TICKFORD

XUD9 Nozzle coking test

Test procedure : CEC F-23-01 Issue 21
Test number : ON-XUD9-006
Client : PKN Orlen
Fuel code : Orlens base diesel
Additive code : Sample 5
Treat rate : 300 mg/kg
Test complete date : 20-Aug-11

Client address : PKN Orlen S.A
ul.Chemikow 7
09-411 Plock

Client distribution : Ireneusz Bedyk

Client order number : 602/05/2011

Test items supplied by : PKN Orlen.S.A
Test fuel received date : 22-Jul-11
Test additive received date : 27-Jul-11
Test lubricant : RL223

"The estimate of uncertainty of measurements for all test results are in accordance with the stated method listed in the report"

Authorised by : R. WALKER

Signed : RSWalker

Date : 23/09/2011

UKAS TESTING
4245

Contents

Test Number : ON-XUD9-006
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1.0 Introduction

This test method is designed to evaluate the capability of a diesel fuel to control the formation of deposits on the injector nozzles of an Indirect Injection diesel engine. Results of tests run to this method are expressed in terms of the percentage airflow loss at various injector needle lift points. Airflow measurements are accomplished with an airflow rig complying with ISO 4010.

2.0 Test description

2.1 Test engine

The engine used for this test is a Peugeot XUD9AL unit supplied by PSA specifically for Nozzle Coking Testing, originally at the request of the CEC PF-023 Working Group.

Engine part number:	70100
Swept volume:	1.9 litre
Injection Pump:	Roto Diesel DCP R 84 43 B910A
Injector body:	Lucas LCR 67307
Injector nozzle:	Lucas RDNO SDC 6850 (unflatted)
Firing order:	1,3,4,2 (No. 1 at flywheel end)

2.2 Engine build and item preparation

The injector nozzles are cleaned and checked for airflow at 0.05, 0.1, 0.2, 0.3 and 0.4mm lift. Nozzles are discarded if the airflow is outside of the range 250ml/min to 320ml/min @ 0.1 mm lift. The nozzles are assembled into the injector bodies and the opening pressures set to 115±5 bar.

2.3 Test procedure

A slave set of injectors is fitted to the engine. The previous test fuel is drained from the system. The engine is run for 25 minutes in order to flush through the fuel system. During this time all the spill-off fuel is discarded and not returned. The engine is then set to test speed and load and all specified parameters checked and adjusted to the test specification. The slave injectors are then replaced with the test units.

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2.4 Engine warm-up

Engine warm-up

Duration (mins)	Speed/load
5	Idle speed / no load
10	2000 rev/min / 34Nm torque
10	3000 rev/min / 50 Nm torque

Immediately after the warm-up the following test cycle is run 134 times giving a total test time of 10 hours and 3 minutes.

Test operating conditions

Stage	Time (secs)	Speed (rev/min)	Torque (Nm)
1	30	1200 ± 30	10 ± 2
2	60	3000 ± 30	50 ± 2
3	60	1300 ± 30	35 ± 2
4	120	1850 ± 30	50 ± 2

2.5 Other operating parameters

Run parameters

Coolant outlet temperature (°C)	95 ± 2
Coolant delta (°C)	4 ± 2
Oil gallery temperature (°C)	100 ± 5
Air inlet temperature (°C)	32 ± 2
Fuel temperature at pump (°C)	31 ± 2
Fuel pump inlet pressure - stage 2 (mbar)	-100 to +100
Fuel pump outlet pressure - stage 2 (mbar)	-50 to +100
Exhaust back pressure - stage 2 (mbar)	50 ± 10
Air Intake Pressure (mbar)	950 ± 10

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3.0 Results

3.1 Pre-test

Reference (Nozzle 215)

Lift (mm)	Reading %	Obs. flow (cc/min)	Corr. flow (cc/min)
0	0.1	1	1
0.1	36.5	183	197

Settings

Test Hours	0
Date	19-Aug-11
Operator	IP
Pa (mbar)	1011.6
Ta (°K)	295.0

Meter specification

Serial No.	Max Flow (cc/min)	Pi	Ti
98205460A	500	1013.25	273

Cylinder 1 **Nozzle: D41**

Lift (mm)	Reading (%)	Obsflow (cc/min)	Corr.flow (cc/min)
0	0.1	1	1
0.05	37.1	186	200
0.1	50.9	255	275
0.2	73.9	370	399
0.3	91.3	457	492
0.4	111.1	556	599

Cylinder 2 **Nozzle: D42**

Lift (mm)	Reading (%)	Obs.flow (cc/min)	Corr.flow (cc/min)
0	0.1	1	1
0.05	37.7	189	203
0.1	51.4	257	277
0.2	69.8	349	376
0.3	90.7	454	489
0.4	106.9	535	577

Cylinder 3 **Nozzle: D43**

Lift (mm)	Reading (%)	Obs. flow (cc/min)	Corr. flow (cc/min)
0	0.1	1	1
0.05	37.4	187	202
0.1	50.3	252	271
0.2	74.8	374	403
0.3	94.1	471	508
0.4	113.1	566	610

Cylinder 4 **Nozzle: D44**

Lift (mm)	Reading (%)	Obs. flow (cc/min)	Corr. flow (cc/min)
0	0.1	1	1
0.05	35.0	175	189
0.1	51.0	255	275
0.2	72.4	362	390
0.3	91.5	458	493
0.4	109.5	548	591

$$\text{Corrected flow} = \text{Observed flow} * \frac{P_i}{P_a} * \frac{T_a}{T_i} * \sqrt{\frac{293}{T_a}}$$

where P_i = Calibration pressure of mass flow meter in mbar
P_a = Ambient pressure in mbar
T_a = Ambient temperature in °K
T_i = Calibration temperature of mass flow meter in °K

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3.2 Post-test

Reference (Nozzle 215)

Lift (mm)	Reading %	Obs. flow (cc/min)	Corr. flow (cc/min)
0	0.1	1	1
0.1	35.8	179	194

Settings

Test Hours:	10
Date:	20-Aug-11
Operator:	SD
Pa (mbar)	1010.98
Ta (°K)	296.5

Meter Specification

Serial No.	Max Flow	(cc/min)	Pi	Ti
98205460A	500		1013.25	273

Cylinder 1 **Nozzle: D41**

Lift (mm)	Reading (%)	Obs.flow (cc/min)	Corr.flow (cc/min)
0	0.1	1	1
0.05	31.4	157	170
0.1	43.1	216	233
0.2	69.2	346	374
0.3	88.2	441	477
0.4	105.6	528	571

Cylinder 2 **Nozzle: D42**

Lift (mm)	Reading (%)	Obs.flow (cc/min)	Corr.flow (cc/min)
0	0.1	1	1
0.05	32.2	161	174
0.1	44.1	221	239
0.2	65.4	327	354
0.3	85.0	425	460
0.4	101.8	509	551

Cylinder 3 **Nozzle: D43**

Lift (mm)	Reading (%)	Obs.flow (cc/min)	Corr.flow (cc/min)
0	0.1	1	1
0.05	34.0	170	184
0.1	46.2	231	250
0.2	72.6	363	393
0.3	92.3	462	499
0.4	109.7	549	594

Cylinder 4 **Nozzle: D44**

Lift (mm)	Reading (%)	Obs.flow (cc/min)	Corr.flow (cc/min)
0	0.1	1	1
0.05	33.4	167	181
0.1	47.8	239	259
0.2	71.4	357	386
0.3	90.4	452	489
0.4	108.1	541	585

$$\text{Corrected flow} = \text{Observed flow} * \frac{P_i}{P_a} * \frac{T_a}{T_i} * \sqrt{\frac{293}{T_a}}$$

where P_i = Calibration pressure of massflowmeter in mbar
P_a = Ambient pressure in mbar
T_a = Ambient temperature in °K
T_i = Calibration temperature of massflowmeter in °K

Test Number : ON-XUD9-006
Fuel Code : Orlens base diesel
Additive Code : Sample 5
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3.3 Flow loss calculations

nozzle test runs	6

Cylinder 1 (Flywheel end) — **Nozzle : D41**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	200	170	85%	15%
0.1	275	233	85%	15%
0.2	399	374	94%	6%
0.3	492	477	97%	3%
0.4	599	571	95%	5%

Cylinder 2 — **Nozzle : D42**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	203	174	86%	14%
0.1	277	239	86%	14%
0.2	376	354	94%	6%
0.3	489	460	94%	6%
0.4	577	551	96%	4%

Cylinder 3 — **Nozzle : D43**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	202	184	91%	9%
0.1	271	250	92%	8%
0.2	403	393	97%	3%
0.3	508	499	98%	2%
0.4	610	594	97%	3%

Cylinder 4 — **Nozzle : D44**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	189	181	96%	4%
0.1	275	259	94%	6%
0.2	390	386	99%	1%
0.3	493	489	99%	1%
0.4	591	585	99%	1%

Average Nozzle fouling at 0.1 mm lift 11%

$$\text{Nozzle Fouling (\%)} = 100 \times \left[\frac{\text{clean - dirty}}{\text{clean}}\right]$$

Where test is valid according to procedure CEC F - 23 - 01

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4.0 Unscheduled occurences

Unschedulded Issues

Time of Issue (hours into test)	Time off Test	Issue

Unschedulded Shutdowns

Time of shutdwon (hours into test)	Time off Test	Reason for shutdown

Deviations

Time of deviation (hours into test)	Max deviation	Name of "out of spec" parameter

5.0 Averaged test data

Parameter	Pre Checks	Stage 1	Stage 2	Stage 3	Stage 4
Speed (rpm)	3000.0	1199.5	2999.9	1300.0	1849.8
Torque (Nm)	50.1	10.0	50.0	35.0	50.0
Fuel Press In (mbar)	13.7	15.4	8.8	16.5	17.5
Fuel Press Out (mbar)	15.4	7.3	12.6	6.1	5.9
Coolant Out (deg C)	95.1	95.0	94.6	95.6	94.9
Coolant Flow (l/min)	85.1		84.8		
EBP (mbar)	49.0		47.7		
Fuel Con (kg/hr)	4.97				
Oil (deg C)	104.5	98.3	101.8	99.7	99.3
AIT (deg C)	31.9	32.2	32.0	32.1	32.1
Fuel Temp (deg C)	31.0	31.7	31.6	31.7	31.6
Exh Man Temp (deg C)	371.5	189.3	357.6	225.9	280.7
Intake Press (mbar)	954.0		954.0		

Test Number : ON-XUD9-006
Fuel Code : Orlens base diesel
Additive Code : Sample 5
Treat rate : 300 mg/kg

6.0 Referencing history Engine No 0715050

Two calibration fuels have been selected to enable the tuning of the XUD9A/L engine.

CEC Calibration fuel DF90 is used as an additised calibration product and currently the result from this test should provide a result of 65±5% as a rolling average No result should lie outside 65±8% .

As of 16th October 2008 the 2008 Round Robin Fuel has been adopted as the new Reference fuel with a description of CEC DF-96-08 currently the result from this test should provide a result of 69±5% as a rolling average No result should lie outside 69±8% .

Average % fouling @ 0.1mm lift

Tests	Test No.	Date	RF93T095 Fuel	DF96 Fuel
1	TK-XUD9-114	24-Dec-09	n/a	66%
7	TK-XUD9-119	12-Jan-10	n/a	74%
10	TK-XUD9-122	16-Jan-10	n/a	72%
14	TK-XUD9-126	21-Jan-10	n/a	70%
37	TK-XUD9-192	07-Jan-11	n/a	69%
38	TK-XUD9-194	17-Jan-11	n/a	67%
47	TK-XUD9-202	28-Jan-11	n/a	70%
73	TK-XUD9-204	18-Feb-11	n/a	73%
87	TK-XUD9-205	13-Mar-11	n/a	71%
107	TK-XUD9-209	05-Apr-11	n/a	71%
126	TK-XUD9-210	12-May-11	n/a	70%
153	TK-XUD9-217	04-Jul-11	n/a	73%
174	TK-XUD9-220	01-Aug-11	n/a	75%
193	TK-XUD9-221	14-Aug-11	n/a	69%

Rolling Average 72.3%

Test Number : ON-XUD9-001
Fuel Code : Orlen base fuel
Additive Code : N/a
Treat rate : N/a

Flow loss calculations

nozzle test runs	1

Cylinder 1 (Flywheel end) — **Nozzle : D41**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	183	28	15%	85%
0.1	264	57	22%	78%
0.2	383	136	36%	64%
0.3	491	243	50%	50%
0.4	583	363	62%	38%

Cylinder 2 — **Nozzle : D42**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	198	23	12%	88%
0.1	264	43	16%	84%
0.2	366	100	27%	73%
0.3	470	197	42%	58%
0.4	566	305	54%	46%

Cylinder 3 — **Nozzle : D43**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	200	44	22%	78%
0.1	259	69	27%	73%
0.2	397	149	37%	63%
0.3	503	249	49%	51%
0.4	606	363	60%	40%

Cylinder 4 — **Nozzle : D44**

Needle lift (mm)	*Corrected airflow (cc/min)*		*Residual flow*	*Nozzle Fouling (%)*
	Clean	*Dirty*		
0.05	192	27	14%	86%
0.1	260	53	20%	80%
0.2	388	124	32%	68%
0.3	491	224	46%	54%
0.4	592	336	57%	43%

Average Nozzle fouling at 0.1 mm lift 79%

$$\text{Nozzle Fouling (\%)} = 100 \times \frac{\text{clean - dirty}}{\text{clean}}$$

Where test is valid according to procedure CEC F - 23 - 01