Bob F.

RICARDO

# PEUGEOT XUD-9-AL NOZZLE COKING TEST
# 10 HOUR CYCLIC PROCEDURE

| | | |
|---|---|---|
| Ricardo Test No | : | 11536-00 |
| Procedure | : | F 23-T-00 |
| Fuel Reference | : | BP, EN 590<br>Low sulphur Diesel |
| Additive Reference | : | N/A |
| Test Completed | : | 02-Jun-00 |

**Test Conducted For:**

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# THE EVALUATION OF INJECTOR NOZZLE COKING USING THE PEUGEOT XUD-9 ENGINE

## 1.0 INTRODUCTION

The Peugeot XUD-9 Nozzle Coking Test has been developed by the CEC PF-023 group. The test is designed to evaluate the capability of Diesel fuel additives to prevent injector nozzle coking in a modern indirect injection passenger car engine.

## 2.0 TEST ENGINE

| | | |
|---|---|---|
| Designation | - | Peugeot XUD-9-AL |
| No of cylinders | - | 4 |
| Swept volume | - | 1.9 litre |
| Injector Nozzle | - | RDNOSDC 6850 |
| Nozzle Opening Pressure | - | 115 +/- 5 bar |
| Injection Pump | - | Roto Diesel Type 047 |
| Dynamic Injection Timing | - | 10° BTDC |

## 3.0 TEST PROCEDURE

| Stage | Time | Speed | Torque |
|---|---|---|---|
| 1 | 30 | 1200±30 | 10±2 |
| 2 | 60 | 3000±30 | 50±2 |
| 3 | 60 | 1300±30 | 35±2 |
| 4 | 120 | 1850±30 | 50±2 |

| | |
|---|---|
| Coolant out | 95°C ± 2°C |
| Coolant delta | 4°C (Stage 2) |
| Oil gallery | 100°C ± 5 |
| Air inlet | 32°C ± 2°C |
| Fuel return pressure | -50 to +100 mbar |
| Fuel supply pressure | -100 to +100 mbar |
| Exhaust back pressure | 50 ± 10 (Stage 2) |

## 3.1 ENGINE PRE-TEST PREPERATION

The fuel system is flushed with the test fuel.
A clean set of slave injectors are fitted to the engine.
The engine is started and warmed up to procedure.
The fuel pump is flushed through to procedure with the test fuel.
The engine is then ramped up to 3000 r/m - 50 Nm and conditions are allowed to stabilise for ten minutes.
The engine is then set to the required set-up conditions and the data is logged.
Once all the set up conditions are correct the engine speed and load is reduced to 1000 r/m - 5 Nm for five minutes before stopping the engine.
New fuel filters are installed.
The slave injectors are removed from the engine.

## 3.2 ENGINE SET UP CONDITIONS

| | |
|---|---|
| Speed (r/m) | 3004 |
| Load (Nm) | 50 |
| Fuel Temp, pump (deg C) | 31 |
| Inlet Air (deg C) | 32 |
| Exhaust (deg C) | 333 |
| Exhaust bp (mbar) | 51 |
| Coolant in (deg C) | 90.9 |
| Coolant out (deg C) | 95.3 |
| Coolant delta (deg C) | 4 |
| Oil temp (deg C) | 100 |
| Smoke (AVL) | 1.1 |
| Blow-by (lpm) | 11 |
| Fuel consumption (kg/hr) | 4.8 |
| Fuel pump pressure in (mb) | 35 |
| Fuel pump pressure out (mb) | 4 |
| Dynamic injection pump timing | 10.0 |

## 3.3 TEST INJECTOR PREPARATION

New nozzles are flowed with air, using the nozzle flow testing rig to ISO 4010.

Measurements are taken at lift points 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5 mm.

The nozzles are assembled, set to the correct opening pressure and then fitted to the engine.

## 3.4 TEST RUN

The engine is warmed up to test conditions and run for 10 hours without stops, using the fuel to which the test additive has been added.

## 3.5 END OF TEST

At the end of test the injectors are removed from the engine, dismantled, and the nozzles reflowed on the test rig.

## 3.6 REPORTING OF RESULTS

Results are expressed as the percentage residual airflow for each lift point.

## 3.7 FUEL BLENDING

Market place fuel, additive pre-blendid at distribution terminal.

## 3.8 ENGINE OPERATING CONDITIONS

The engine operating conditions are monitored and recorded every 5th cycle throughout the test. The minimum, maximum and average values are displayed below for all 4 stages.

| | Stage 1 | | | Stage 2 | | |
|---|---|---|---|---|---|---|
| | min | max | ave | min | max | ave |
| Speed (r/m) | 1199 | 1205 | 1202 | 3002 | 3004 | 3002 |
| Load (Nm) | 10.4 | 10.9 | 10.7 | 50.0 | 50.8 | 50.4 |
| Fuel Temp, pump (deg C) | 31 | 32 | 31 | 31 | 32 | 31 |
| Inlet Air (deg C) | 32 | 33 | 32 | 32 | 33 | 32 |
| Exhaust (deg C) | 192 | 201 | 197 | 310 | 318 | 312 |
| Exhaust bp (mbar) | 12 | 15 | 14 | 49 | 50 | 49 |
| Coolant in (deg C) | 89 | 93 | 91 | 91 | 93 | 92 |
| Coolant out (deg C) | 94 | 96 | 96 | 95 | 96 | 96 |
| Oil temp (deg C) | 98 | 99 | 99 | 101 | 102 | 102 |
| Smoke (AVL) | * | * | * | 0.8 | 1.2 | 1.0 |
| Fuel pump pressure in (mb) | 19 | 42 | 32 | 16 | 37 | 28 |
| Fuel pump pressure out (mb) | 5 | 23 | 10 | 7 | 21 | 10 |

| | Stage 3 | | | Stage 4 | | |
|---|---|---|---|---|---|---|
| | min | max | ave | min | max | ave |
| Speed (r/m) | 1299 | 1302 | 1300 | 1848 | 1851 | 1850 |
| Load (Nm) | 34.4 | 35.5 | 35.2 | 50.1 | 50.6 | 50.4 |
| Fuel Temp, pump (deg C) | 31 | 32 | 32 | 31 | 32 | 31 |
| Inlet Air (deg C) | 32 | 33 | 32 | 31 | 33 | 32 |
| Exhaust (deg C) | 210 | 213 | 211 | 251 | 254 | 252 |
| Exhaust bp (mbar) | 13 | 14 | 14 | 16 | 17 | 16 |
| Coolant in (deg C) | 91 | 92 | 91 | 90 | 93 | 91 |
| Coolant out (deg C) | 94 | 95 | 95 | 94 | 96 | 96 |
| Oil temp (deg C) | 99 | 100 | 100 | 99 | 99 | 99 |
| Smoke (AVL) | * | * | * | 0.8 | 1.5 | 1.1 |
| Fuel pump pressure in (mb) | 18 | 42 | 30 | 15 | 39 | 28 |
| Fuel pump pressure out (mb) | 8 | 22 | 11 | 8 | 22 | 11 |
| Total fuel consumption for test (lts) | **34.0** | | | | | |

## 3.9 REPORT OF OPERATION OUTSIDE SPECIFICATION LIMITS

None.

## 4.0 FLOW RATES AND % RESIDUAL FLOW TABLES

| | | | |
|---|---|---|---|
| Customer Fuel Code | BP, EN 590 Low sulphur Diesel | RTS Number | N/A |
| | | | |
| Additive | N/A | RTS Number | N/A |
| Fuel volume | 60 lts | | |
| Dose Rate | N/A | Engine Number | 2 |
| Rater SOT | MIH | Rater EOT | MCT |

### Cylinder 1

Nozzle 01

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.206 | 0.027 | 13 |
| 0.1 | 0.296 | 0.050 | 17 |
| 0.2 | 0.387 | 0.059 | 15 |
| 0.3 | 0.475 | 0.098 | 21 |
| 0.4 | 0.566 | 0.161 | 28 |
| 0.5 | 0.673 | 0.371 | 55 |

### Cylinder 2

Nozzle 02

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.219 | 0.043 | 19 |
| 0.1 | 0.269 | 0.054 | 20 |
| 0.2 | 0.341 | 0.079 | 23 |
| 0.3 | 0.422 | 0.118 | 28 |
| 0.4 | 0.522 | 0.217 | 42 |
| 0.5 | 0.642 | 0.401 | 63 |

### Cylinder 3

Nozzle 03

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.194 | 0.044 | 23 |
| 0.1 | 0.282 | 0.065 | 23 |
| 0.2 | 0.371 | 0.125 | 34 |
| 0.3 | 0.457 | 0.219 | 48 |
| 0.4 | 0.550 | 0.332 | 60 |
| 0.5 | 0.663 | 0.487 | 73 |

### Cylinder 4

Nozzle 04

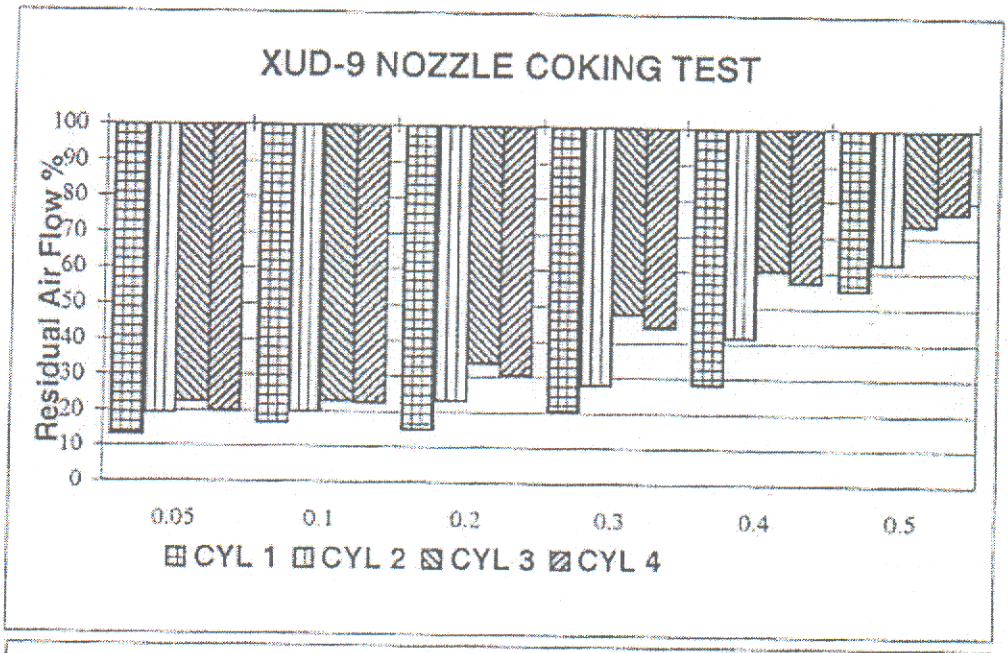
| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.200 | 0.040 | 20 |
| 0.1 | 0.259 | 0.059 | 23 |
| 0.2 | 0.351 | 0.107 | 30 |
| 0.3 | 0.446 | 0.197 | 44 |
| 0.4 | 0.547 | 0.313 | 57 |
| 0.5 | 0.674 | 0.518 | 77 |

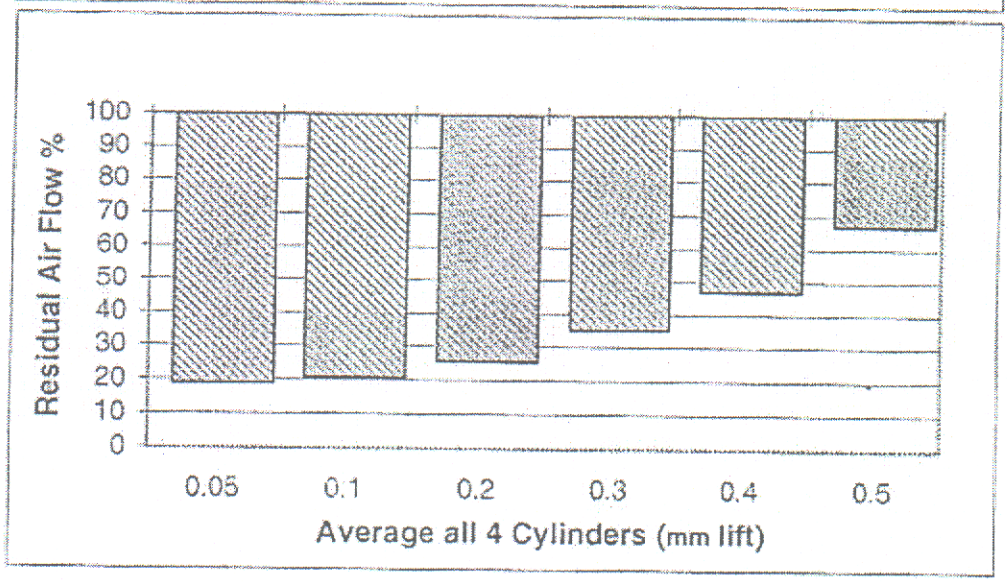
### Average of all 4 nozzles

| Lift (mm) | 0 | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
|---|---|---|---|---|---|---|---|
| Residual flow % | 0 | 19 | 21 | 26 | 35 | 47 | 67 |

All results are corrected to standard conditions, 293 K / 980 mbar.

4.1 RESIDUAL AIR FLOW GRAPHS



## 5.0 REFERENCE BASE FUEL, RESULTS SUMMARY

| | | | |
|---|---|---|---|
| Test Number | 11529-00 | Procedure | F 23-T-00 |
| Test Date | 23-May-00 | Test Stand | 4:1 |
| Fuel Code | RF 93-T-95 | RTS Number | N/A |
| Additive | None | RTS Number | N/A |
| Dose Rate | N/A | | |

### Cylinder 1
Nozzle JK 963

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.217 | 0.028 | 13 |
| 0.1 | 0.274 | 0.042 | 15 |
| 0.2 | 0.370 | 0.084 | 23 |
| 0.3 | 0.465 | 0.156 | 34 |
| 0.4 | 0.563 | 0.302 | 54 |
| 0.5 | 0.685 | 0.488 | 71 |

### Cylinder 2
Nozzle JK 964

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.227 | 0.030 | 13 |
| 0.1 | 0.284 | 0.039 | 14 |
| 0.2 | 0.373 | 0.070 | 19 |
| 0.3 | 0.461 | 0.138 | 30 |
| 0.4 | 0.543 | 0.226 | 42 |
| 0.5 | 0.664 | 0.346 | 52 |

### Cylinder 3
Nozzle JK 965

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.199 | 0.026 | 13 |
| 0.1 | 0.246 | 0.036 | 15 |
| 0.2 | 0.321 | 0.104 | 32 |
| 0.3 | 0.405 | 0.208 | 51 |
| 0.4 | 0.499 | 0.332 | 66 |
| 0.5 | 0.616 | 0.432 | 70 |

### Cylinder 4
Nozzle JK 966

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.214 | 0.019 | 9 |
| 0.1 | 0.269 | 0.021 | 8 |
| 0.2 | 0.360 | 0.029 | 8 |
| 0.3 | 0.453 | 0.045 | 10 |
| 0.4 | 0.549 | 0.105 | 19 |
| 0.5 | 0.670 | 0.400 | 60 |

### Average of all 4 nozzles

| Lift (mm) | 0 | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
|---|---|---|---|---|---|---|---|
| Residual flow % | 0 | 12 | 13 | 20 | 31 | 45 | 63 |

All results are corrected to standard conditions, 293 K / 980 mbar.

## 5.1 REFERENCE ADDITISED FUEL, RESULTS SUMMARY

| | | | |
|---|---|---|---|
| Test Number | 11530-00 | Procedure | F 23-T-00 |
| Test Date | 24-May-00 | Test Stand | 4:1 |
| Fuel Code | RTS 4342 | RTS Number | RTS 4342 |
| Additive | Pre blended | RTS Number | N/A |
| Dose Rate | N/A | | |

### Cylinder 1
Nozzle JK 967

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.232 | 0.098 | 42 |
| 0.1 | 0.285 | 0.128 | 45 |
| 0.2 | 0.365 | 0.218 | 60 |
| 0.3 | 0.448 | 0.310 | 69 |
| 0.4 | 0.543 | 0.419 | 77 |
| 0.5 | 0.666 | 0.598 | 90 |

### Cylinder 2
Nozzle JK 968

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.230 | 0.077 | 34 |
| 0.1 | 0.291 | 0.108 | 37 |
| 0.2 | 0.376 | 0.194 | 52 |
| 0.3 | 0.460 | 0.304 | 66 |
| 0.4 | 0.552 | 0.438 | 79 |
| 0.5 | 0.671 | 0.621 | 93 |

### Cylinder 3
Nozzle JK 969

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.207 | 0.093 | 45 |
| 0.1 | 0.264 | 0.121 | 46 |
| 0.2 | 0.342 | 0.190 | 56 |
| 0.3 | 0.419 | 0.272 | 65 |
| 0.4 | 0.497 | 0.385 | 77 |
| 0.5 | 0.632 | 0.552 | 87 |

### Cylinder 4
Nozzle JK 970

| Lift (mm) | Flow Before test LPM | Flow After test LPM | Residual Flow (%) |
|---|---|---|---|
| 0 | 0.0 | 0.0 | 0 |
| 0.05 | 0.228 | 0.097 | 42 |
| 0.1 | 0.286 | 0.133 | 46 |
| 0.2 | 0.371 | 0.244 | 66 |
| 0.3 | 0.454 | 0.358 | 79 |
| 0.4 | 0.545 | 0.512 | 94 |
| 0.5 | 0.661 | 0.641 | 97 |

### Average of all 4 nozzles

| Lift (mm) | 0 | 0.05 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
|---|---|---|---|---|---|---|---|
| Residual flow % | 0 | 41 | 44 | 58 | 70 | 82 | 92 |

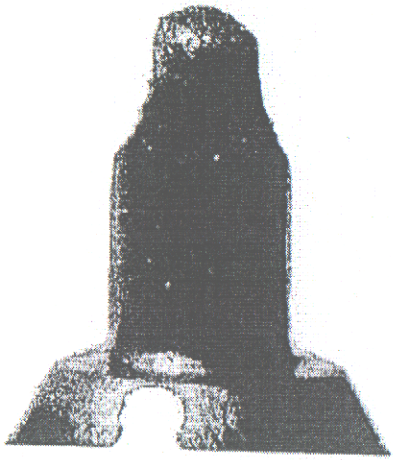
All results are corrected to standard conditions, 293 K / 980 mbar.

## 6.0 PHOTOGRAPHS OF TEST PARTS

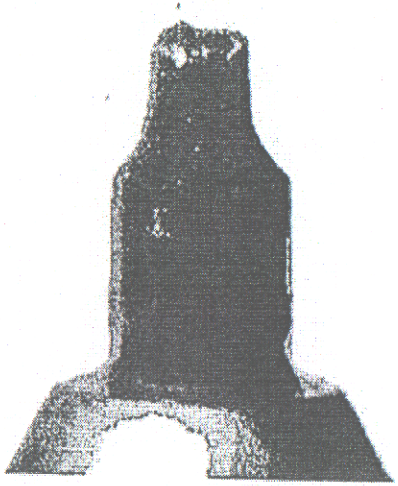
1 Pintle cylinder 1
2 Pintle cylinder 2
3 Pintle cylinder 3
4 Pintle cylinder 4

1536-00

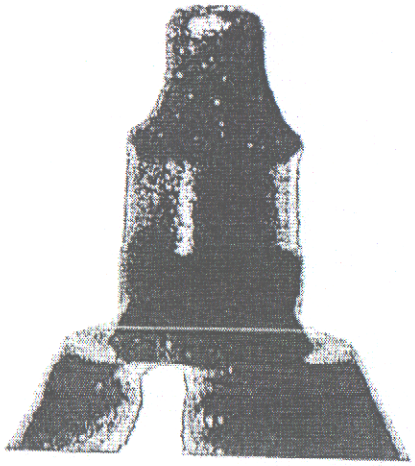
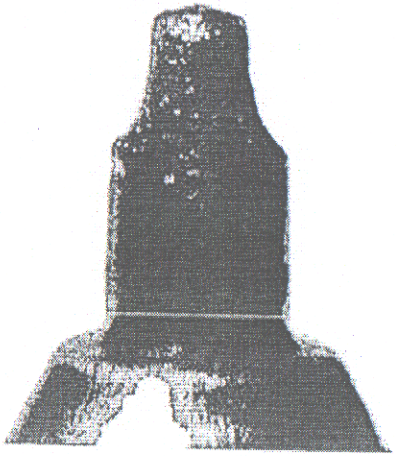
Nozzle 1



Nozzle 2



Nozzle 3



Nozzle 4