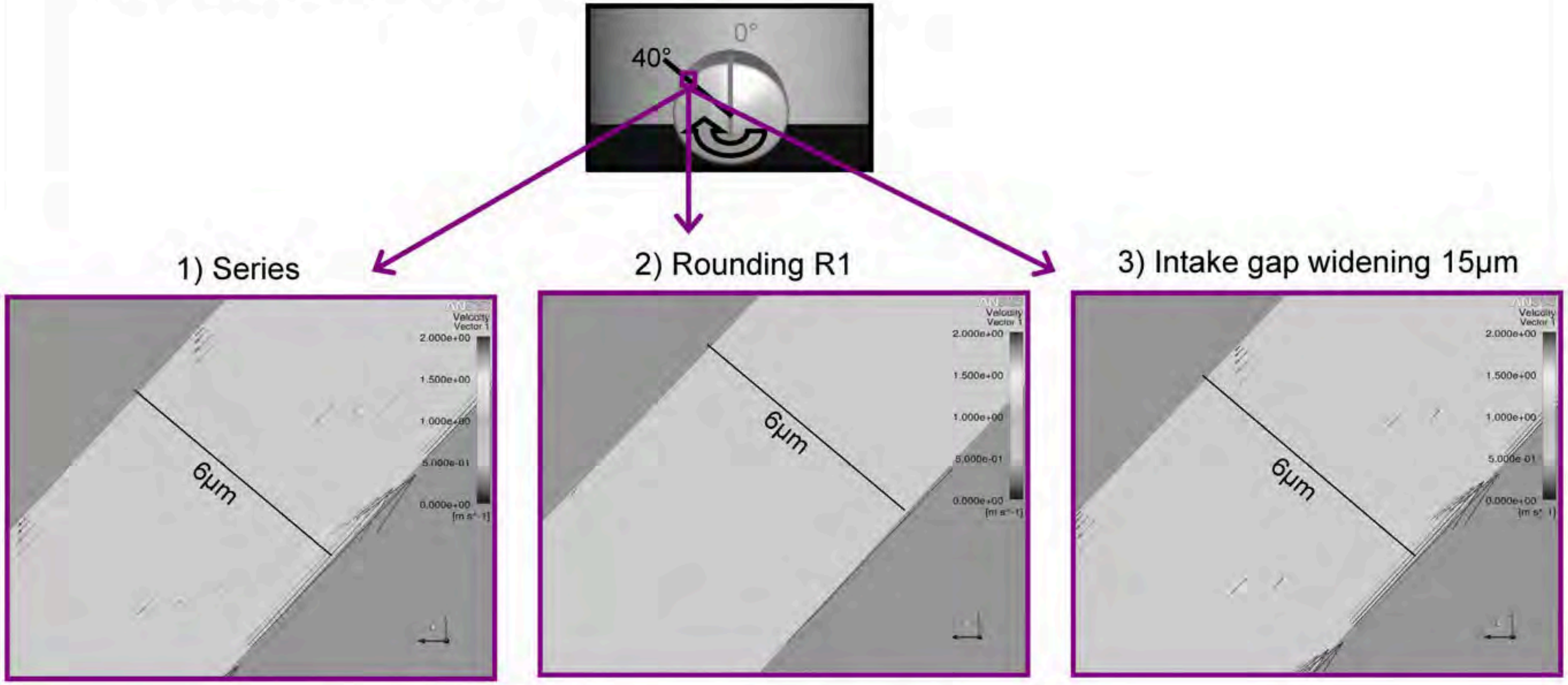


Speed profile is stretched at excessive play

BOSCH

Design hydrodynamic sliding bearing influence geometry leading edge on the flow field

Speed profile at 40°:



same speed profile since the gap size is the same

BOSCH

Figures n_p=4500rpm; p_{Rail}=1800bar		Deadline: Wk 3/2011		
Load		**Series production**	**Rounding R1**	**Intake gap widening 15 µm**
n_p=1000rpm p_{Rail}=1800bar	p_{ToT} [Mpa]			
	p_{ASP} [MPa]			
	h_{min} [µm]			
n_p=4500rpm p_{Rail}=1800bar	p_{ToT} [Mpa]			
	p_{ASP} [MPa]			
	h_{min} [µm]			

BOSCH

Further work

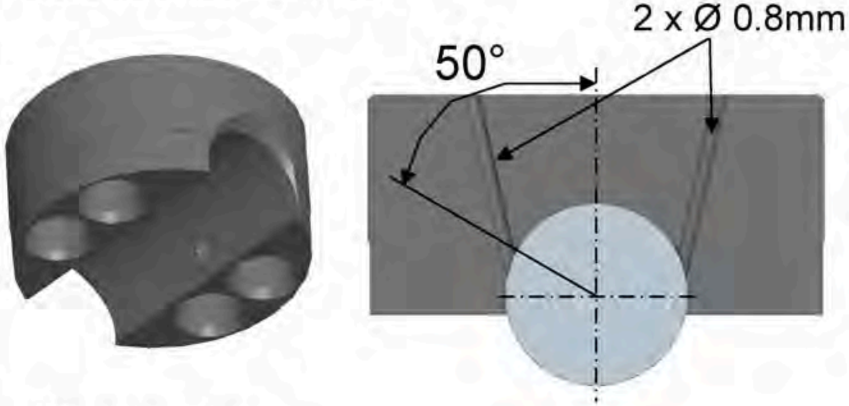
1. Evaluation using simulation
   CFD (2D-current) — Series ;rounding R1 ; intake gap widening
   EHD (EXCITE) — Series ;rounding R1 ; intake gap widening

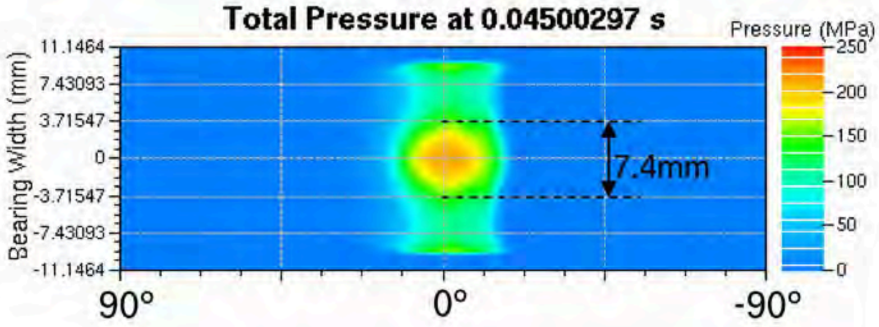
2. Parts procurement:
   Series RP1.1
   Rounding R1
   Intake gap widening 15µm
   Intake gap widening 18µ, 1,2mm

3. Testing:
   - Stribeck inspections
   - Overload test QALT
   - Start-stop-temp.overload test
     MSS-TSTOP

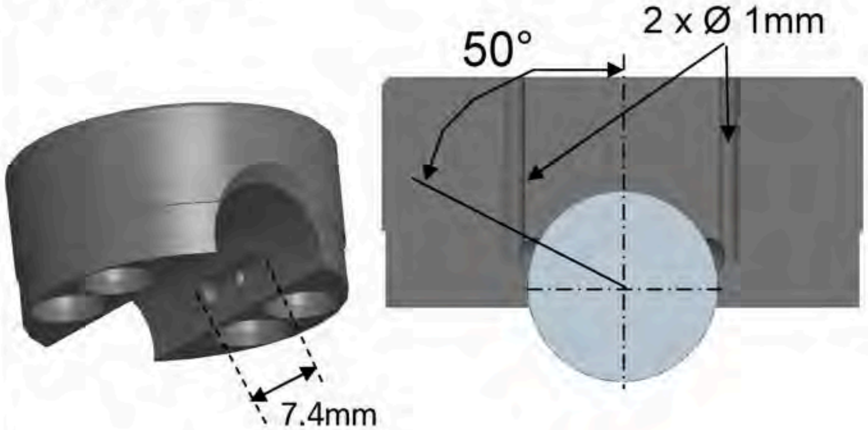
BOSCH

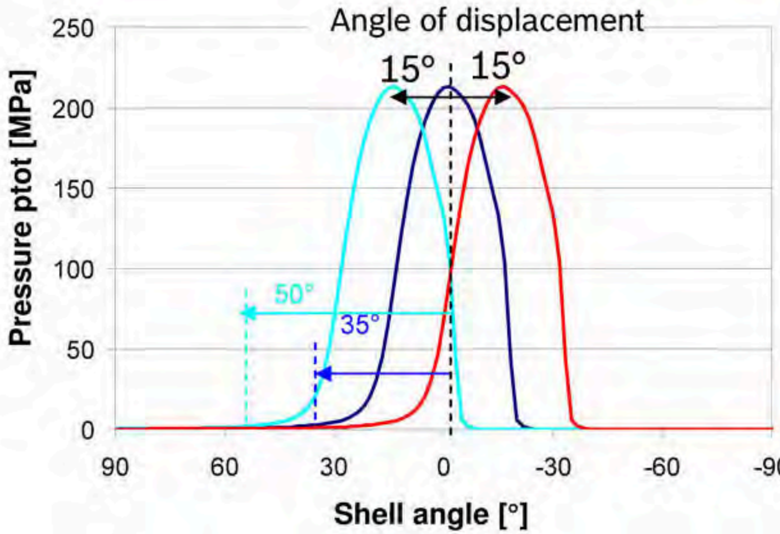
Lubrication holes





Oil grooves





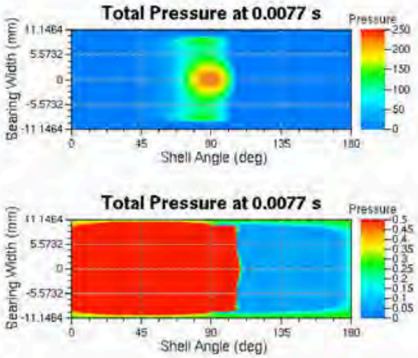
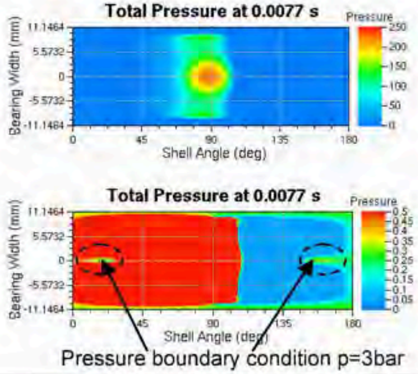
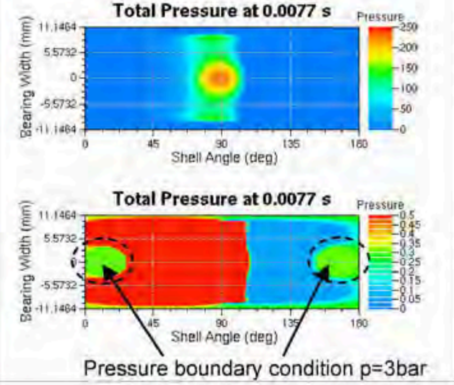
BOSCH

	Series production	Lubrication hole	Oil grooves
CFD-calculations speed n_p=1000rpm	[redacted]	[redacted]	[redacted]

Deadline: 1/2011

BOSCH

EN590 @70° kin. Viscosity 1.26 mm²/s RS2863

Figures n_p=4500rpm; p_{Rail}=1800bar				
Load		**Series production**	**Lubrication hole**	**Oil grooves**
n_p=1000rpm p_{Rail}=1800bar	p_{ToT} [Mpa]	215		
	p_{ASP} [MPa]	71		
	h_{min} [µm]	0,870		
n_p=4500rpm p_{Rail}=1800bar	p_{ToT} [Mpa]	226	227	228
	p_{ASP} [MPa]	3.91	3.93	3.94
	h_{min} [µm]	1,593	1.59	1.586

Further work

1. Evaluation using
   CFD (3D-current) — Series ;lubrication holes; lubrication grooves
   EHD (EXCITE) — Series ;lubrication holes; lubrication grooves

2. Parts procurement: — Lubrication grooves
   Lubrication hole

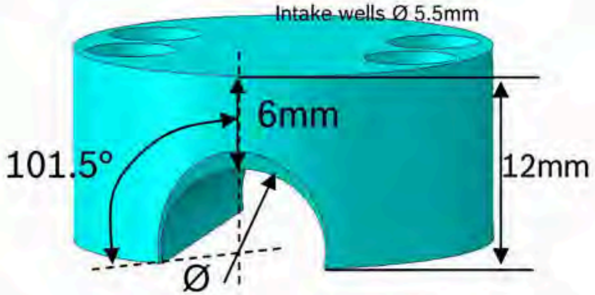
3. Testing:
   - Stribeck inspections
   - Overload test QALT
   - Start-stop-temp.overload test
     MSS-TSTOP

BOSCH

Summary reduced roller enclosure

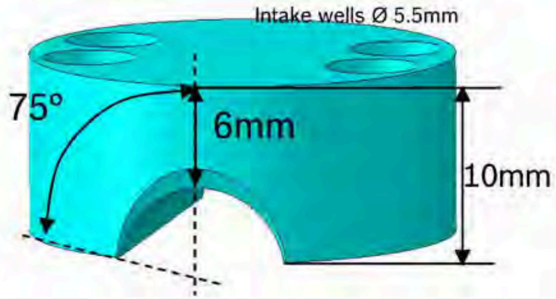
Variant reduced enclosure angle roller support

Roller support series enclosure 200°



Roller Ø 10mm
Connector 6mm (roller support-thickness 12mm)

Roller support reduced roller enclosure 150°



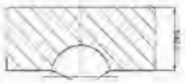
Roller Ø 10mmConnector 6mm (roller support-thickness 10mm)
Opening angle 150°

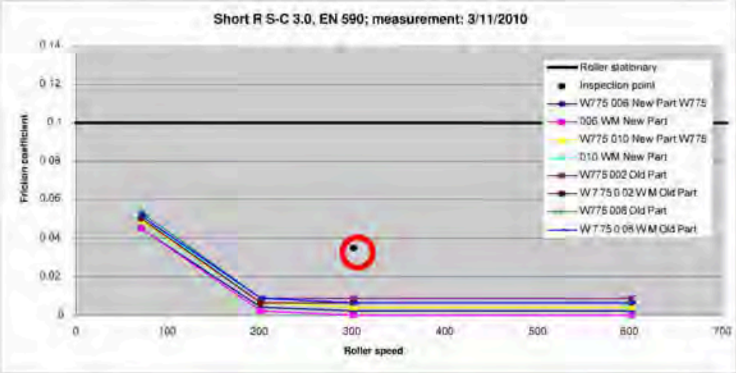
BOSCH

Stribeck curves in comparison with EN590

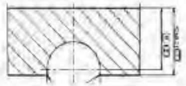
EN 590

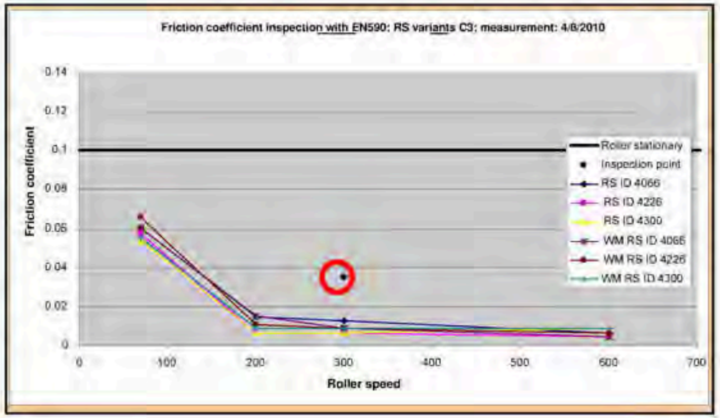
Reduced enclosure 150°





Series enclosure 200°





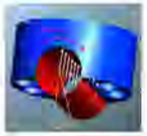
-> Friction behavior of both variants comparable

-> Startup behavior has tended to improve if the closing angle is reduced

○ => Series inspection point

BOSCH

EHD calculation in comparison



Load case: n_P= 1000rpm, p_{Rail}= 1800bar, 0.73mPas @ 70°C Arctic-Diesel

Roller support models	Characteristics in roller support-middle				Total	Protection against slippage @TDC
	Max. lok. Total pressure [MPa]	Max. loc. Pressure limit [MPa]	Min. gap height [µm]	Friction loss density setpoint [W/mm2]	Friction loss limit [W]	
 *Series current status*	**213**	**100**	**0.103**	**8.28**	**224**	**2.9**
 *Reduced enclosure*	219	99	0,103	8.63	227	2.9

-> *Roller support* with reduced enclosure, local characteristics and protection against slippage is comparable to the series roller support (@TDC)

BOSCH

Further work

Other measures discussed during the technical meeting Audi/RB:

- Angle of wrap 250°

- Straightness requirements

  Center accentuation roller / roller
  Support edge accentuation roller/ camshaft

BOSCH

Agenda

1. Design hydrodynamic sliding bearing roller/roller support

2. Hypothetical damage profile drivetrain

3. Startup behavior roller

4. Variant for improving the lubrication of hydrodynamic sliding bearing

5. **Other possible measures for increasing the robustness of WWU**

6. Turning angle acceleration, measurements Audi Q7

BOSCH

Possible WWU-features in development phase

	Package	Resp.	Measures platform	Prerequisite for customer delivery CP4.2	Result RB	
1.	**Power transmission roller/cam** Finish direction camshaft Partially finished cam track	[redacted] [redacted]	Warm-up trial/roughness Temp.tests/QALTS Warm-up trial/temp. tests MSS-T-STOP; GRV/kerosene ER	QALT MSS-T-STOP	12.2010 01/2011	Non-responsive content removed
2.	**red. Drivetrain loading** Pistons Ø 5.5 + stroke 7.5 3 Optimized cam	[redacted]	MBL2000bar; determination of characteristics Volumetric efficiency characteristics diagram application influence Pressure dependency	n-STOP 200h	01/2011	Non-responsive content removed
3.	**Support patterns hydrodynamic sliding bearing** Cylindrical roller Lubrication sliding bearing/ roller crest Spherical cams 3 Optimized cam	[redacted]	Design drivetrain components Producibility drivetrain components ER Kerosene/GRV Warm-up trial (HSC/overload) CER500h / PER2000h	ER Kerosene/GRV QALT PER1000h MSS-T-STOP	05/2011	Non-responsive content removed Non-responsive content removed
4.	**Support patterns hydrodynamic sliding bearing** C 3.1+ Standardized layer development	[redacted]	QALT Warm-up trial (HSC/over-load)friction value Pilot projects C-coating	MSS-T-STOP	03.2011	Non-responsive content removed
5.	**Temperature interior drivetrain** RL on plunger equalization bore hole Interior pressure increase p0,üv	[redacted] [redacted]	MBL-volumetric efficiency Low pressure pulsation/cavitation Evaluation LP-pulsation in the system QALT MSS - T-STOP	n-HALT - Kerosene Function Tests System evaluation application	06/2011	Non-responsive content removed

Possible WWU-features in development phase

Other characteristics in the ongoing inspection program

1. Mass reduction moved mass optimization program
2. Roller diameter ideal optimization program
3. Leading edge geometry optimized, section 4 Non-responsive content removed
4. Reduced angle of wrap roller support Non-responsive content removed

BOSCH

Design drive CP4, contact roller - cam

Comparison of design data for various cam profiles for

W19 1 Gen load spectrum

		AUDI, W19 1. Gen			
		4.85 stroke / 1800 bar	3- compatible 4.85 stroke / 1800 bar	Half-sine* 4.85 stroke / 1800 bar	Half-sine, stroke 6.5 Ø5.5 / 1800 bar
min. radius of curvature	(mm)	14.3	16.7	15.8	14.6
maximum pressing hertz roller/camshaft	(N/mm^2)	1862	1840	1850	1594
maximum speed cams C1000	(m/s)	0.373	0.493	0.42	0.589
$Md_{max; (no\ dynamic)}$	(Nm)	22.9	30.4	25.6	26.2
$Md_{min; (no\ dynamic)}$	(Nm)	-2	-2.6	-2.8	-2.4
Md_{max}	(%)	100	133	112	114
expected failure-mileage	(km)	1,110,000	1,239,000	1,169,000	3,001,000
Safety @ 300,000 km	(km)	3.7	4.1	3.9	10.0

* expected values

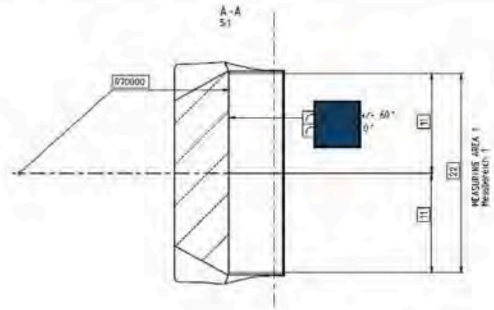
BOSCH

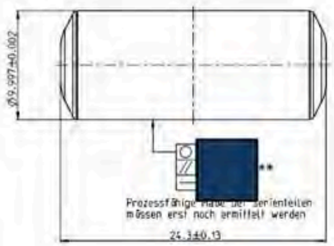
WWU roller tappet advancement

Objective: Roller lubrication improvement, improved definition of the bearing surface edge area

Characteristics

- Roller support with lateral cooling cross sections
- Roller support with sliding bearing edge waste
- Roller support with C3.1+ coating
- Cylindrical roller without edge waste and without crest coating
- Cams with roller contact edge waste





BOSCH

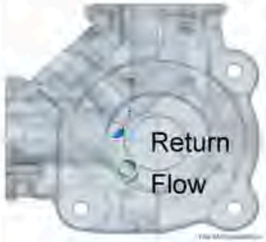
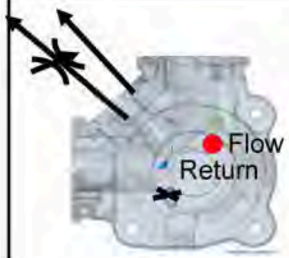
ENTIRE PAGE CONFIDENTIAL

EA11003EN-00580[24]

Return connection on tappet space compensation hole

Objective: Temperature reduction and ventilation

Operating conditions: n=1000 rpm, P_{Rail}=2300 bar, T_{Zul}=40°C, $Q_{Kühl}$=150 l/h

	Series up to Wk 47	RP2	RP2 + RL from connection hole, metering unit to connection hole	RP2 + RL from connection hole, metering unit to interior
				
T_roller support[°C]	**59.5 (100 %)**	**54.1 (-10 %)**	**47.5 (-20 %)**	**In progress**
T_connection hole [°C]	**57.8 (100 %)**	**57 (-3 %)**	**48 (-17 %)**	**In progress**
Problems:			- LP-Pulsations - FM-characteristic curve	

BOSCH

Possible WWU-features in development phase

Preliminary schedule for introduction of measures to improve lubrication

1. Inspection of the individual measures (subject to pattern producibility)

Measure	Simulation	Pattern	Function	Overload
Roller support-edge chamfer R1	Wk 4	Wk 5	Wk 8	Wk 12
Roller support-edge chamfer18µ/1.2mm	(done)	Wk 12	Wk 14	Wk 16
Lubrication hole in the roller support	(done)	Wk 12	Wk 14	Wk 16
Angle of wrap 150°	(done)	(done)	(done)	Wk 9
Angle of wrap 250°	Wk 8	Wk 16?	Wk 18	Wk 20
Support patterns roller support spherical, camshaft edge waste				
Cylindrical roller	Wk 8	(done)	(done)	Wk 15
High roller	Wk 8	t.b.d.	t.b.d.	t.b.d.
Roller diameter 12	Wk 10	Wk 18	Wk 20	Wk 22
Housing return connection spring chamber	-	Wk 9	Wk 10	-

- Work is discontinued with the relevant measure if the results are negative
- Prerequisite for further tracking is proof of robustness gain in the overload test
- Prerequisite is the development of overload test for proof of robustness gain

Possible WWU-features in development phase

Preliminary schedule for introduction of measures to improve lubrication

2. Combination of individual measures with verification

-	Combination of the individual measures after pre-testing	**5.2011**
-	Part sampling/100% documentation	7.2011
-	Functional tests/Stribeck	8.2011
-	Overload test	8.2011
-	Endurance test 2000h	2.2012
-	Customer pattern after 500h ER	**10.2011**
-	Customer test	5.2012
-	Possible SOP RB if test successful	5.2012*

*) additional development period for new processes approx.3 months

- Process development period depends on the measure and can be longer

BOSCH

Technical Meeting Audi

Preliminary schedule of the design inspections coordinated with Audi

Measure	Sim	Pattern	Function	QALT	MSS-ER	ER 500h	Special
Roller support edges R1	Done	Done	Done	Done	Done	Wk 22	
Roller support edges 18μ/1.2mm	Done	Wk 19	Wk 19	Wk 23	Wk 23	Wk 32	
Roller support upper edge 15μ/4mm	Done	Done	Done	DTD	-	PTD	
Lubrication holes *	Done	Done	Done	Done	Done	Wk 22	
Oil grooves *	Done	Done	Done	Wk 20	Wk 20	Wk 27	
Angle of wrap 150°	Done	Done	Done	Wk 20	Wk 20	Wk 27	
Angle of wrap 250°	Done		Process development C-coating > 1 year				
Cylindrical roller*	Done	Done	Done	Wk 23	Wk 23	Wk 32	
3-point support- concave form *	Done	Wk 22	Wk 23	Wk 30	Wk 30	Wk 30	
Roller diameter 12 *	Done	WK24	WK27	Wk 30	Wk 30	Wk 35	
Return connection spring chamber		Done	Done	Clarification of producibility t.b.d.			

- Work is discontinued with the relevant measure if the results are negative
- Prerequisite for further tracking is proof of robustness gain in the overload test/vehicle test

positive
neutral
negative

Alternatives for implementation of the examined measures
> Classification for measures which can only be implemented with a platform development
> Implementation of measures in ongoing serial projects only with project agreement and specifications

Diesel Systems

BOSCH

TF Audi Findings CP4

Overview testing of modified tappet design

Variant 1: Roller support with modified entry and exit geometry 15µm/4 mm (0445W20935)

1) Roller-roller support-QALT (pump 2011-CP4_0041)
   15 h startup program 4000rpm / 2000bar / 40°C / Arcticdiesel and thereafter
   150h at 600rpm / 2300bar / 90°C / Arcticdiesel
   Target-run time: 165h
   AS IS-status: ***Failure after 2h in the startup program with drivetrain damage***

2) Program endurance run (pump 2011-CP4_0043) 3750rpm / 2000bar / 80°C / Diesel GDK570
   Target-run time: 2000h
   AS IS-status: ***Failure after 3h with drivetrain damage***

3) Program endurance run(pump 2011-CP4_0042) 3750rpm / 2000bar / 80°C / Diesel EN590
   Target-run time: 2000h
   AS IS-status: ***Switch-off endurance run testbench (particle counter) with many position lines (R5) after 71h***

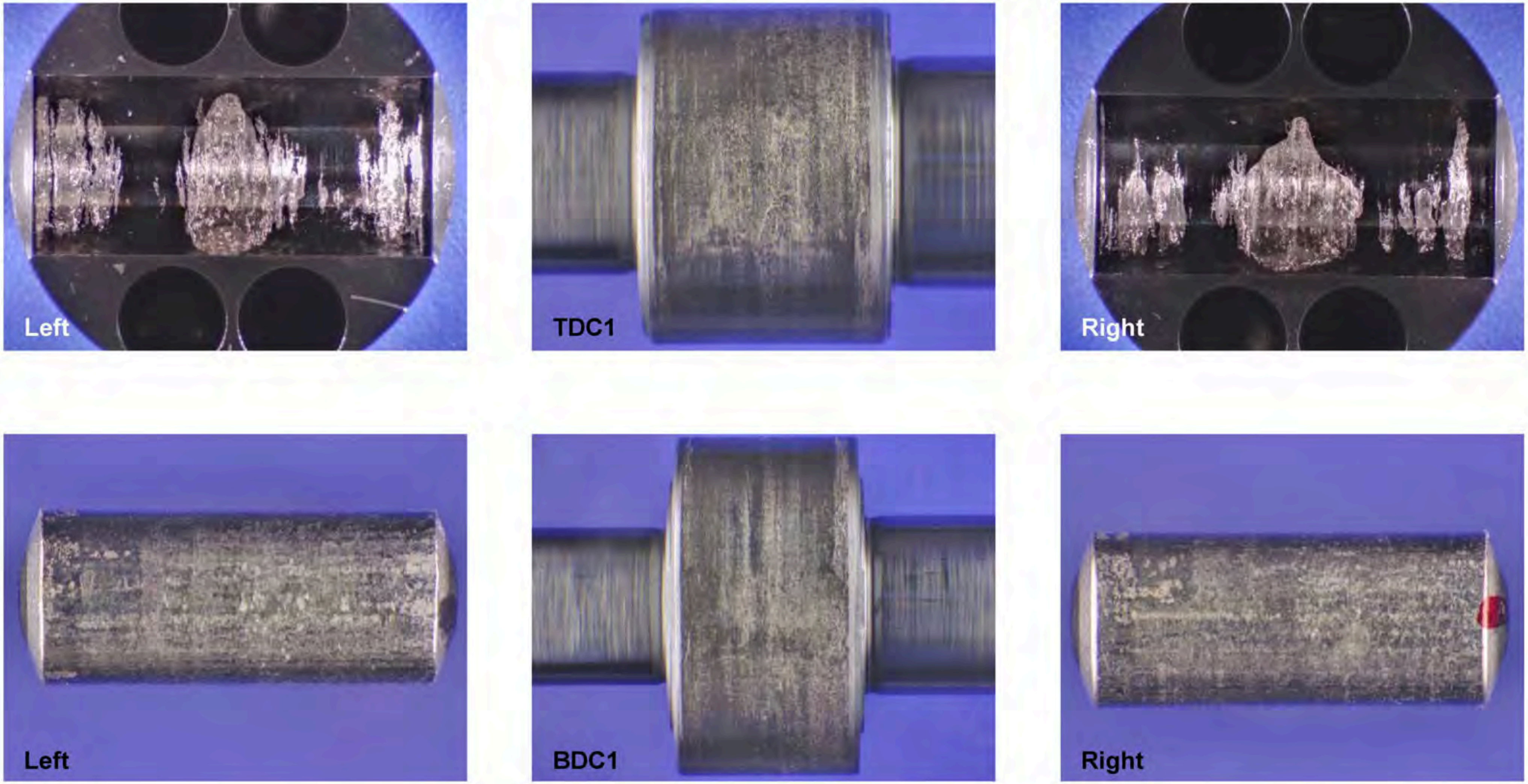
Result: The roller support design according to 0445W20935 is not suited for application in the CP4!

TF Audi Findings CP4

1) Roller-roller support-QALT - failure after 2h in the startup program

2011-CP4_0041 pump 0445 010 640 W19 BIN5 with RP2, however roller support 0445W20935

Variant 1: Roller support with modified entry and exit geometry (0445W20935)



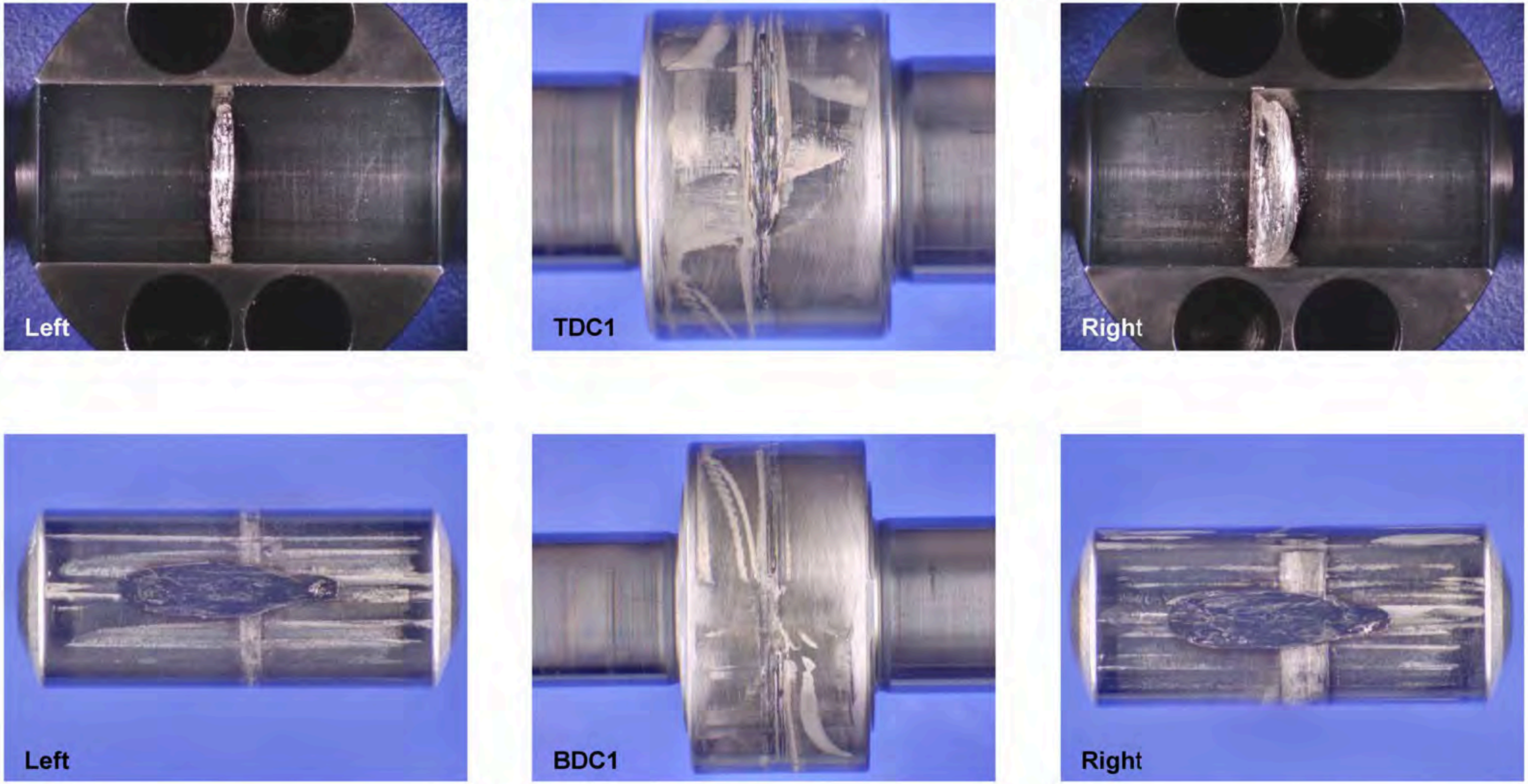
BOSCH

TF Audi Findings CP4

2) Program endurance run GDK570 – failure after 3h

2011-CP4_0043 pump 0445 010 640 W19 BIN5 with RP2, however roller support 0445W20935

Variant 1: Roller support with modified entry and exit geometry (0445W20935)



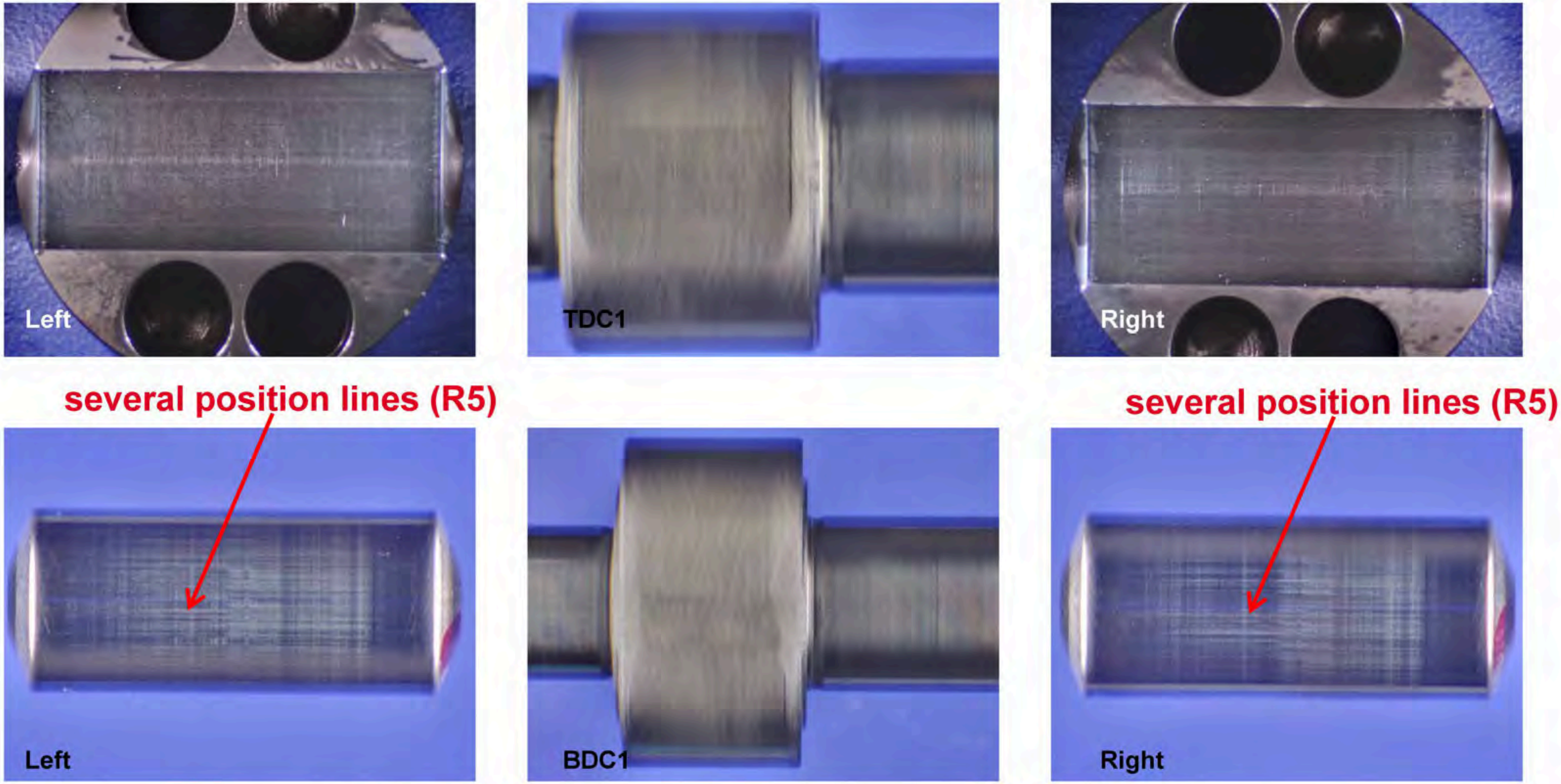
BOSCH

TF Audi Findings CP4

3) Program endurance run EN590 – bench switch-off after 71h

2011-CP4_0042 pump 0445 010 640 W19 BIN5 with RP2, however roller support 0445W20935

Variant 1: Roller support with modified entry and exit geometry (0445W20935)



BOSCH

TF Audi Findings CP4

Overview testing of modified tappet design

Variant 2: Roller support with edge chamfer R1 (0445C21644)

1) Roller-roller support-QALT (pump 2011-CP4_0248)

    15 h startup program 4000rpm / 2000bar / 40°C / <u>Arcticdiesel</u> and thereafter 150h at 600rpm / 2300bar / 90°C / <u>Arcticdiesel</u>

    Target-run time: 165h

    AS IS-status: **165h completed, in findings**

2) ISS motor-start-stop-endurance run (pump 2011-CP4_0249) 3750rpm / 2000bar / 90°C / <u>Diesel B20</u>

    Target-run time: 120h

    AS IS-status: **120 h completed, in findings**

3) Program endurance run (pump 2011-CP4_0336) 3750rpm / 2000bar / 80°C / <u>Diesel GDK570</u>

    Target-run time: 2000h

    AS-IS status: **active**

TF Audi Findings CP4

Overview testing of modified tappet design

Variant 3: Roller support with lubrication hole (0445C21657)

1) Roller-roller support-QALT (pump 2011-CP4_0250)

   15 h startup program 4000rpm / 2000bar / 40°C / Arcticdiesel and thereafter

   150h at 600rpm / 2300bar / 90°C / Arcticdiesel

   Target-run time: 165h

   AS IS-status: **165h completed, in findings**

2) ISS motor-start-stop-endurance run (pump 2011-CP4_0251)

   3750rpm / 2000bar / 90°C / Diesel B20

   Target-run time: 120h

   AS IS-status: **120 h completed, in findings**

3) Program endurance run (pump 2011-CP4_0335)

   3750rpm / 2000bar / 80°C / Diesel GDK570

   Target-run time: 2000h

   AS-IS status: **active**

Field analysis

Field analysis	
Gen.2 better than Gen.1	- 6 bar tank system (faster pressure build-up) - no small circle (better ventilation directly in the tank)
[redacted] better than [redacted]	- large stroke - different chain tensioner - rotary oscillation measurements (tests)
Q5 failure RP2 and MJ11 comparable high (especially in [redacted]	- no saddle tank - no intake jet pump for adjacent chambers - less fluid level for same fluid volumes
Failure in [redacted] higher in summer	- viscosity?
Kaluga-effect?	- present?
4- and 8-cylinder better than 6- and 12-cylinder	- stroke larger - ratio higher 1:1 - different assembly position (cyl. to the right not standing at 90°)
End of line-failure BOSCH correlate with MJ08-failure in the field	- impact of production
etc.	

Air in the system

High-pressure fuel pump CP4
- **P: Cannot be completely ventilated because of total volume**
- Tests — M: Self-ventilating pump => new Housing design, OV etc.
- M: Optimized electric fuel pump control for reduction of the air volume
- E: Optimum ventilated HP pumps

Cold test motor [redacted]
- **P: Air in the HP system**
- M: High-performance conveyor pump for prefilling prior to 1st rotation
- E: Optimally ventilated system with the exception of residual air in pump that cannot be ventilated
- E: Reduced initial start times in the vehicle plants

Ventilation in the vehicle plants
- P: Air in the system in spite of complete ventilation of CP4 range in advance
- M: Specify time (and speed?) after initial start of vehicle and implement in all plants
- Tests — M: Optimized roller operating program for complete ventilation of contemporary pump CP4.2 > 2,000/rpm / 10 sec CP4.1 > 900/rpm completed
- Tests — M: Quick release fasteners
- Tests — M: Coupling forward / return flow vehicle side (Dorsch-Nilp-solution)
- E: No fuel leakage from the ZP4-perimeter at assembly (occupational safety)
- E: No air entry at assembly
- E: Optimally ventilated system with the exception of residual air in pump that cannot be ventilated
- E: Reduced initial start times in the vehicle plants

Component replacement in the field
- **P: Air in the system**
- M: Self-ventilating pump => new housing design, OV etc.
- M: Apply repair guidelines
- E: fast and complete ventilation of the system

Tank
- P: Air entry due to running tank dry
- M: Prevent running tank dry in the vehicle plant through repetitive filling
- Tests — M: Prevent running tank dry at the customer through software solution (motor buckling shut-off motor if nec essary)
- Tests — M: Pressure sensor in the LP circuit upstream of the HP pump
- E: Not air entry from running tank dry

Legend
- Description of problem
- Measure BOSCH
- Measure Audi
- Positive result
- Negative result
- Test to be executed - Detailed definition required

Robustness CP4, TCD and brown discoloration roller (cam)

High-pressure fuel pump CP4
- **P: Insufficient robustness roller-cam-drive**
- Tests — M: Improved inlet geometry Roller support
- Tests — M: Oil grooves(Audi-recommendation)
- Tests — M: Roller form optimized
- Tests — M: Reduced piston diameter / larger stroke
- Tests — M: larger roller diameter (same as Delphi)
- Tests — M: C-coating on MU piston etc.
- E: Reduced load / prevent slippage

High-pressure fuel pump CP4
- **P: BOSCH-TCD definition is not exact / insufficient**
- M: Comparison Gen.1 / Gen.2 technical customer documentation
- Tests — M: Air definition (free/ dissolved/ sum)
- Tests — M: Water definition EN590 / ASTM / Japan / worldwide(free/ dissolved/ sum)
- Tests — M: Return flow volume
- Tests — M: Lubrication and coolant volume
- Tests — M: Temperature prior to/ after shut-off etc.
- E: Clear design guideline for OEM

High-pressure fuel pump CP 4
- **P: Brown discoloration roller / cam - Iron hydroxide / - iron oxide**
- Tests — M: Simulate theory of development
- Tests — M: Check effect on durability / startup behavior
- M: Review past endurance runs
- E: Awareness of development of brown discoloration with EN590 fuel in the vehicle-plant and motor / vehicle-test
- E: Increased friction value in the Stribeck-test

High-pressure fuel pump CP4
- **P: End of line failure in the pumps Manufacturing plants and 0 km VW/Audi**
- M: Improve fault elimination process (Components-Ofl./ - Form)
- M: Additional optimization inspection program?
- E: End of line failure is still too high
- E: Correlation end of line failure with field failure MJ 2008

Fuels

Fuel BOSCH - plant
- P: no problem identified
- M: Compare viscosity, lubrication capacity, brown discoloration
- E: Optimum inlet CP4

Fuel motor plant [redacted]
- P: Aging capacity Bio-diesel percentage in EN590
- M: Changeover to NATO diesel in the cold and hot test
- E: no risk of aging in the tank and ZP4 engine even after extended storage times

Fuel vehicle plants VW Group
- P: Poor inlet / damage capacity for non-OK fuel
- M: Comprehensive introduction NATO diesel
- M: Introduction V-Power without Biodiesel ? - Improved lubrication capacity / but limited summer / winter suitability
- E: Optimum inlet CP4

Fuels in the field worldwide
- P: Failure CP4 with poor fuel
- Tests — M: development of a worldwide versatile, robust pumps
- Tests — M: LP system advancement, pressure sensor, optimized water-/(air) separator
- Tests — M: Prevent running tank dry
- E: Optimum inlet CP4

Determine cost assumption so that ongoing improvement processes are not continuously blocked

Advancement + production High-pressure fuel pump and software	**=> BOSCH**
Advancement + production Tank- / LP system, pressure sensor, water / (air) separator, introduction of software	**=> Audi, VW**
Warranty	**Negotiation**