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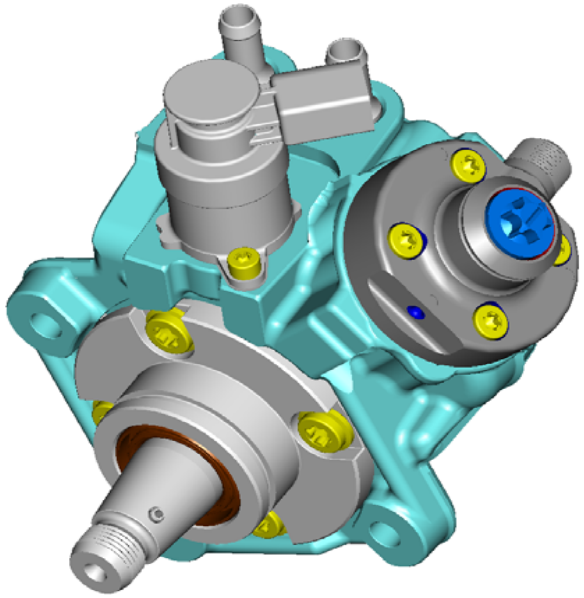

Meeting with NHTSA

December 12, 2012

EA11-003 TDI High Pressure Fuel Pump

AGENDA

1. Design, Robustness Packages & Design Margins
2. Field Data, Market Comparison, Customer Pay
3. Fuel Samples, Impact on Lubricity/Viscosity, Robustness Gain and Failure Mechanism
4. Field Return Analysis (8D Reports)
5. Root Cause Discussion
6. Test Drives / Videos
7. Misfuel Detection / Customer Information Action / Measures Against Misfueling
8. Summary & Conclusions

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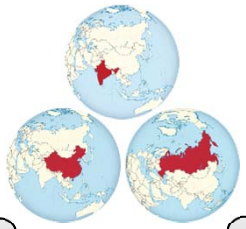
HPFP Development & Optimization

- Original development for European market
- Adaptation to US market low lubricity diesel fuel
- Improvements against off-spec fuel in fuel critical markets
- Further improvements against off-spec fuel in fuel critical markets

HPFP w/o Anti Wear Package

HFRR 460→520µm

HPFP with AWP „RP0“

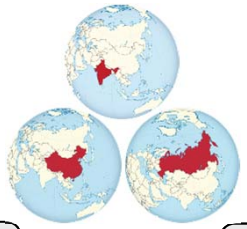


Off-spec fuel sold from fuel station

HPFP Robustness Optimization „RP1“

CP4.2

HPFP Thermal Optimization „RP2“



CP4.1

Off-spec fuel sold from fuel station

HPFP Robustness Optimization „RP1+“

RP0	High pressure plunger	C-Coating, reduced plunger clearance
RP1	Roller, roller shoe	C2.1-Coating roller shoe, reduced radial roller clearance
RP1+	Roller, roller shoe Pump housing, roller tappet	C3.1-Coating roller shoe, reduced radial tappet clearance
RP2	Thermal Optimization	Inlet&Outlet of HPFP „swapped“ to improve cooling diesel oil flow

Qualitätssicherung

RP*: Packages must be understood as „add-on“: RP0 is added to base HPFP, RP1 added to RP0 properties (actually the pump is RP0+RP1 then), RP1+ is added to the HPFP; „RP0+RP1+RP1+“ HPFP. To avoid confusion, only the latest addition is referenced, i.e. RP1 build.

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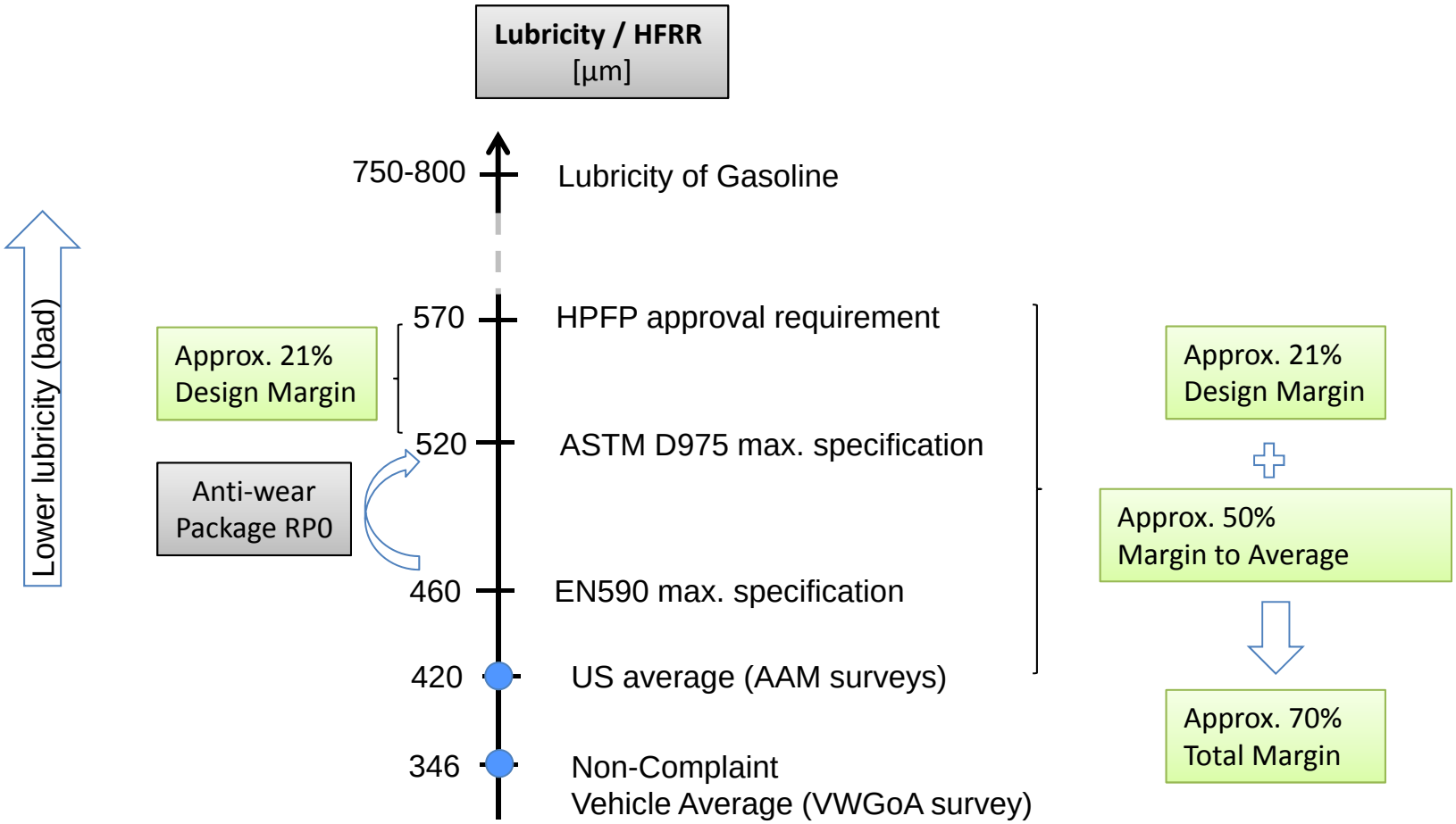
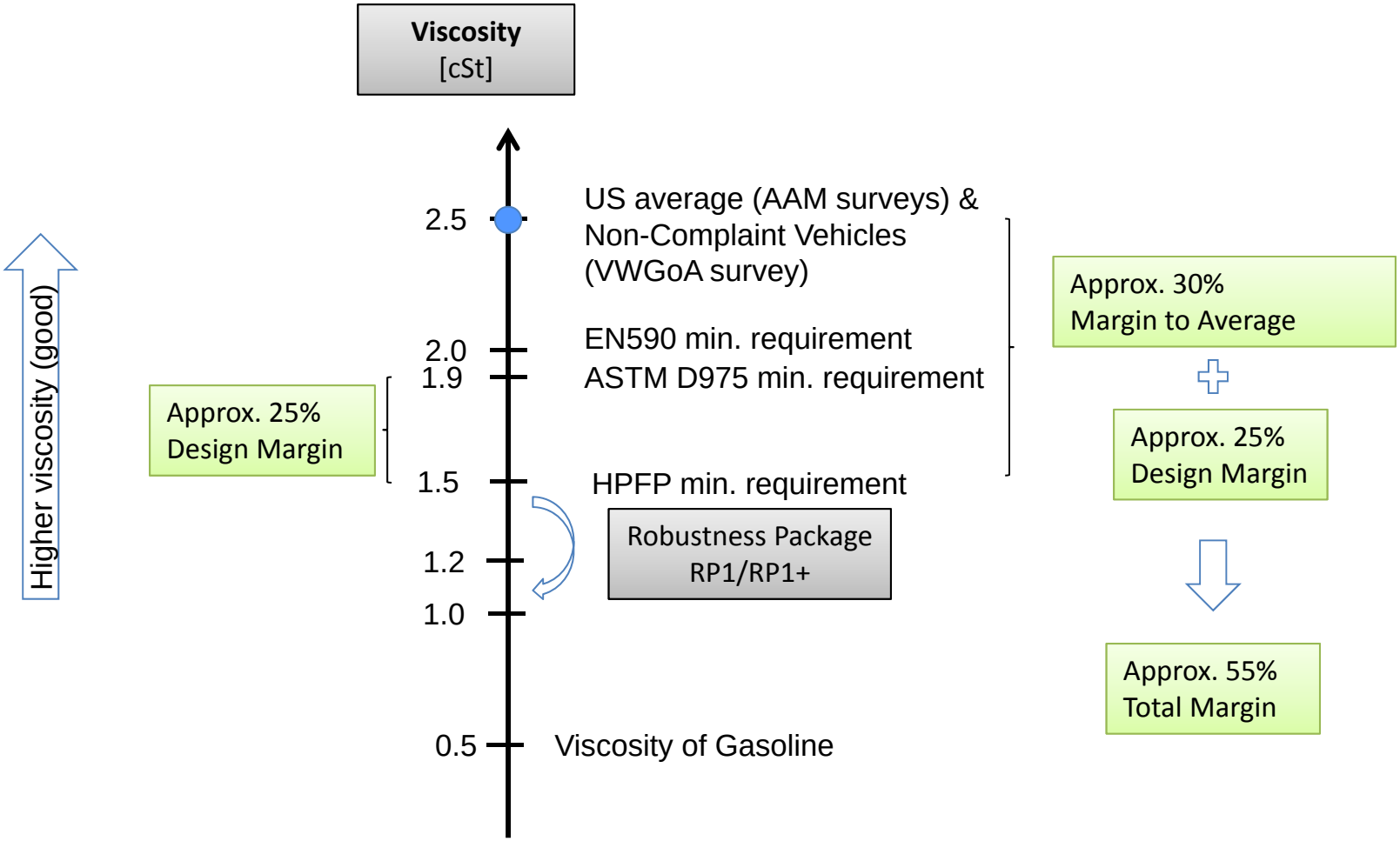
Fuel Properties & Design Margins (general approach)



Fuel Properties & Design Margins (general approach)



Approval Testing

- HPFP was thoroughly tested and evaluated in multiple bench and vehicles tests
- Reports have been provided to the agency.

Summary	Count	Passed	Failed	Failure Details
EUR reports	73	71	2	1 piston seizure, no pressure generated 1 drivetrain failure caused by water/rust
US reports	29	27	2	1 suction valve particle, no pressure generated 1 drivetrain failure, fuel quality related
Other markets	9	7	2	1 drivetrain failure, Mexican fuel 1 drivetrain failure, Argentinian fuel (HPFP not built for those fuels)

Development Tests – Overview – Reports from 2005 through 2011 as provided with the EA

Summary

- HPFP was designed to market specifications plus over 20% design margin
- Thus diesel fuel “out of specification” was considered
- HPFP has been successfully tested, validated and approved
- Approx. 100 reports have been provided to NHTSA
- Design changes (RP1, RP1+) result from poor fuel in other (non-U.S.) markets

→ **The HPFP was properly designed, tested and validated.**

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Subject Vehicles

Subject Vehicles	MY 2009	MY 2010	MY 2011	MY 2012
VW Jetta	37,889	53,088	42,477	51,538
VW Golf (A6)	-	4,446	9,068	11,231
VW Touareg	833	1,771	2,454	5,500
Audi A3	-	2,180	3,791	3,865
Audi Q7	1,121	2,459	4,152	3,416

⇨ 241,279 subject vehicles

Numbers

Count (aff. VINs)	Alleged Defect HPFP repl./Flakes/Fuel System Repl, fuel pump (all) failure, fuel sys -> stall
Warranty Claims	4,672 (4,456)
Customer Complaints	579 (532)
Field Reports	5,891 (5,208)
Crashes/Injuries	0
Part Sales	6,057

HPFP replacement, not necessarily failure

Dealers are required to call prior to an HPFP replacement

Numbers x-Chart Analysis

Misfuel Counts	Misfuels	Part Sales
Misfuels Identified	2,102	6,057
Warranty Claims	1,090	4,672
Non-Warranty / Customer Pay	1,012	1,385

Field information (FR, CC, TACS etc.) shows that customer pay parts sales normally result from a misfuel incident

→ 1,090 + 1,385 = 2475 misfuels

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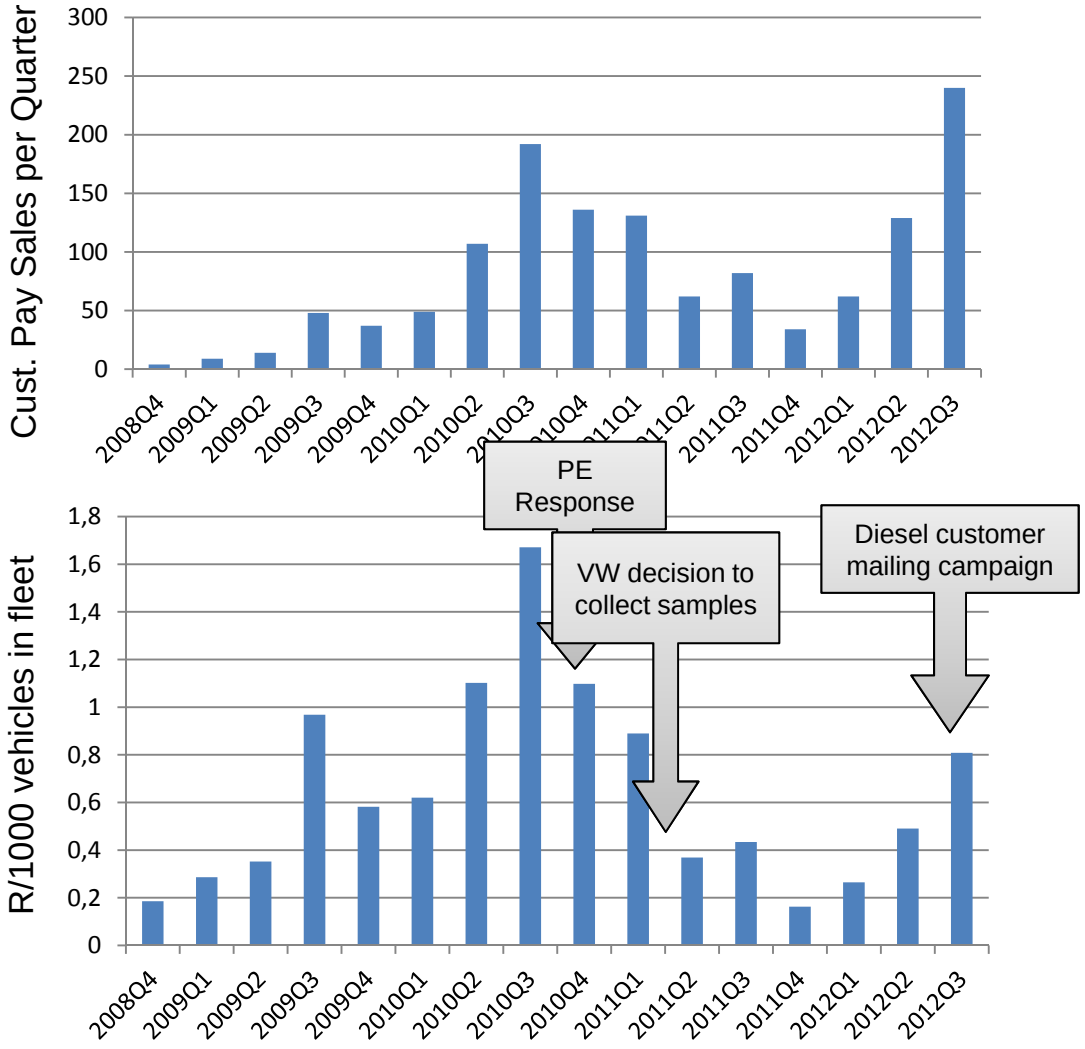
Part Sales – Customer Pay



- 1385 HPFPs have been paid by customers, although **all** vehicles/HPFPs were still covered under warranty --- Why?
- Over 1000 of these replacements contain misfuel information in VWs data
- Customer Pay went to minimum when VW started to retrieved field samples
- Customer Pay would have been even higher w/o this approach
- Customer Pay to rise with VW mailing campaign

<u>Conclusion:</u>

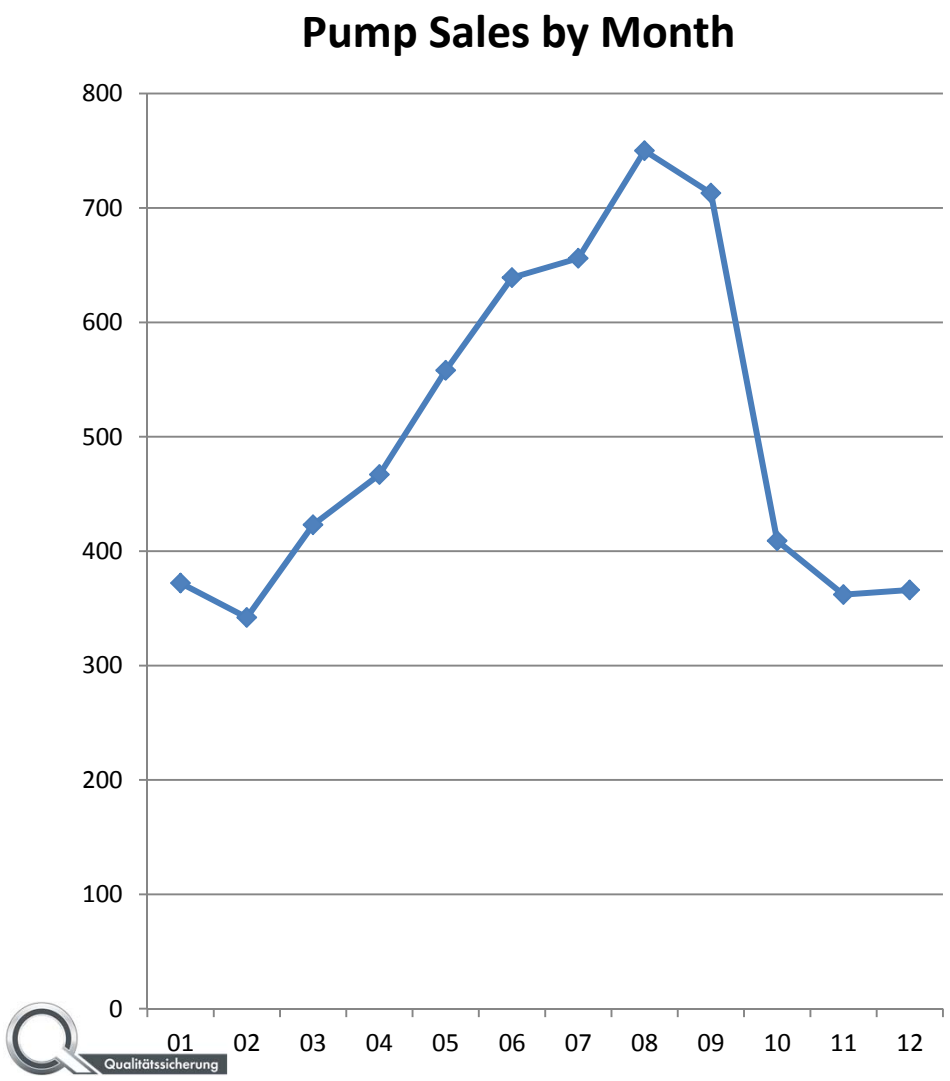
Customer Pay while vehicle HPFP is still under warranty results from misfuel incident (customer's responsibility)

Records do not disclose all misfuel incidents, depending on the actual wording used by the dealership technician etc.

Calculation: Quarterly; Number of Part Sales – Warranty Claims = Customer Pay

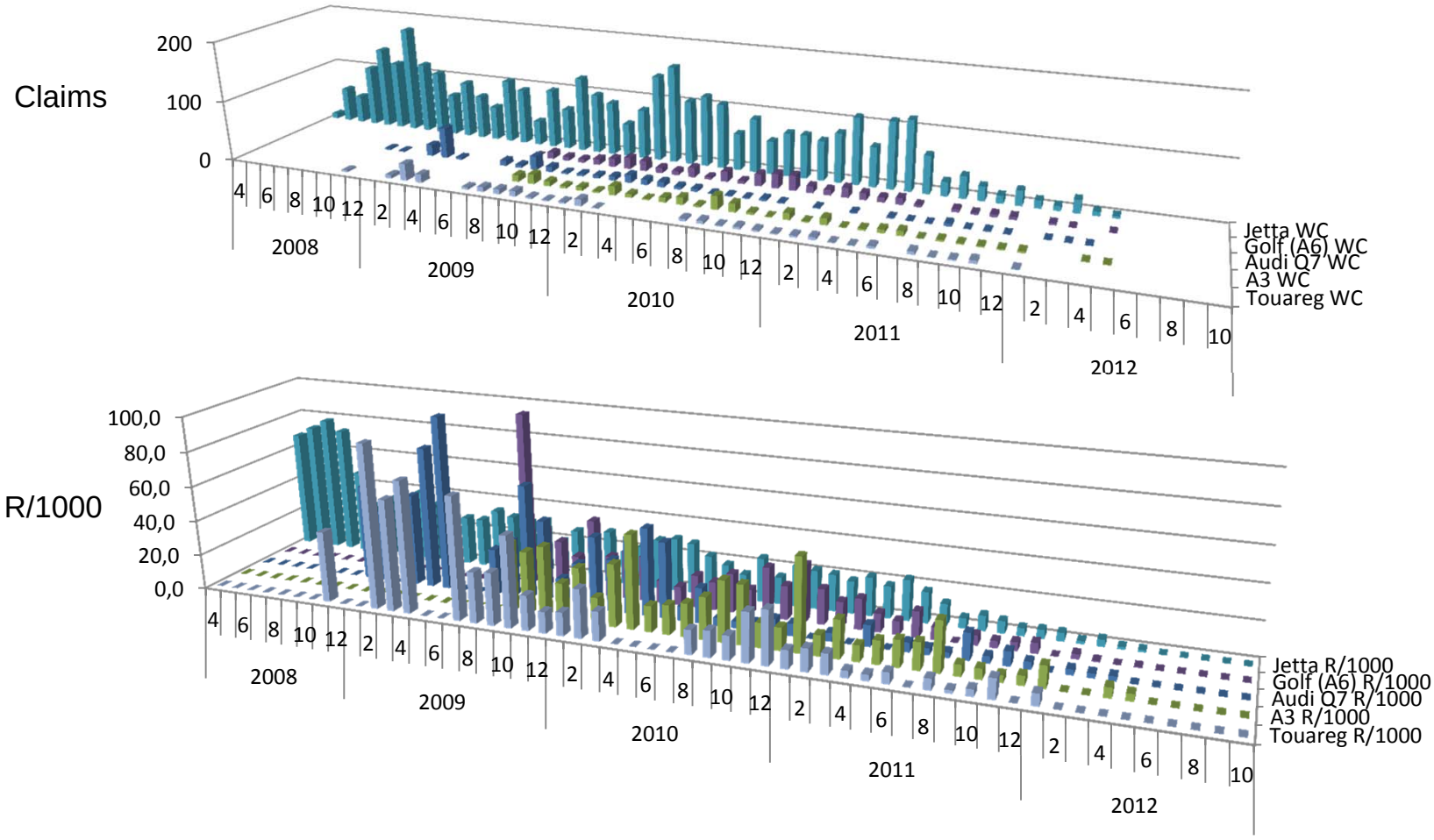
Qualitätssicherung

Part Sales – Seasonal Effect



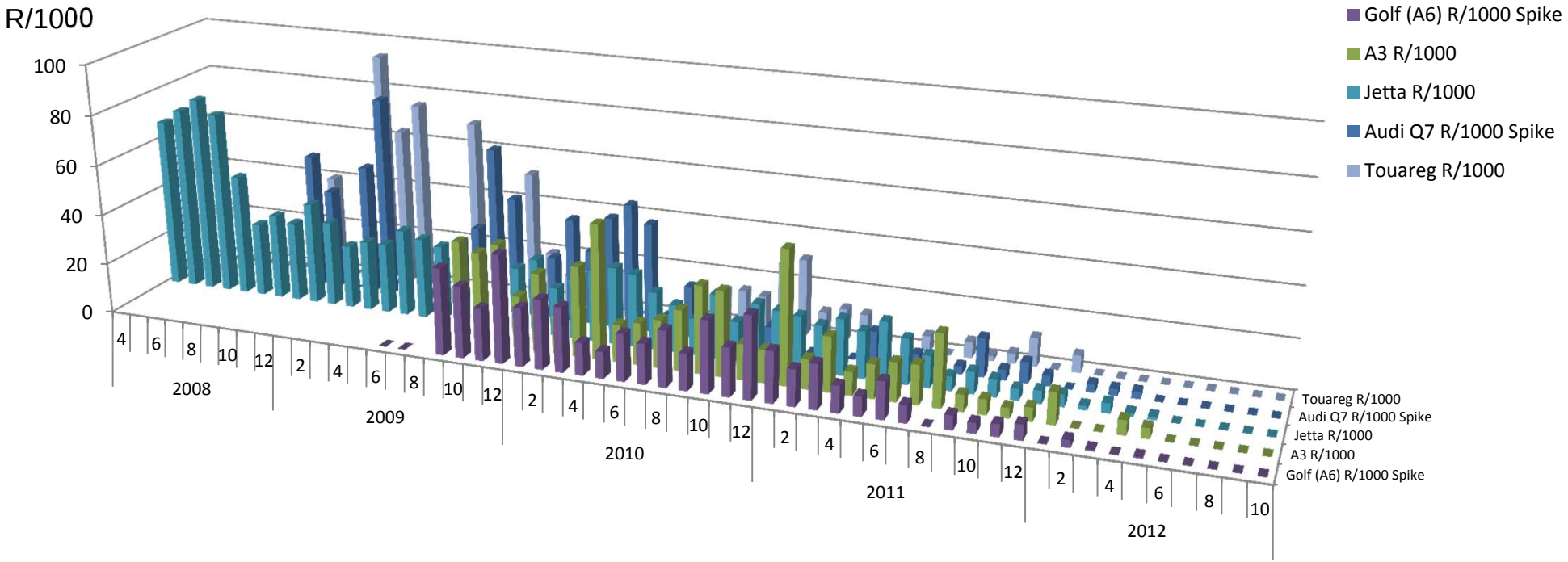
- When analyzed by season, pump sales reveal a maximum in the warm months
- This is another indication for misfuel related failures:
- Normally higher failures would be expected in winter: Winterized diesel fuel or gasoline added to diesel by customers to winterize the fuel, but actual pattern is different
- In summer actual viscosity is lower, simply depending on higher ambient temperatures.
- As viscosity is significantly reduced when gasoline is mixed into diesel fuel, warm temperatures contribute to even lower viscosity – increasing the possibility of an interrupted lubrication – leading to higher part sales in summer.

Warranty Claim Plots by month of production



Warranty Claim Plots by month of production

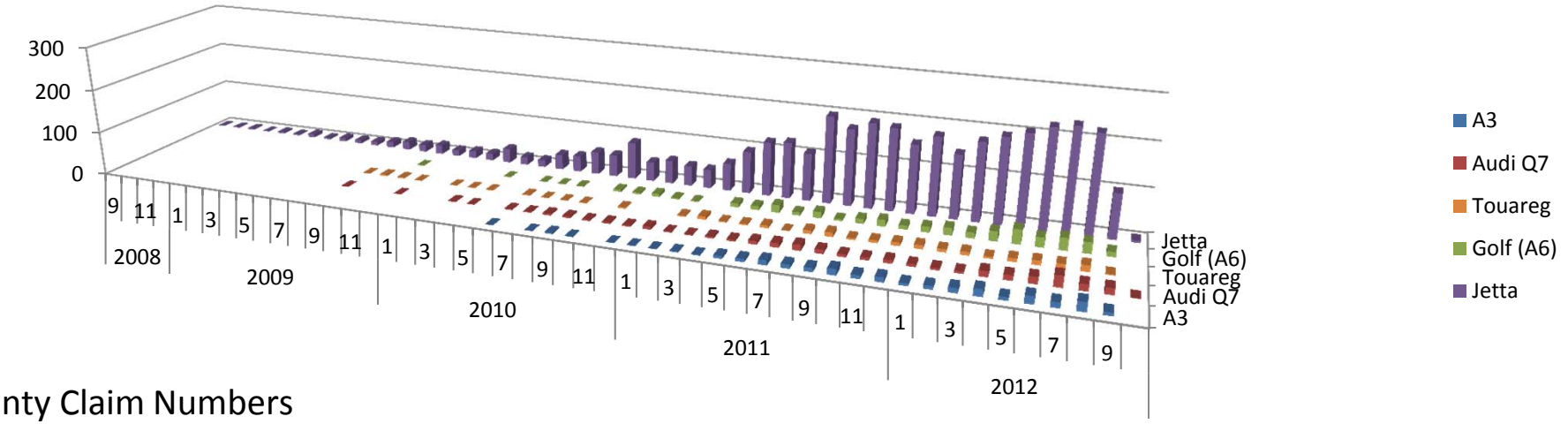
Spikes removed



- Two months with very limited production (19 & 9 vehicles) created spikes due to single replacements
- These spikes have been removed for better interpretation

→ All model lines show consistent patterns; deviations are within normal statistical spread („not significant“)

Warranty Claim Plots by Repair Date



Warranty Claim Numbers

- Many HPFPs are replaced as in abundance of caution (per repair guidelines), not b/c the HPFP has actually failed
- Volkswagen trying to receive additional HPFP samples → causes exaggerated numbers
- Increase of claims when starting to extensively collect parts, claims previously rejected are now being paid

→ Warranty data cannot be used to calculate actual failure rates (also: NTF rates)

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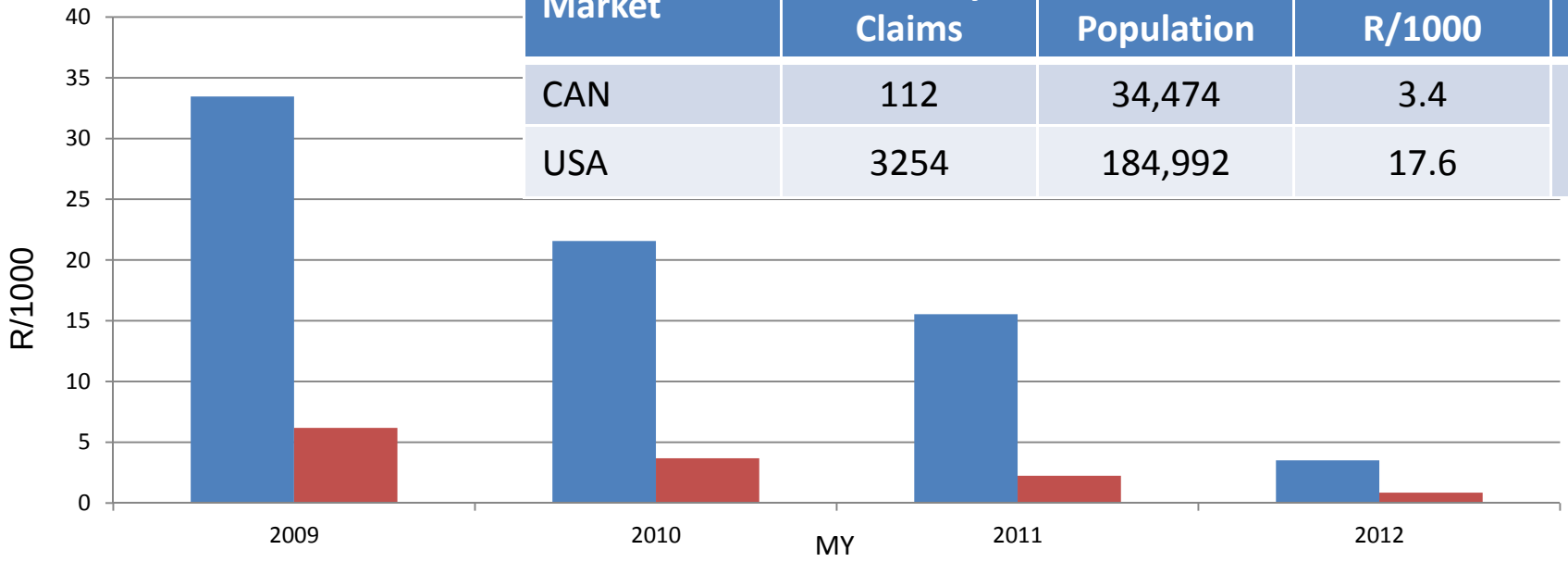
Field Data

Market Comparison USA vs. Canada (Jetta only)

Market	Warranty Claims	Vehicle Population	Rate in R/1000	Factor USA vs CAN
CAN	112	34,474	3.4	5.3
USA	3254	184,992	17.6	



- Same fuel standard, same fuel supply
- Same vehicles (model, engine, injection system, emission standard)
- Warranty Rate in USA over 5 times higher than in Canada

* same screening method, same criteria used

Customer Pay & Warranty in Canada

Part Sales	Parts
Part Sales	395
Warranty Claims	112
Customer Pay	**283**

Over 70% of all replaced HPFPs are Customer Pay, although the vehicles are covered under warranty.
→ VW does not cover misfuels under warranty in Canada
→ Customers accept responsibility for misfueling

	Population	Part Sales	R/1000
USA	241,279	6,057	25
CAN	61,323	395	6

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Fuel Samples in Complaint Vehicles

827 Samples were taken from complaint vehicles (vehicles visiting workshop with fuel system related complaint).

Viscosity examined to identify misfuels

203 samples out of spec (<1,9 cSt), 186 below 1,5 cSt (HPFP min. requirement)

Average viscosity: 0,86 cSt → approx. 82% gasoline content

→ Empty tank and the completely filled up → Engine likely will not run

→ Combustion (& lubrication) interrupted (vehicle stalling stall due to gas content)

Lubricity examined to assess increased wear

59 samples with HFRR out of specification (>520µm) – 18 are also misfuels

22 of those exceed 570µm, possibly causing increased wear

→ off-spec-lubricity is endurable for limited period of time (wear reserve)

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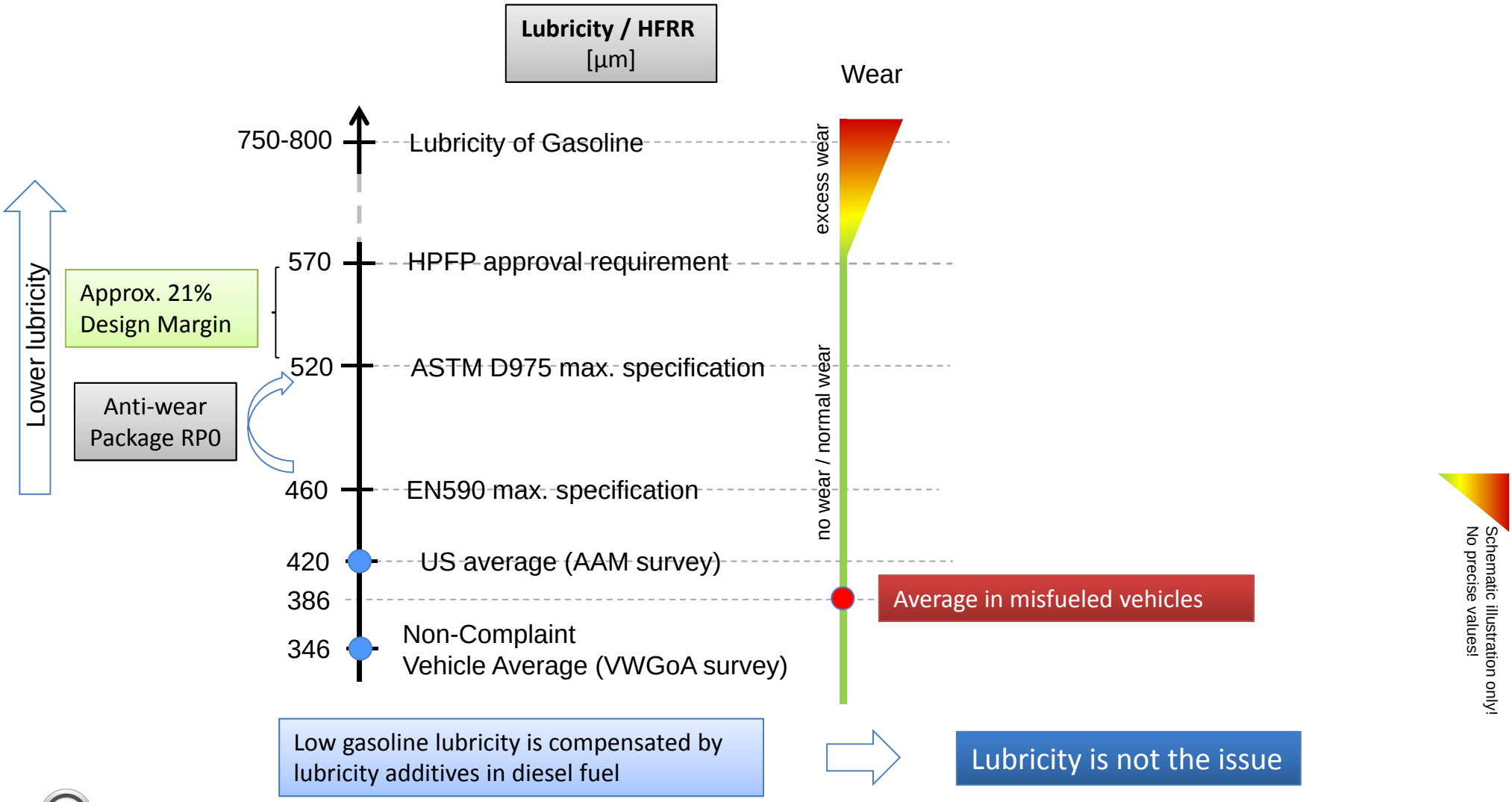
Fuel Properties & Design Margins – Applied to Fuel Samples: Lubricity



Qualitätssicherung

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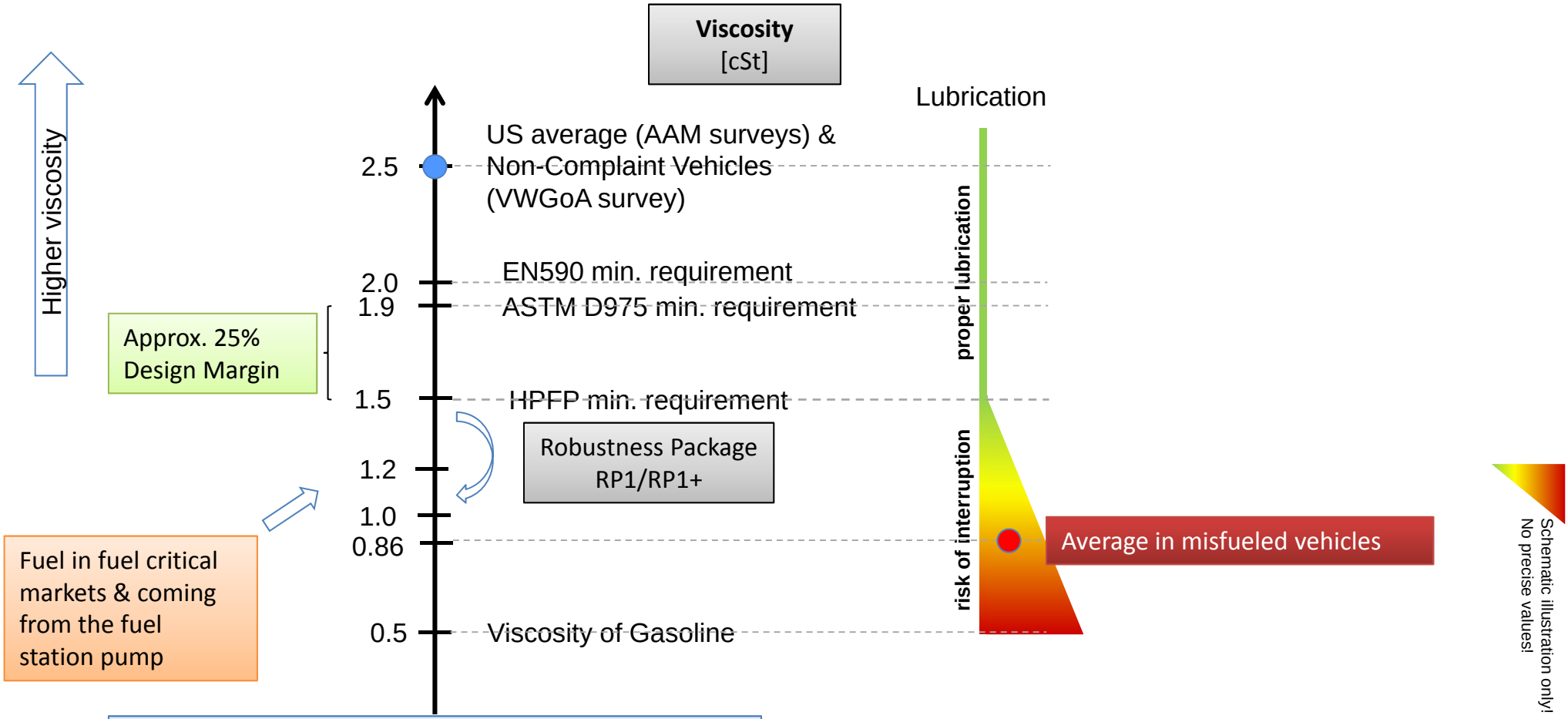
Fuel Properties & Design Margins – Applied to Fuel Samples: Viscosity



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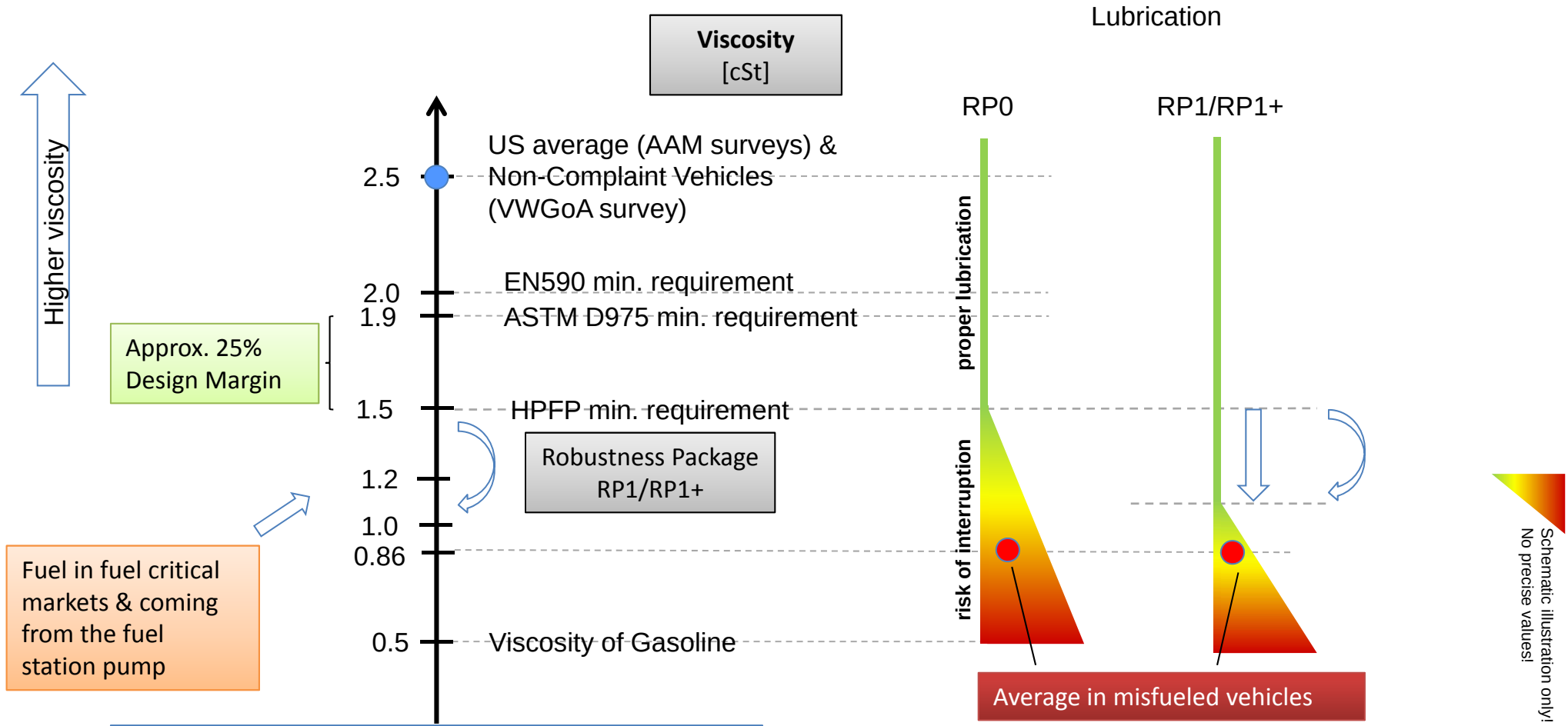
Fuel Properties & Design Margins – Effect of Robustness Packages



Robustness measures provide ability to operate with lower viscosity fuel („bad fuel“ in fuel critical markets)

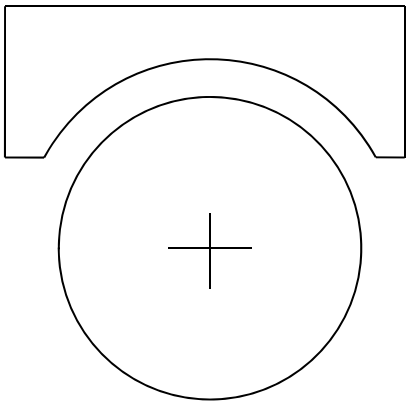
Viscosity is the issue; RP1/1+ developed to accomodate certain levels of bad fuel and also provide more robustness against gasoline contamination.

Qualitätssicherung

Friction Bearings – Effect of Viscosity

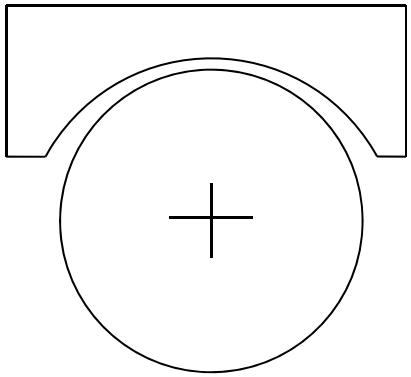
Failure Mechanism

Proper Viscosity
>1.9 cSt



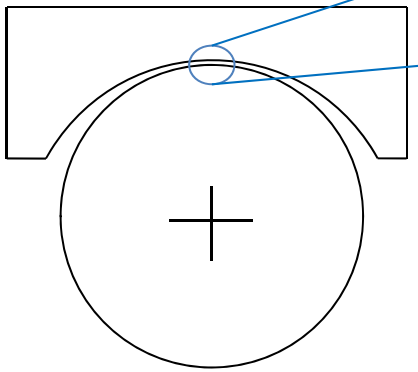
- Proper lubrication
- Proper distance of surfaces

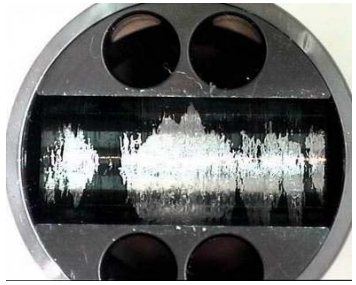
Reduced Viscosity
<1.9 cSt



- Lubrication impaired
- Reduced distance of surfaces

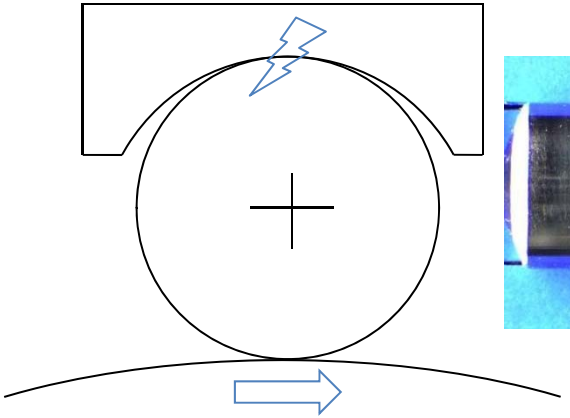
Viscosity too low
<1.5cSt





Surface Structure
Roughness

- Lubrication interrupted / Surfaces in contact
- Mixed friction / Abrasion of coatings



- Roller is stopped and slides on camshaft
- Brake marks / damage to surfaces

Fuel Samples in Complaint Vehicles

Water examined to assess corrosion (ASTM requires less than 0,02% / 200ppm)

4 samples with high amounts of water: 1,5 – 1,8 – 2,5 and >10%

→ incidents of corrosion also found in 8D reports

→ lubrication impaired

Biodiesel examined to assess use of "non-allowed" fuel, B5 required per owner's manual

79 samples with use of biodiesel >5%,

20 of those with biodiesel >10%

→ only harmful, if biodiesel deteriorates/ages; single occurrences in data and 8Ds

→ **Main driver: Gasoline Misfuel**

→ **Other contributors (water, aged biodiesel) only in single occurrences**

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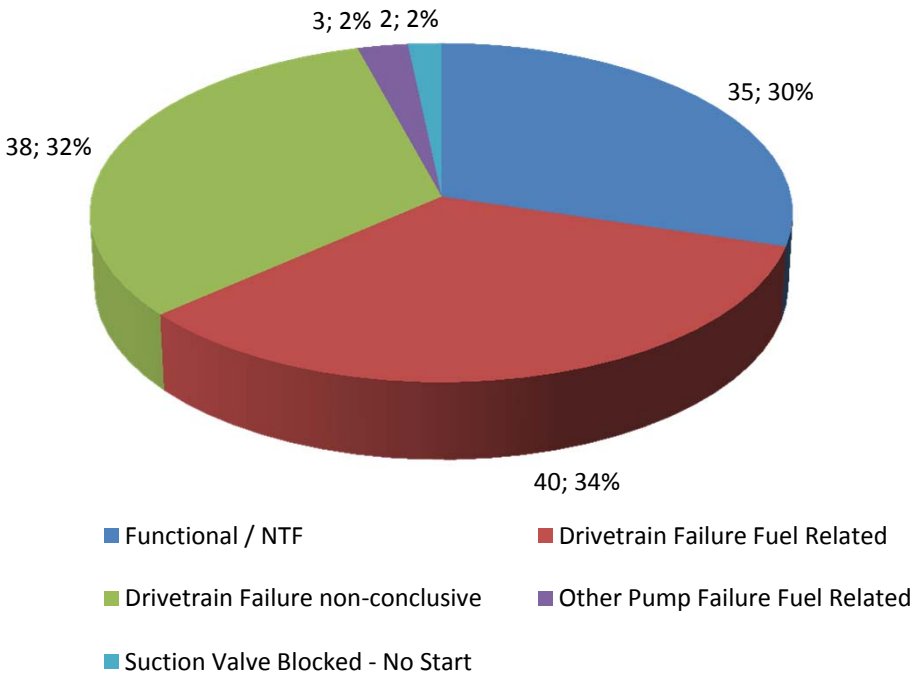
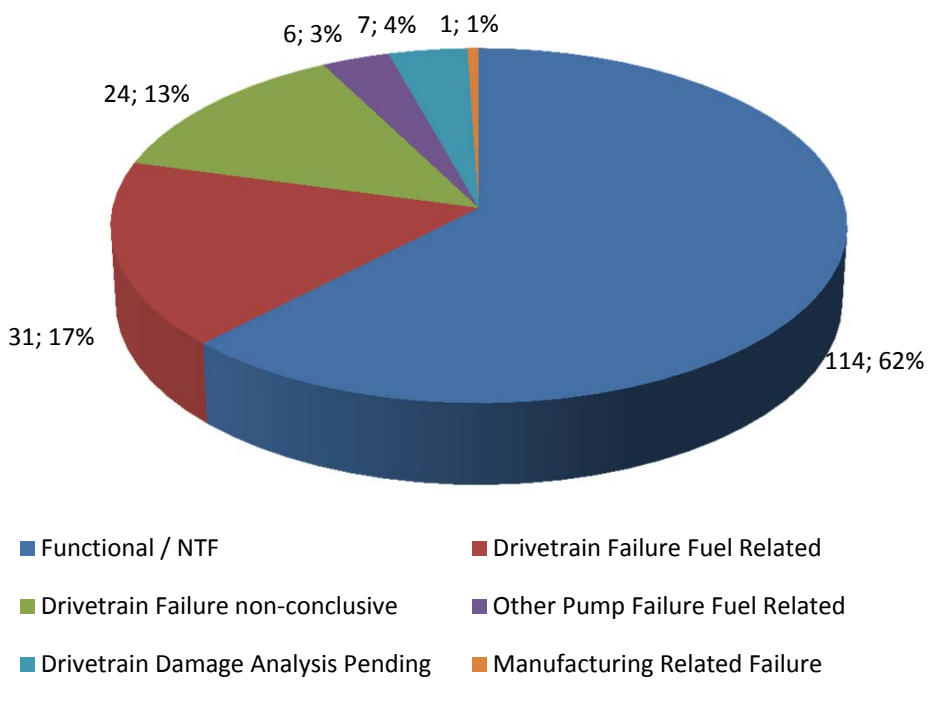
Evaluation of 8D Reports (covers all 8Ds from PE & EA)

RP0
(118 reports)



RP1/RP1+
(183 reports)



Evaluation of 8D Reports

- RP0 HPFP exhibit a damage rate of 2/3 and 1/3 no-trouble-found (NTF)
- RP1/1+ HPFPs show 2/3 of NTF results and 1/3 with damage to the pump.
- The majority (>80%) of the 8D identify either NTF or fuel related failures as cause, while the remainder does not allow a conclusion – but may also be misfuel caused.

Two Reasons:

- RP1/1+ pumps are more robust against bad fuel and can also tolerate more gasoline than RP0 pumps
- Volkswagen started to collect pumps, when RP1 was in production. This increased the amount of HPFP replacements available for 8D analysis.

Conclusion

- Robustness packages have reduced – but not eliminated – the risk of an interruption.
- Average gasoline misfuel level provides viscosity below HPFP operation limit.

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DTC – Diagnostic Trouble Code

GPL – GlowPlugLight

MIL – Malfunction Indicator Lamp

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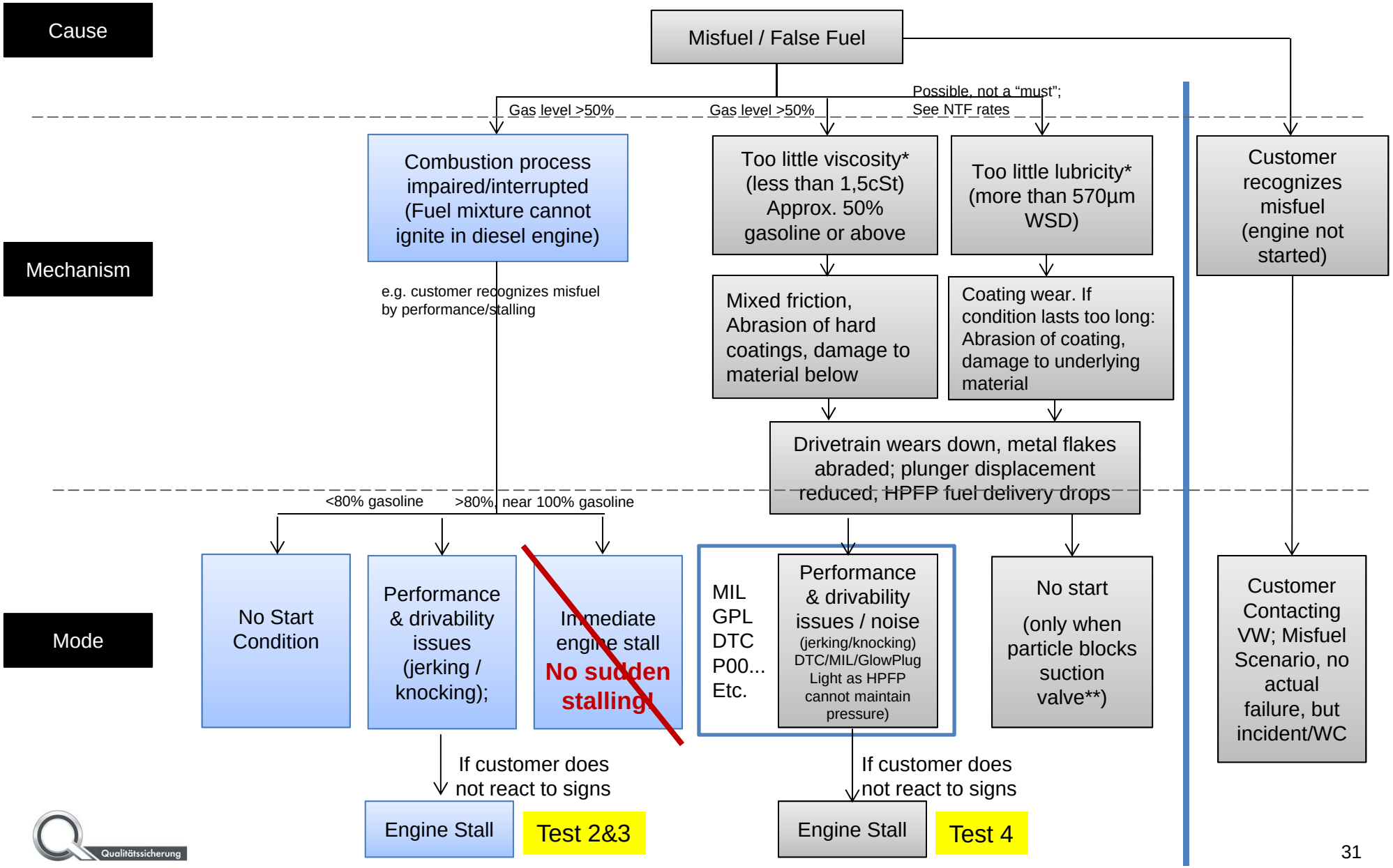
*) this is a nominal value, impact depends on actual value / engine load / exposure time

**) Please also refer to Response 19



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Misfueling Test #1

Misfueled with 5% gasoline

RP0 design level HPFP

Misfueling Test #1 – Misfuel Rate 5%

Test Results

- 378 miles traveled
- No performance problems detected
- No high pressure fuel pump damage

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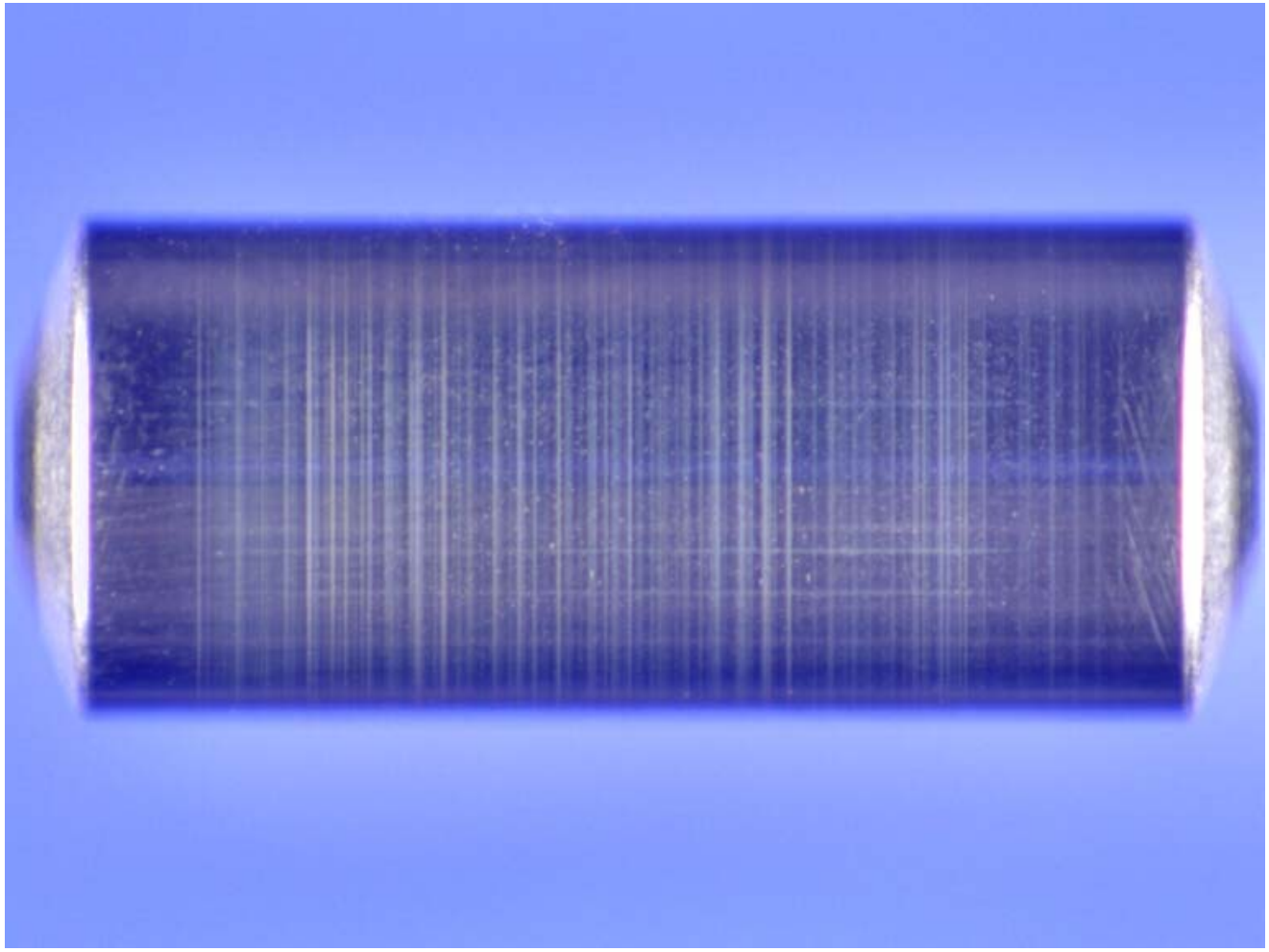
Misfueling Test #1 Misfuel Rate 5%



Non-critical standstill lines detected.

Misfueling Test #2

Misfueled with 80% gasoline

RP0 design level HPFP

Misfueling Test #2 Misfuel Rate 80%

Test results

- No damage in high pressure fuel pump
- Occurrence of initial change in engine performance at about 0.3 km (0.2 miles)
  - Knocking sound from engine
  - No spontaneous engine response
- Engine response with significant hesitation at about 0.9 km (0.6 miles)
- Occurrence of limp home mode at about 1.2 km (0.75 miles)
- End of test at about 1.5 km (1 mile)

Misfueling Test #2 Misfuel Rate 80%

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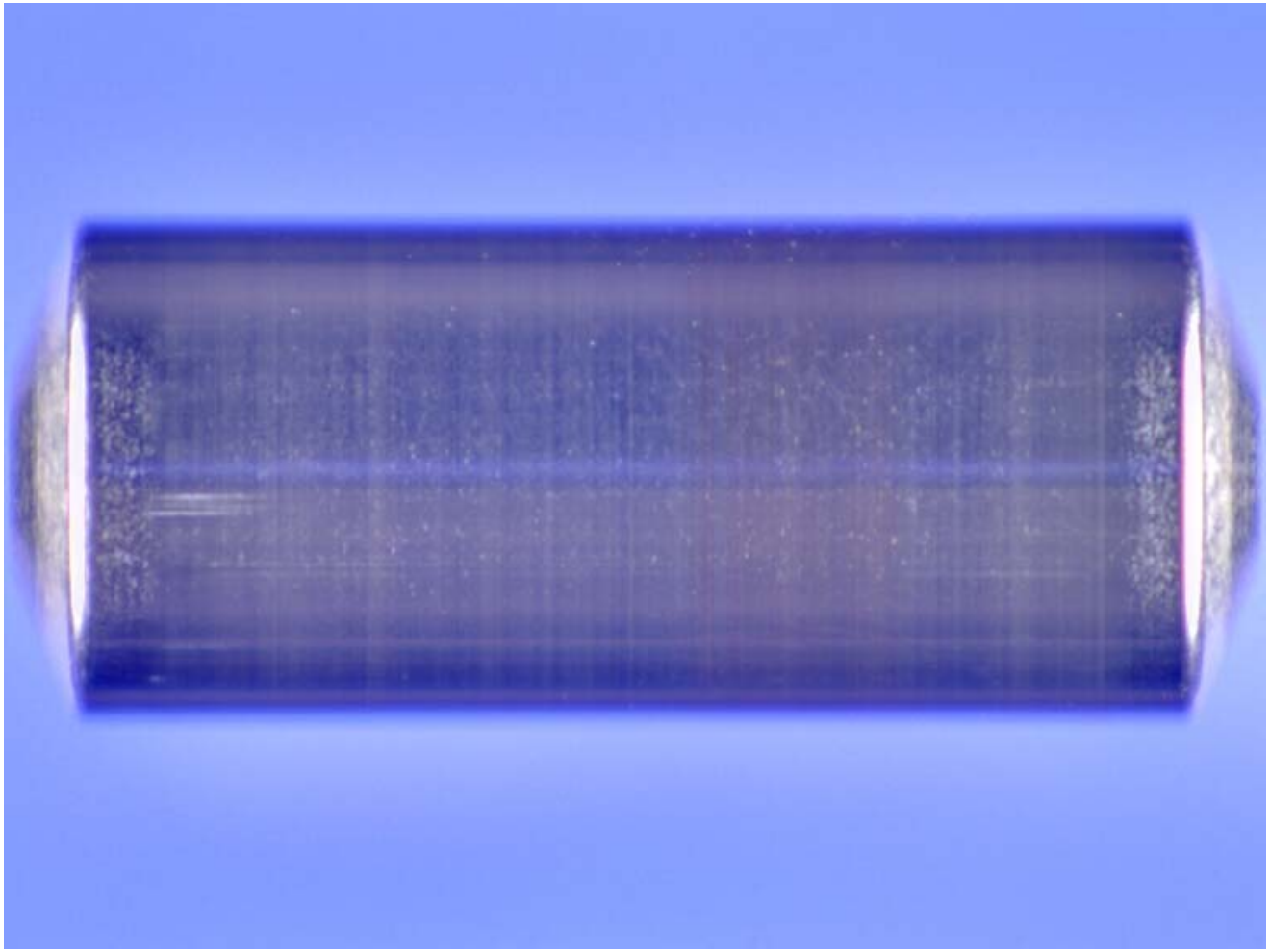
Misfueling Test #2 Misfuel Rate 80%



Non-critical standstill lines detected.

Misfueling Test #3

Misfueled with 85% gasoline

RP0 design level HPFP

Misfueling Test #3 Misfuel Rate 85%

Test results

- No damage in high pressure fuel pump
- Occurrence of initial change in engine performance at about 0.25 km (0.16 miles)
  - Knocking sound from engine
  - No spontaneous engine response
- Engine response with significant hesitation at about 1.2 km (0.75 miles)
- Occurrence of limp home mode at about 1.4 km (0.87 miles)
- End of test at about 2.1 km (1.3 mile)

Misfueling Test #3 Misfuel Rate 85%

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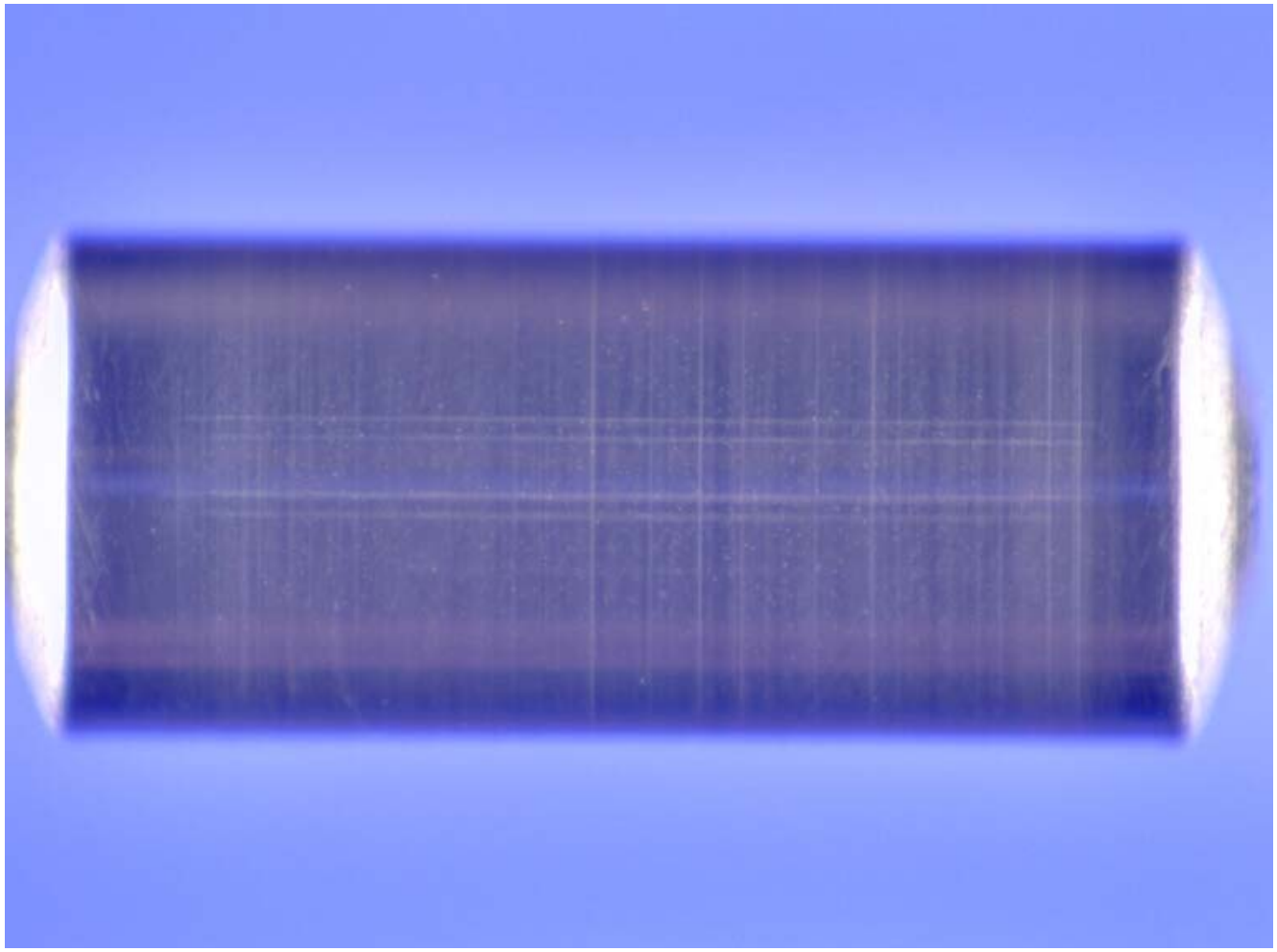
Misfueling Test #3 Misfuel Rate 85%



Non-critical standstill lines detected.

Misfueling Test #4

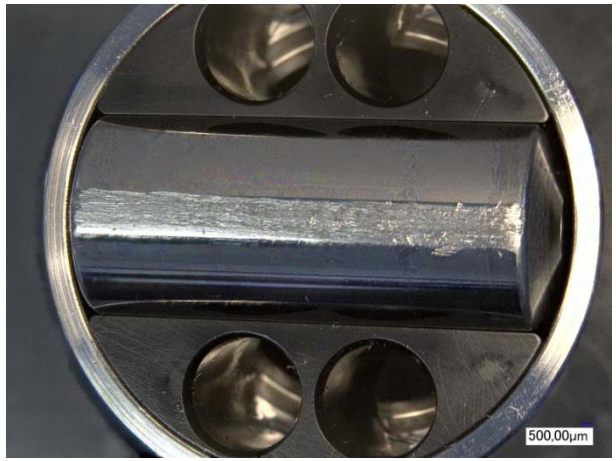
Misfueled with 60% gasoline

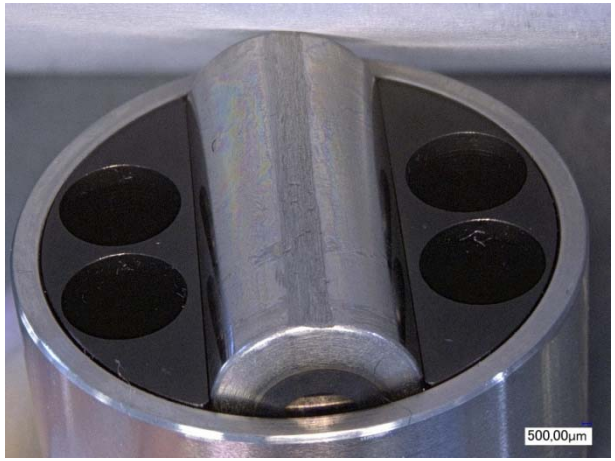
Predamaged Pump

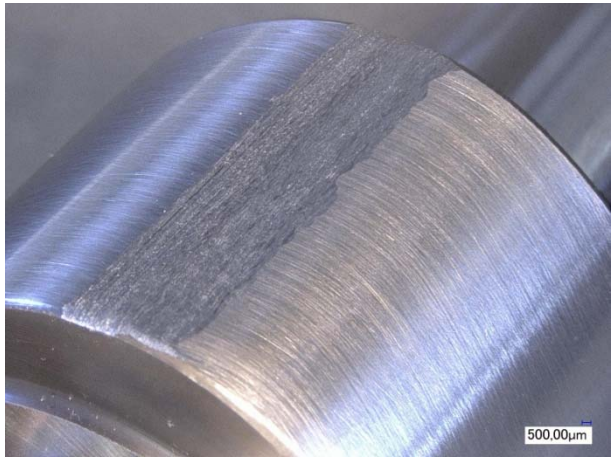
RP0 design level

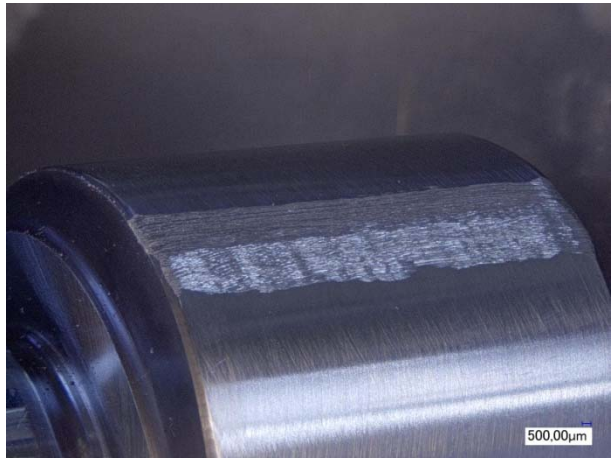
Misfueling Test #4 Misfuel Rate 60%

Roller and Cam Damage Pattern / Artificial damage, simulating a severe brake mark









Misfueling Test #4 Misfuel Rate 60%

- Test Description
  - Engine Performance Test
  - High Misfueling Rate (8 liter (2.1 gal) diesel, 12 liter (3,2 gal) gasoline)
  - Endurance Test on dynamometer under normal use requirements
    - Highway/Autobahn

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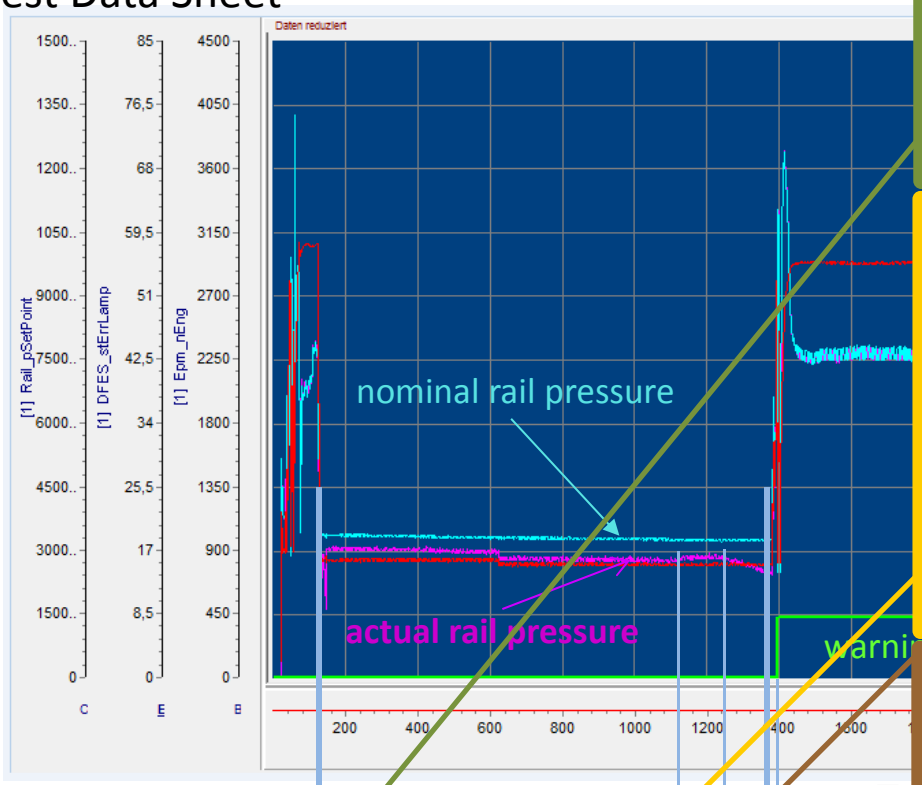
Misfueling Test #4 Misfuel Rate 60%

Test Data Sheet

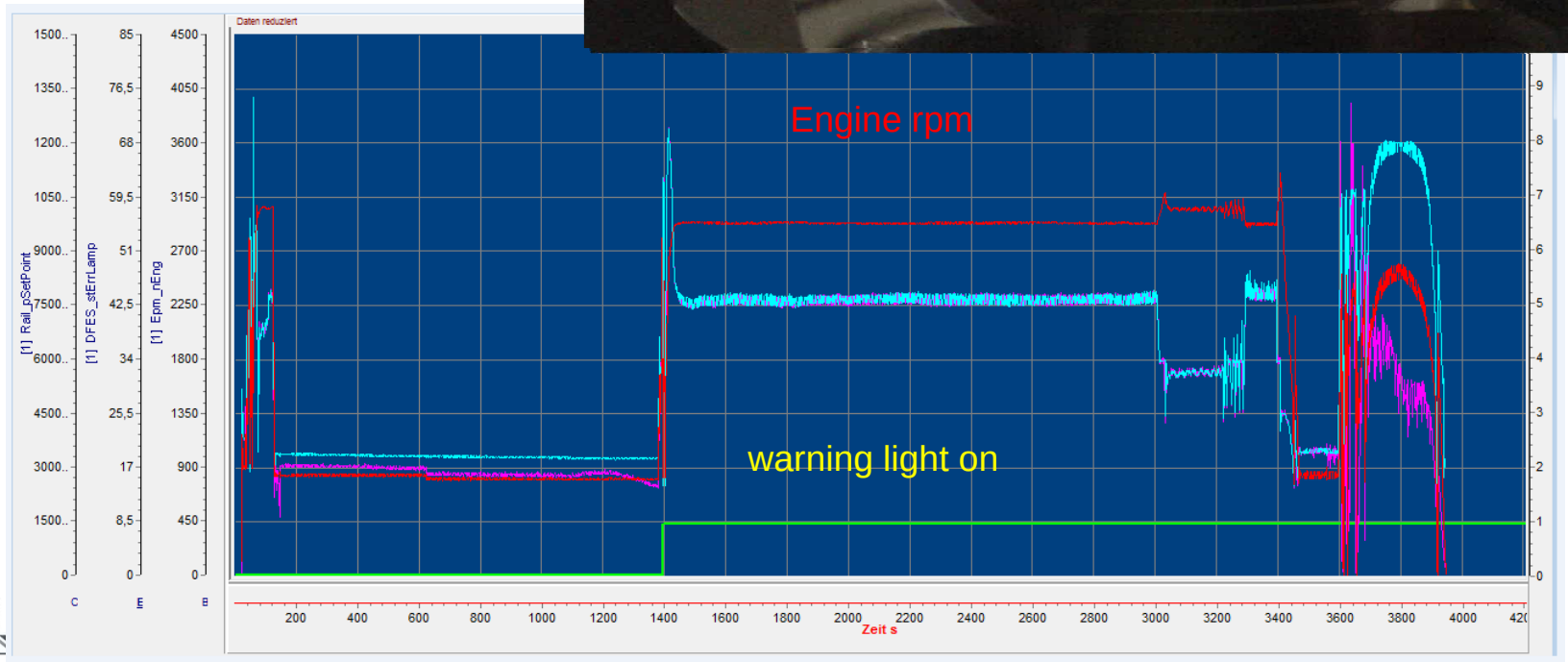


misfuel

engine warm up

Entire Page
Confidential

Misfueling Test #4 Misfuel Rate



Misfueling Test #4 Misfuel Rate 60%

Test results

- About 23 min engine warm up
- Warning Light (Glow Plug) coming up within initial acceleration up to 78 $^{km}/_{h}$ (about 50 mph)
  ➡ Trigger for Limp Home Mode
- About 43 min driving cycle with flashing glow-plug indicator light and reduced performance
- Significant loss of pressure supply from HPFP in the final 5 minutes of the test
- End of test after 66 minutes at 58.4 km (36,3 miles)
- Metal flakes found in HPFP did not cause engine shutdown, plunger displacement was reduced and impaired fuel supply (see pictures)

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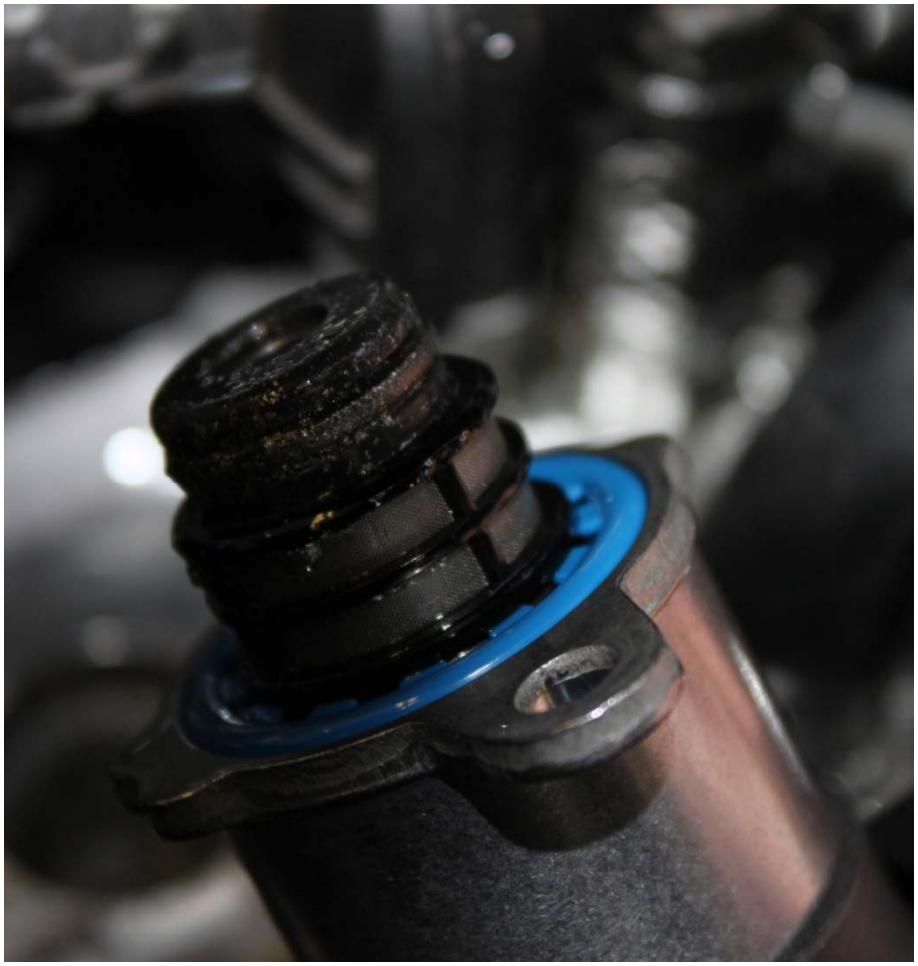
Misfueling Test #4 Misfuel Rate 60%

Test results



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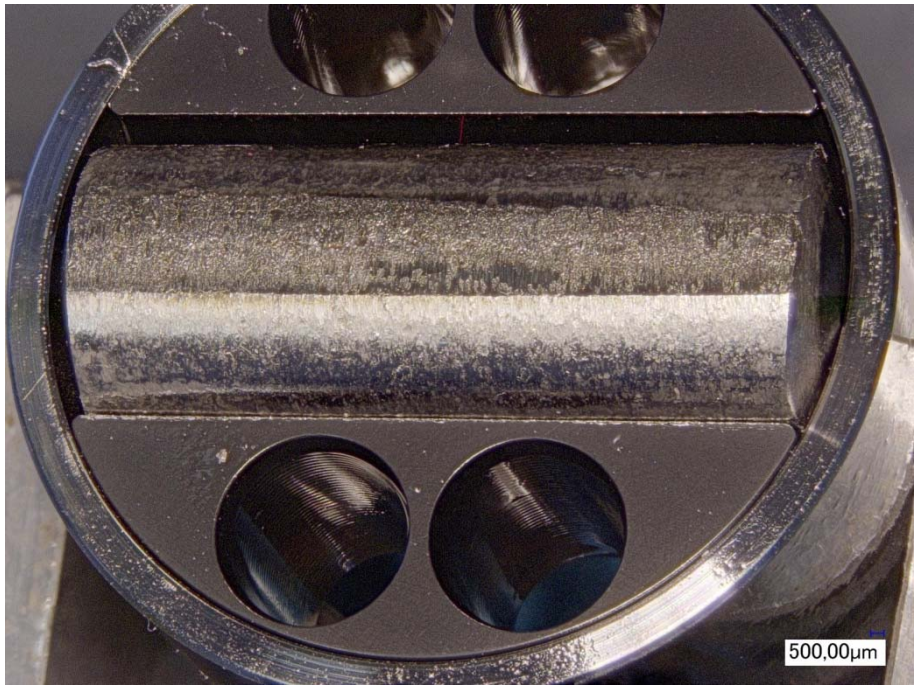
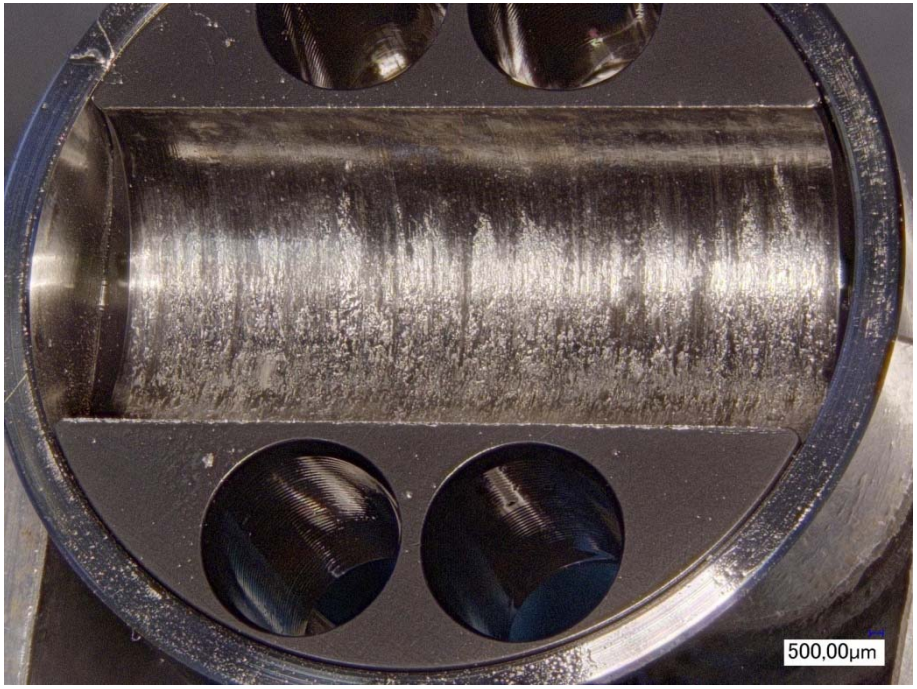
Misfueling Test #4 Misfuel Rate 60%

Test results





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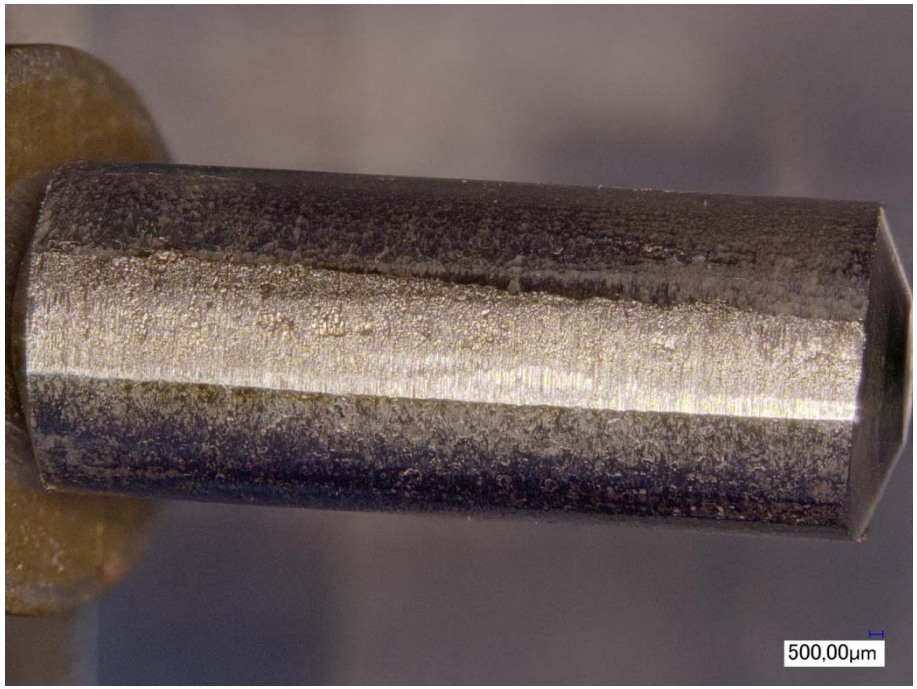
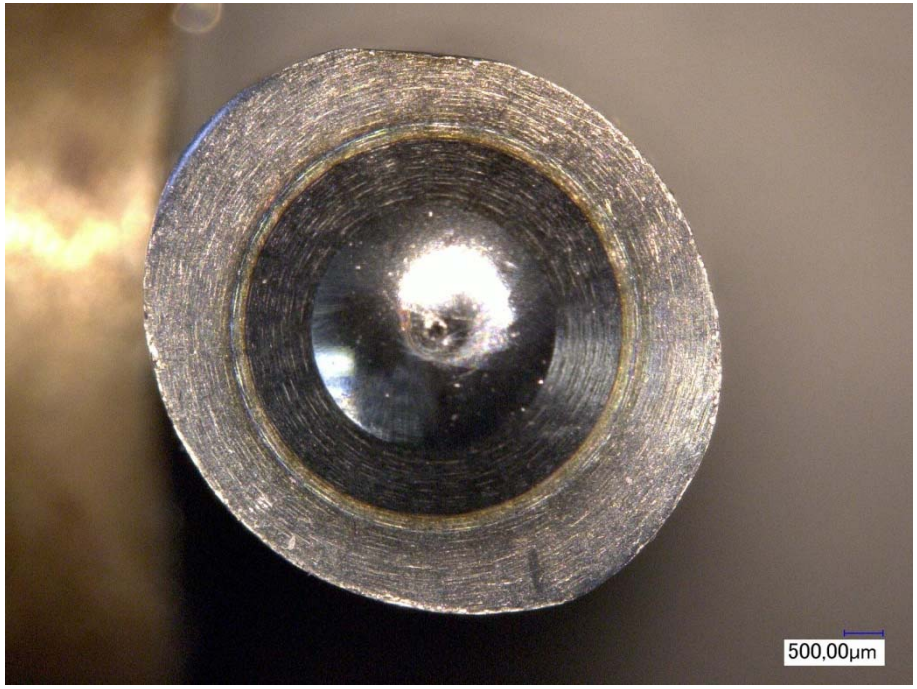
Misfueling Test #4 Misfuel Rate 60%

Test results





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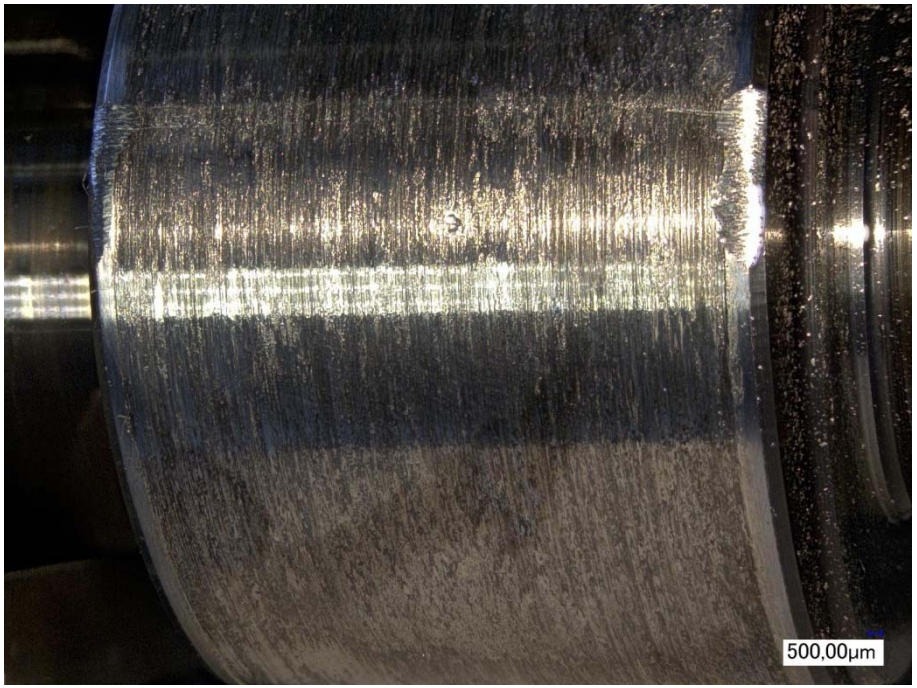
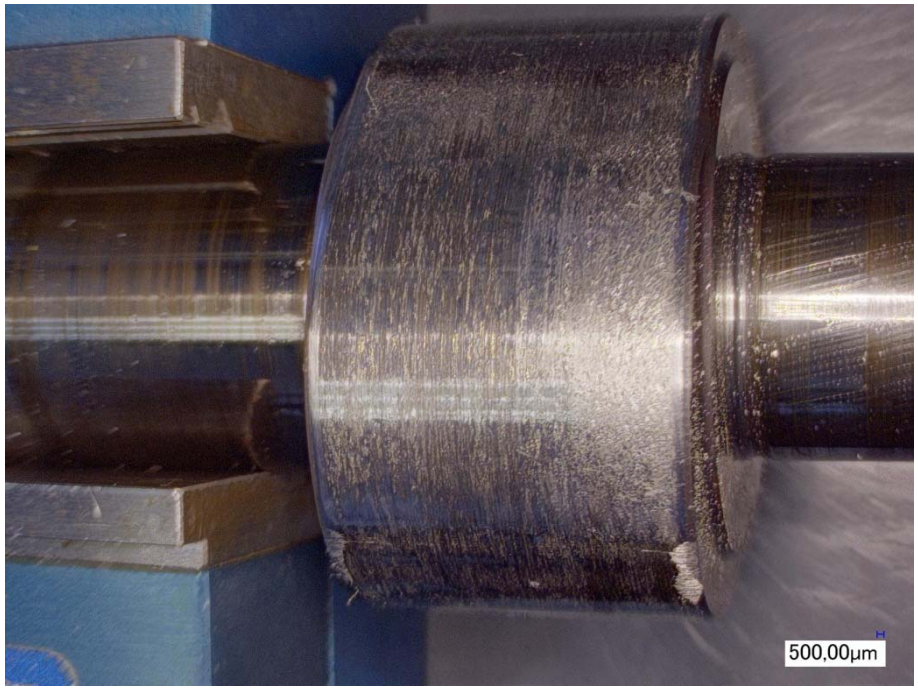
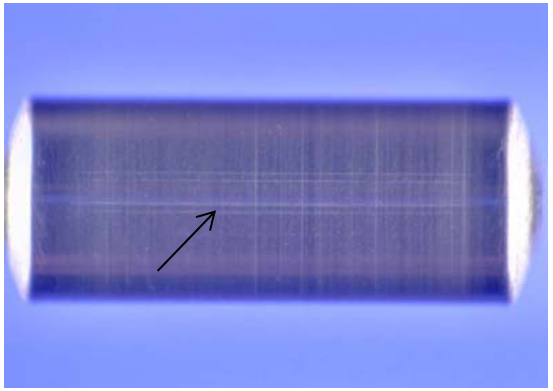
Misfueling Test #4 Misfuel Rate 60%

Test results



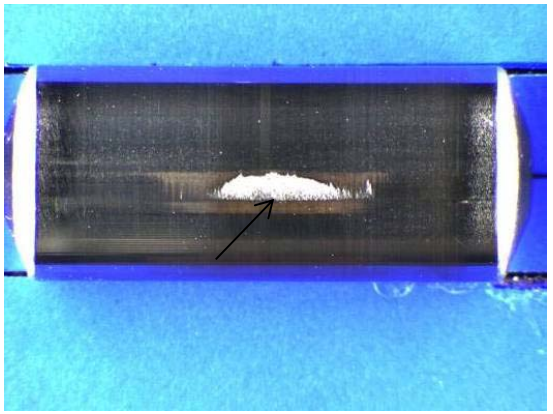


Brake Marks/Plates vs. Standstill Lines



Standstill Lines

- Standstill lines are only visually detectable surface smoothing lines. Such smoothings are not measureable and without negative effect on durability of the HPFP.
- Standstill lines may appear after long periods without operating (initial slip when pump starts to rotate) and when lubrication is impaired and roller speed is reduced for short instances (also slip between roller and camshaft).



Brake Marks

- Brake marks are measurable abrasions of the roller surface, damaging the surface structure of the roller.
- Having damaged the surface, the roller may not withstand the pressure during operation and material may further deteriorate due to fatigue (→ HPFP drivetrain failure)
- Brake marks appear when lubrication is interrupted, the roller is stopped and the camshaft slides under the roller.

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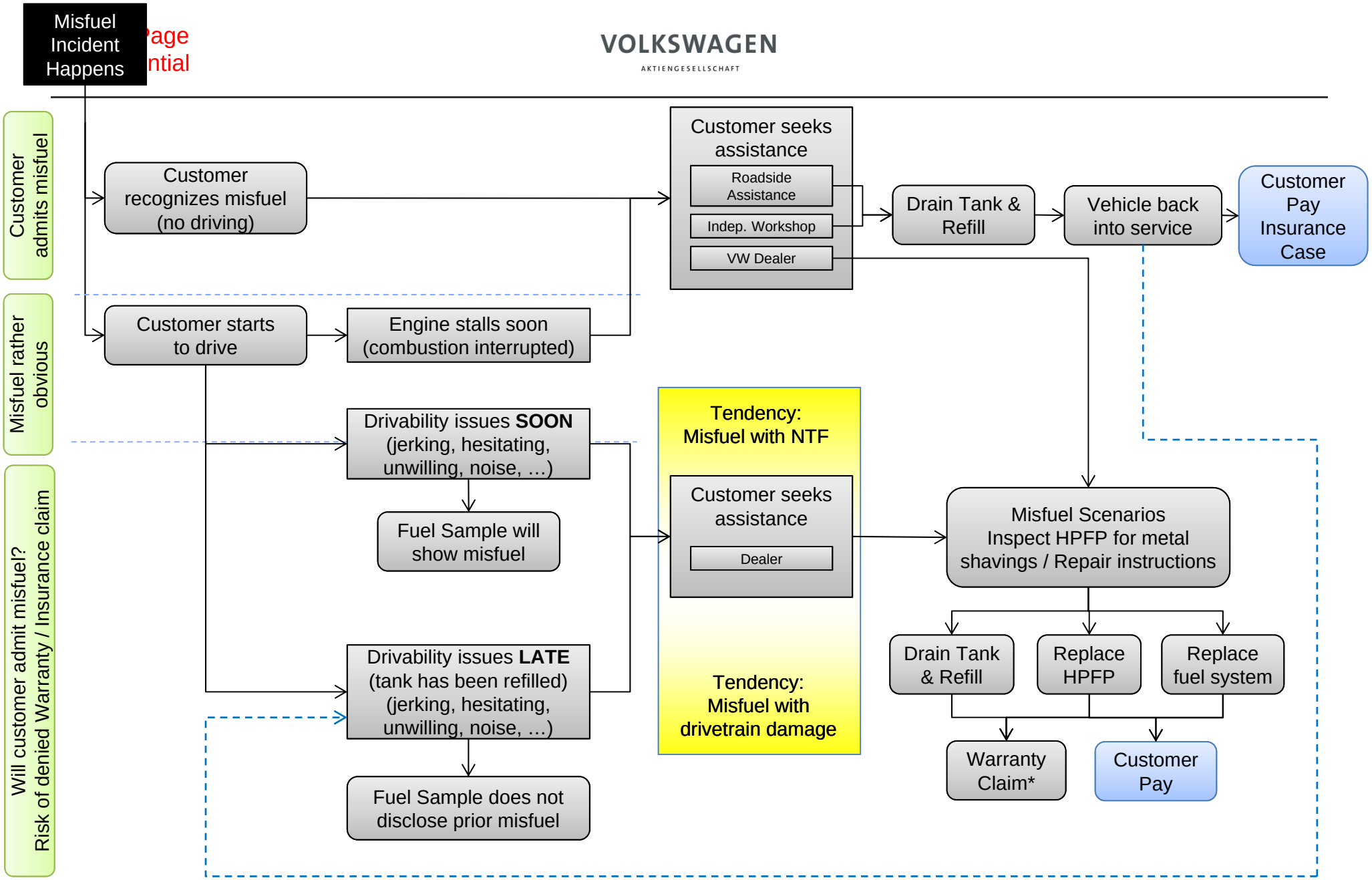

Qualitätssicherung

Customer Pay: Not recorded in VWGoA Databases; *Warranty Claim does possibly not spell out the misfuel; just the replacement/repair

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Customer Information Mailing Action / Field Action

- July 2012 a customer information campaign was launched, providing labels, a filler neck collar and a manual insert to inform customer's about the importance to use the right fuel

- The image shows the plenty of warning. Normally only the grey label and the "Diesel" on the filler cap would be present.

- Also, an action code was assigned to the vehicles, ordering dealerships to inspect for proper application of labels/collar and manual insert.

Misfuel Protection – General Issues

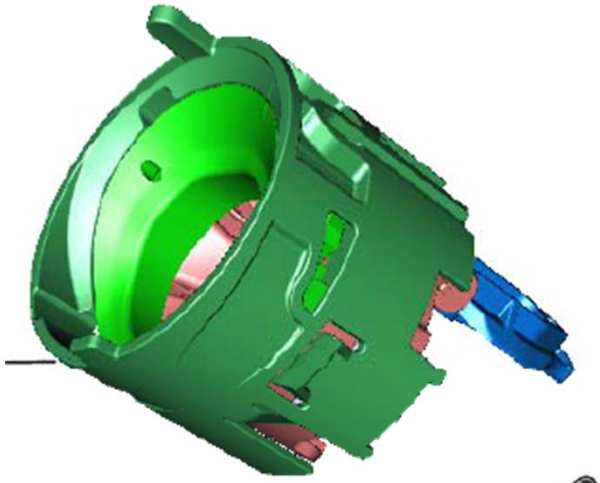
- Diesel pump fuel nozzle is not standardized (unlike unleaded gasoline)
- Common: 24.6mm, but also available: gasoline nozzles (21mm) & high capacity truck nozzles (30mm)
- Solution to fill with “uncommon” nozzle is necessary

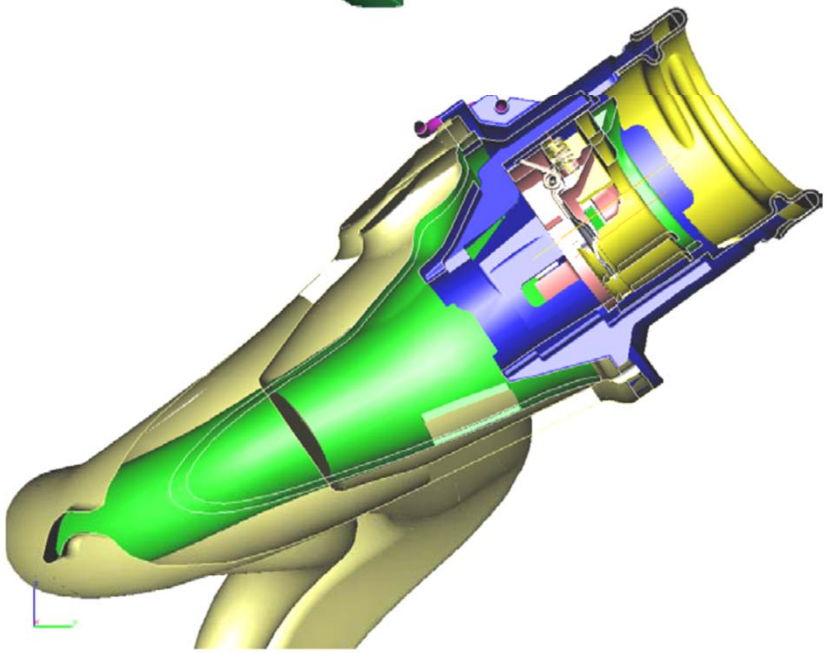
Retrofit protection:

- Must meet Crash & Rollover requirements (no leaking in rollover, no separation in crash)
- Must meet fueling performance requirements (compatible with fuel pump volume)
- Very little room for installation available

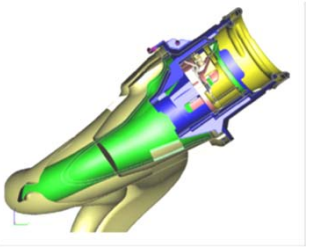
Series Misfuel Protection

- Implemented as of MY13 (Q7 since SOP2009)
  Starting May/June 2012 depending on individual model
- Device detects outer diameter of fuel nozzle and opens only when 24.6 mm diesel nozzle is detected (plus tolerance)
- 21mm gasoline nozzles will not open restrictor and nozzle cannot be inserted into vehicle's filler neck
- "emergency fueling" option allows bypass of approx. 6L/min w/o release of the restrictor, for example when filling with a fuel canister (commonly equipped with a small nozzle)





Series Misfuel Protection – Field Data



- Analysis of 8D reports show 22 reports with misfuel happening at the first fueling of the vehicle (7% of all reports)

→ Conclusion: A number of misfueled MY13 would “normally” have occurred, but

No misfuel related HPFP replacements in MY13 to date

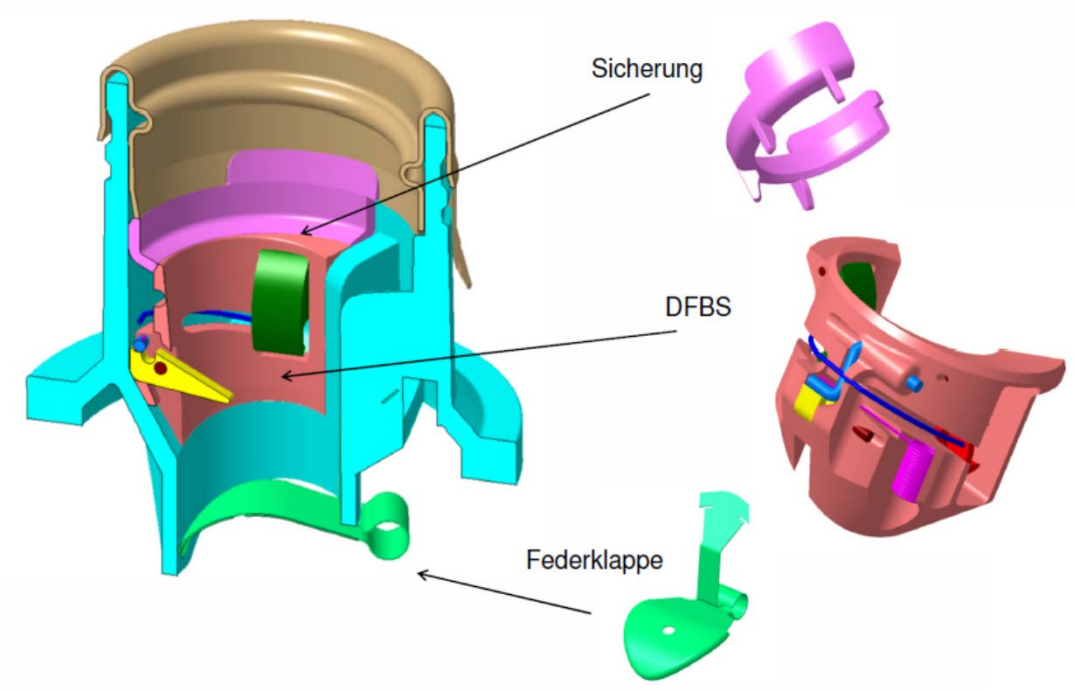
<u>Misfuel protection effectively addresses “HPFP issue”</u>

→ VWAG understands this as proof for misfueling as the root cause

→ Education action as important element to avoid misfueling

→ Misfuel protection (if possible) can aid the customer’s to avoid misfuels and expensive repairs

Retrofit Misfuel Protection



- Misfuel protection device is installed in small cavity of the vehicle's filler neck. Functional principle is similar to series solution (detection of outer nozzle diameter).
- Available for Jetta, Golf and A3 (approx. 95% of the subject vehicles)
- Currently no solution is available for Touareg vehicles due to insufficient space. Alternatives are being investigated, but have not been approved.

Jetta

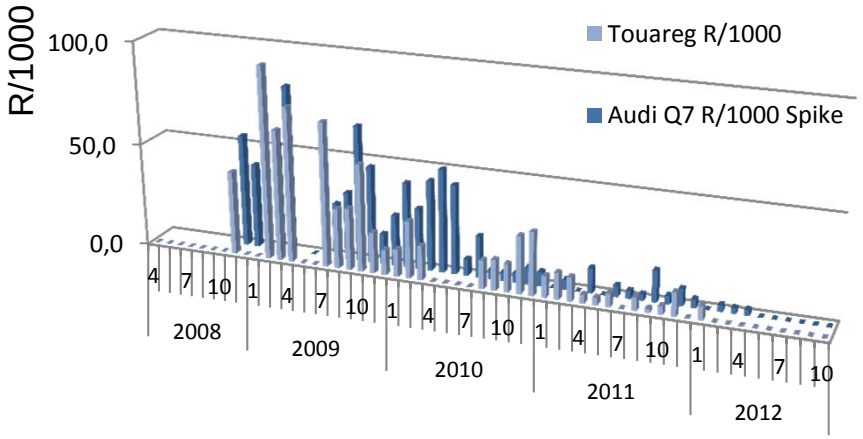
Touareg

Misfuel Protection Override

- To allow fueling with “uncommon” fuel pumps (21mm gasoline or 30mm high capacity truck nozzles)
- Use of the adapter should be an exception and not the rule
- Dealers have been informed via TSB
- Adapter is offered upon request to customers (and commonly sold at fuel stations)

Q7 vs. Touareg

Does the misfuel protection not work?



Volkswagen considers several reasons as the cause for Q7 being „over represented“

- AdBlue filler neck close to fuel filler neck (this was the reason to implement the misfuel restrictor in the Q7) ;
  AdBlue commonly being refilled with bottles (misfuel restrictor allows 6L/min „emergency fueling“)
  → several Q7 AdBlue incidents found
  (Touareg has AdBlue filler neck in the trunk…)
- Small population: Few HPFP replacements have huge effect on rates, statistical evaluation is rather weak
- Expensive premium vehicle: Dealers may be more willing to replace HPFPs to keep customers happy, although it would not be necessary
- Use of adapters to override misfuel inhibitor (sold by dealers and at every fuel station)
  → some misfuels detected in data / fuel samples
- Misfuel by roadside assistance occurred when refueling with spare can

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EPA acknowledges misfueling and the role of labels and information in 2011

- EPA, when requiring greater ethanol content in gasoline, primarily addressed the misfueling problem in July 2011 with a "**Proposed Misfueling Mitigation Measures Program**." See EPA, "Regulation To Mitigate the Misfueling of Vehicles and Engines With Gasoline Containing Greater Than Ten Volume Percent Ethanol and Modifications to the Reformulated and Conventional Gasoline Programs," 76 F.R. 44406 (July 25, 2011) (Final Rule).

- In an earlier Final Rule dealing with highway diesel fuel sulfur control requirements, dated January 18, 2001, EPA sought to minimize the possibility of misfueling by adopting "**labeling requirements that apply both to retail stations and vehicle manufacturers**." Given adoption of its 2001 program, EPA believed that "intentional misfueling will not be a serious problem." And, "because vehicle owners will likely void the manufacturer's warranty if they misfuel with 500 ppm sulfur fuel, they will have additional incentive not to misfuel." See EPA, "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements; Final Rule," 66 FR at 5070-5071 (Jan. 18, 2001).

Joint Approach

In response to the misfueling situation, Volkswagen respectfully proposes regulation:

- diesel fuel quality up to the fuel nozzle at the fuel station similar to the existing regulations for gasoline
- nozzle diameters and gas stations requiring defined different diameters for gas nozzles and for diesel nozzles
- clear and standardized labels for the different fuels and their respective pumps at fuel stations

Incorporating the aforementioned actions will assist manufacturers to meet the federally mandated fuel economy and emissions regulations. This will also supplement the actions taken by Volkswagen and other OEMs to prevent misfueling incidents.

Summary

- Volkswagen has not identified a defect within the TDI Clean Diesel vehicle‘s high pressure fuel pump.

- HPFPs have been designed, tested and approved – including substantial design margins against fuel which is out of specification.

- Volkswagen has not received any reports involving a crash, injury or fatality.

→ Misfueling with gasoline was detected as the predominant reason for the issues seen in the field.

Volkswagen submits that there is no unreasonable risk to motor vehicle safety regarding the alleged High Pressure Fuel Pump failures.

Summary

Nevertheless, Volkswagen will assist its customers in avoiding misfuel incidents

- Volkswagen has initiated a customer information campaign, creating awareness to the importance of proper diesel fuel and possible consequences if wrong fuel is used
- Volkswagen has developed a series misfuel protection device and implemented this into production in MY2013
- Volkswagen has developed a service misfuel protection device for Jetta, Golf and Audi A3 and will initiate another service action with customer mailing to have our dealerships install these inhibitors in customer's vehicles

Thank you for your attention …

Questions / Discussion?