Studio sperimentale di un GPL di nuova formulazione contente DME

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DME/propane blends

Motivation of the project

The main purpose of this research project, commissioned by Liquigas/Assogasliquidi, is to have a complete evaluation of a fuel blend for LPG powered vehicles consisting of LPG (including bio-propane) and renewable dimethyl ether (rDME).

Work packages

- **WP1** RON/MON determination of DME/LPG blends: study completed and results used for WP2
- **WP2** Automotive exhaust emissions: four different cars (two small and two medium segment) are currently being tested following the type-approval procedures (WLTC and RDE). The exhaust emissions include regulated and non-regulated pollutants. Results will be used as primary data for WP3
- **WP3** Cradle to grave Life Cycle Assessment (LCA). The impacts will be compared with those of a petrol car and a full-electric car for both segments

WP1 Experimental study details

- Binary blends made by propane and DME were chosen for the following reasons:
    - samples preparation (simplicity)
    - the importance of bio-propane in the future LPG mix
    - EU winter survey (presented by Renault in WG 23) showed that propane in many countries is > 90% (m/m)
    - comparison with literature data (Amoco patent)
- Both MON, (EN 589 requirement) and RON were measured according to ASTM D2623-86, see next slides
- Sampling from liquid phase

Octane number of DME/LPG blends

ASTM D2623-86 Knock Characteristics of Liquefied Petroleum (LP) Gases by the Motor (LP) Method

- This method was based on the MON method for liquid. It was withdrawn in 1989.
- The fuel is drawn out from the cylinder as a liquid, vaporized and maintained at a constant temperature, then introduced into the intake system through an hole in the standard carburetor inlet elbow.
- A check fuel (pure propane) is used to check the performance of the engine: $MON_{propane} = 96{,}3 \pm 0{,}7$
- The maximum KI (knock intensity) is obtained by varying the opening of the gas metering valve
- r = 1 ON, R = 3 ON

Fuel preparation system

- The standard CFR engine is not equipped to measure the octane numbers of gaseous fuels, so it is necessary to add an additional fuel preparation system

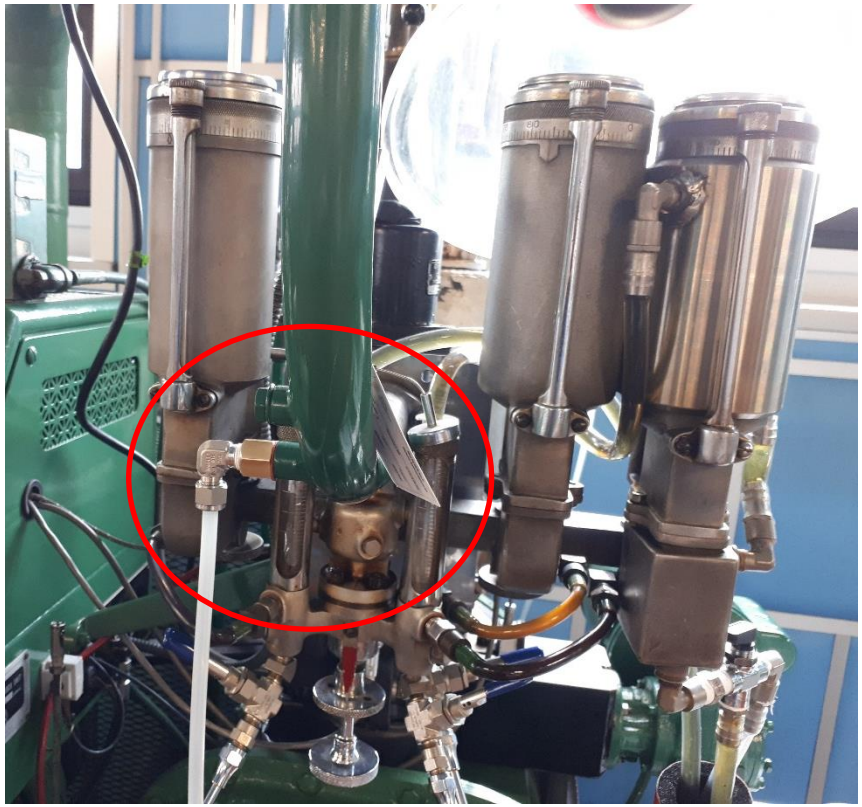
CFR engine equipped with LPG kit

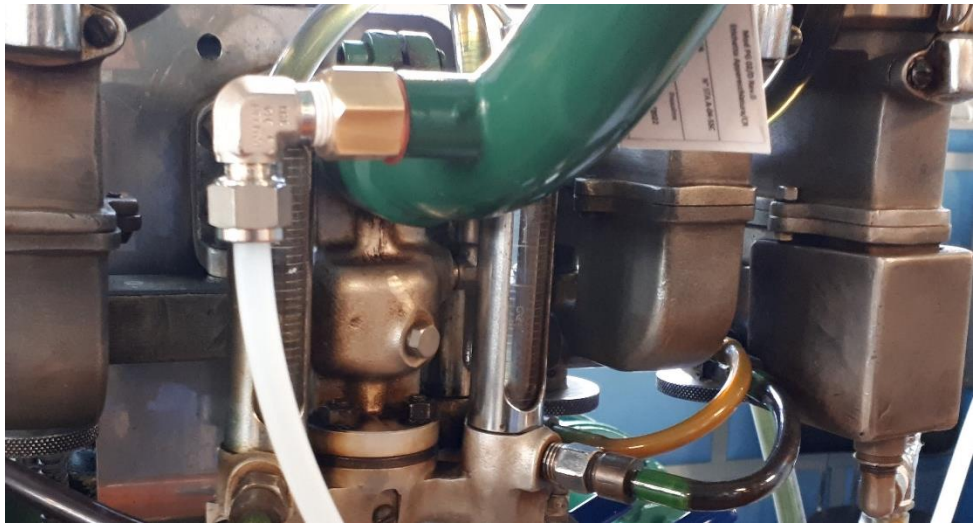
Fuel preparation system

The fuel is drawn out from the cylinder as a liquid, vaporized and maintained at a constant temperature, then introduced into the air stream at constant pressure through a connection on the standard carburetor inlet elbow, upstream of the venturi

Hardware “modification”

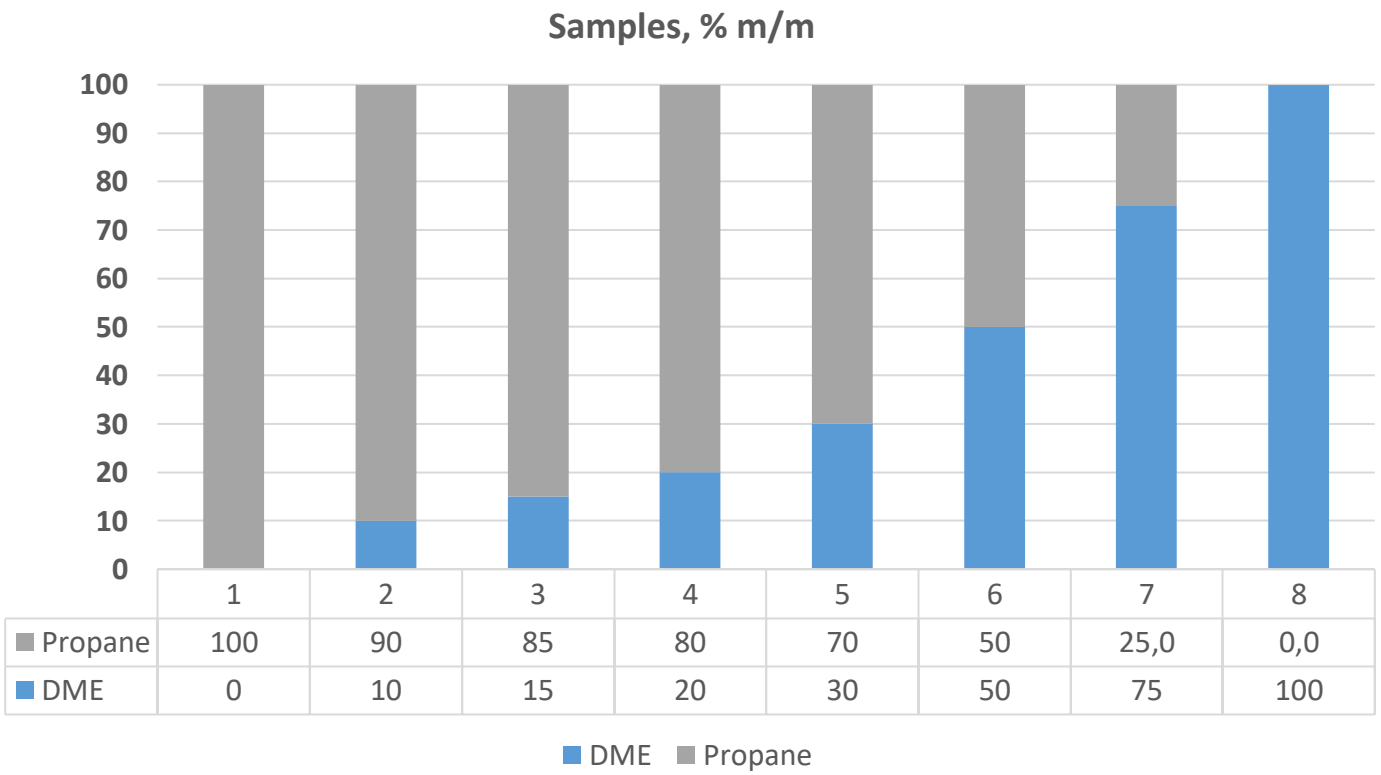
- The modification to the standard intake system is very simple. The standard inlet elbow has already an additional “hole” to permit an additional input of gases





Experimental study details

- Samples tested: 6 blends + 100% propane + 100% DME



	1	2	3	4	5	6	7	8
Propane	100	90	85	80	70	50	25,0	0,0
DME	0	10	15	20	30	50	75	100

Experimental study details

- Calculated vapour pressure of the samples (in red values < 200 kPa)

#	Propane (% m/m)	DME (% m/m)	TVR, kPa							
			Grade A -10 °C	Grade B -5 °C	Grade C 0 °C	Grade D +10 °C	Grade E +20 °C	Current EN 589	Future EN 589	40°C
1	100	0	244,7	303,7	370,7	528,7	724,7	150	200	1251,7
2	90	10	228,6	285,5	350,2	502,9	693,0			1205,3
3	85	15	220,6	276,5	339,9	490,0	677,1			1182,2
4	80	20	212,6	267,4	329,6	477,1	661,3			1159,0
5	70	30	196,6	249,3	309,1	451,4	629,5			1112,6
6	50	50	164,5	213,0	268,1	399,8	566,1			1019,9
7	25	75	124,4	167,7	216,8	335,4	486,9			904,1
8	0	100	84,3	122,3	165,5	271,0	407,6			788,2

DME values taken from*: Saturated pressure measurements of dimethyl ether at temperatures from (219 to 361) K, Journal of Chemical & Engineering Data · June 2006*

Results

- Repeatability and accuracy of the engine/method: <u>1) with a PT sample</u>

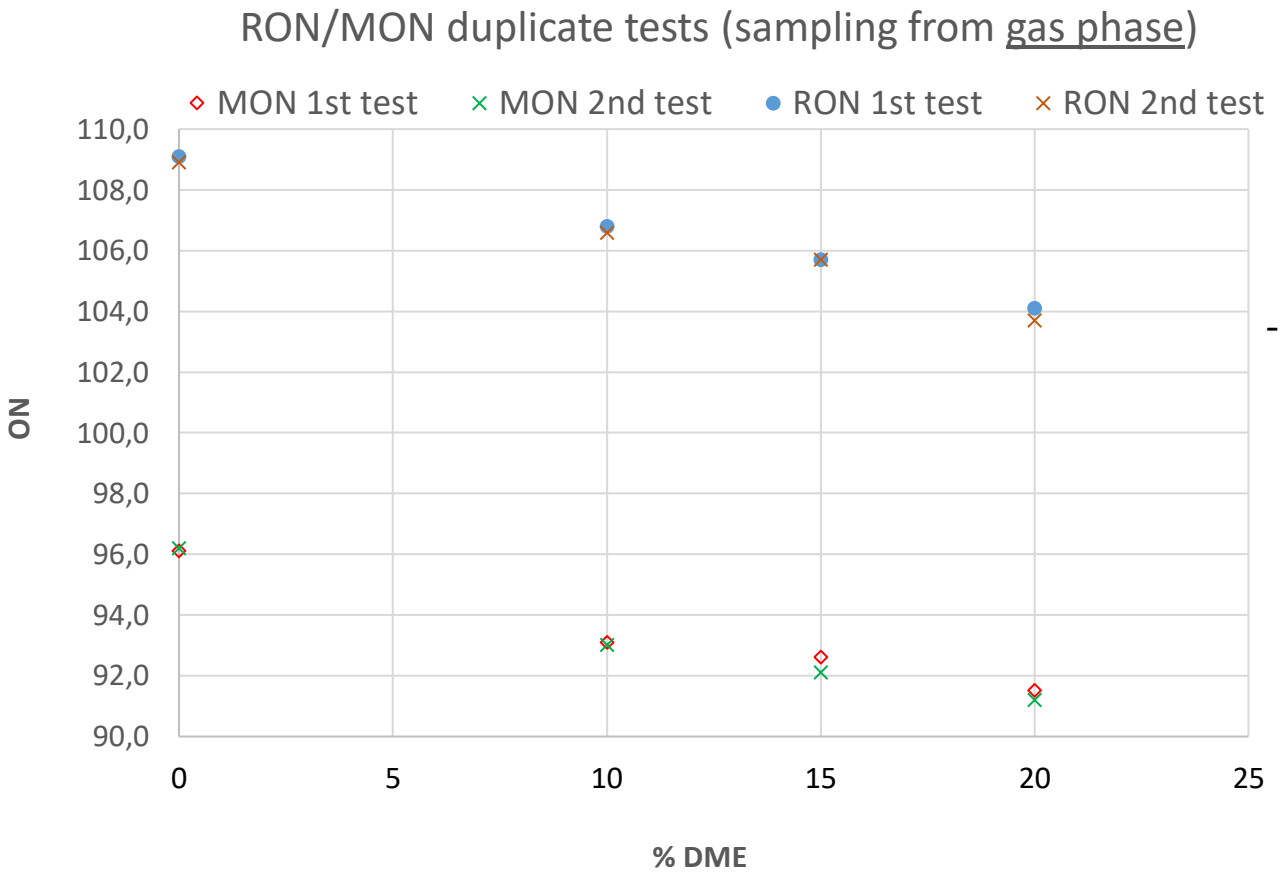
		Composition, % m/m (CoA)							
#	Sample	DME	Propane	Propilene	i-Butane	n-Butane	i-Butene + Butene1	1,3-Butadiene	n-Pentano
1	UNICHIM PT sample	-	81,97	2,73	8,88	3,82	1,226	0,575	0,787
2									

		MON				RON	
		ASTM D2623-86		EN 589 Annex B	Measured-calculated (expected to be max ± 1 ON)		ASTM D2623-86
#	Sample	Check fuel (propane) 96,3 ± 0,7	Measured	Calculated		Check fuel (propane) 108,3 ± 0,8(1)	Measured
1	UNICHIM PT sample	96,5	**95,1**	**94,5**	0,6	-	-
2		96,4	**95,1**		0,6	108,8	107,5

(1) UNI/TR 11795:2020 - Petroleum Products - Results of an experimental study to determine the octane number of LPG using the CFR engine

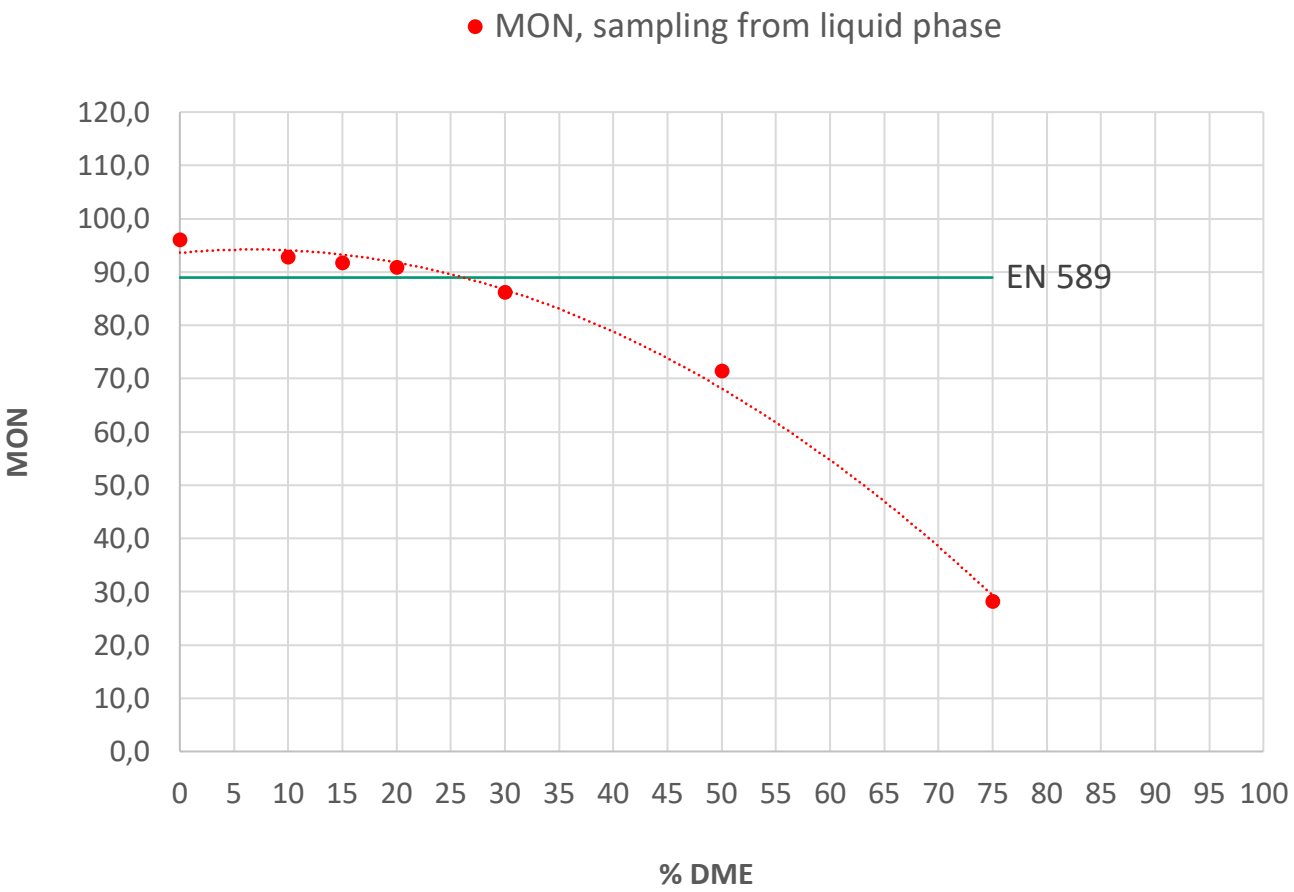
Results

- Repeatability of the engine/method: 2) replicate tests



- The mean of the difference between the two measures is 0,2 ON, well below the repeatability of test method

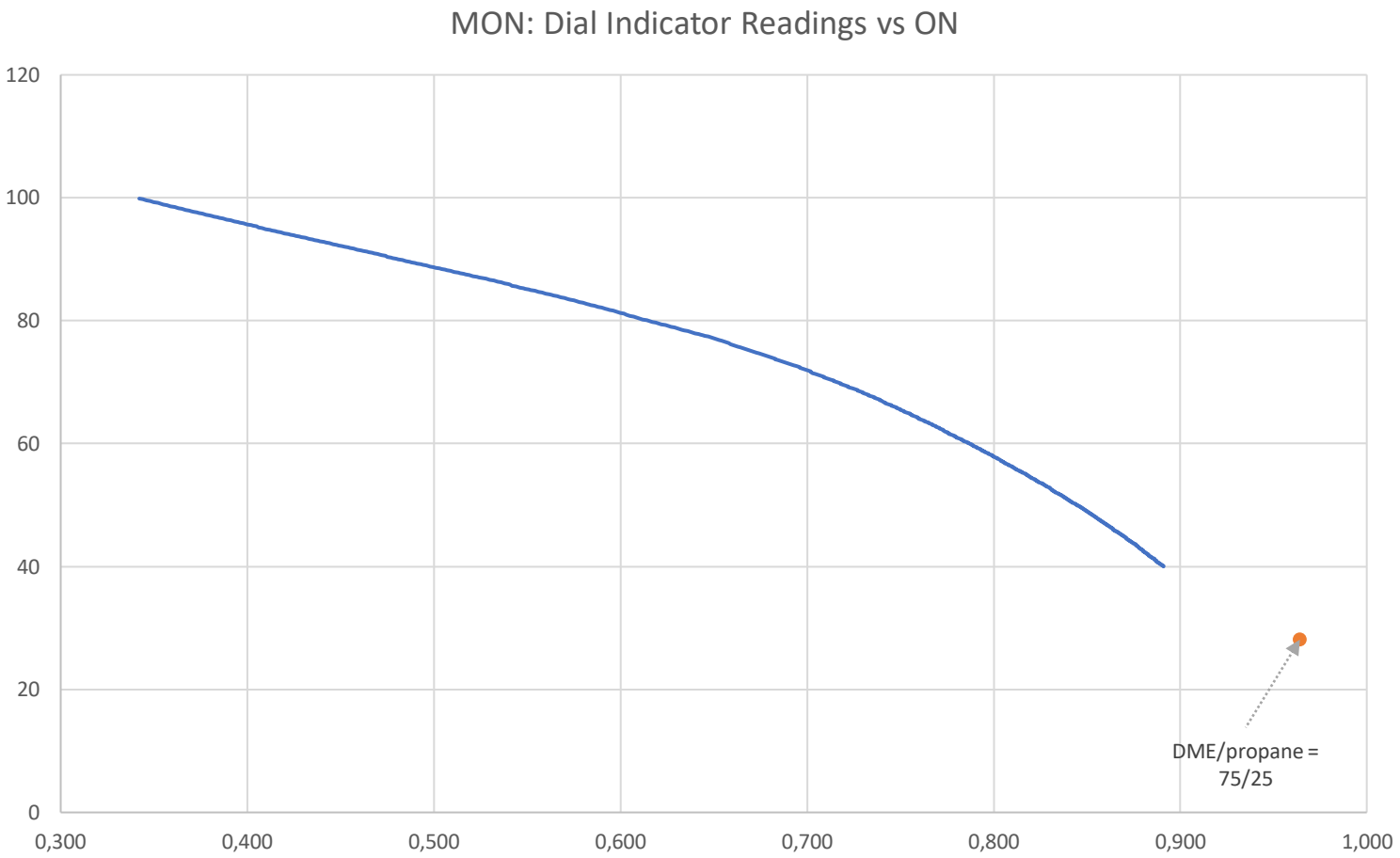
Results



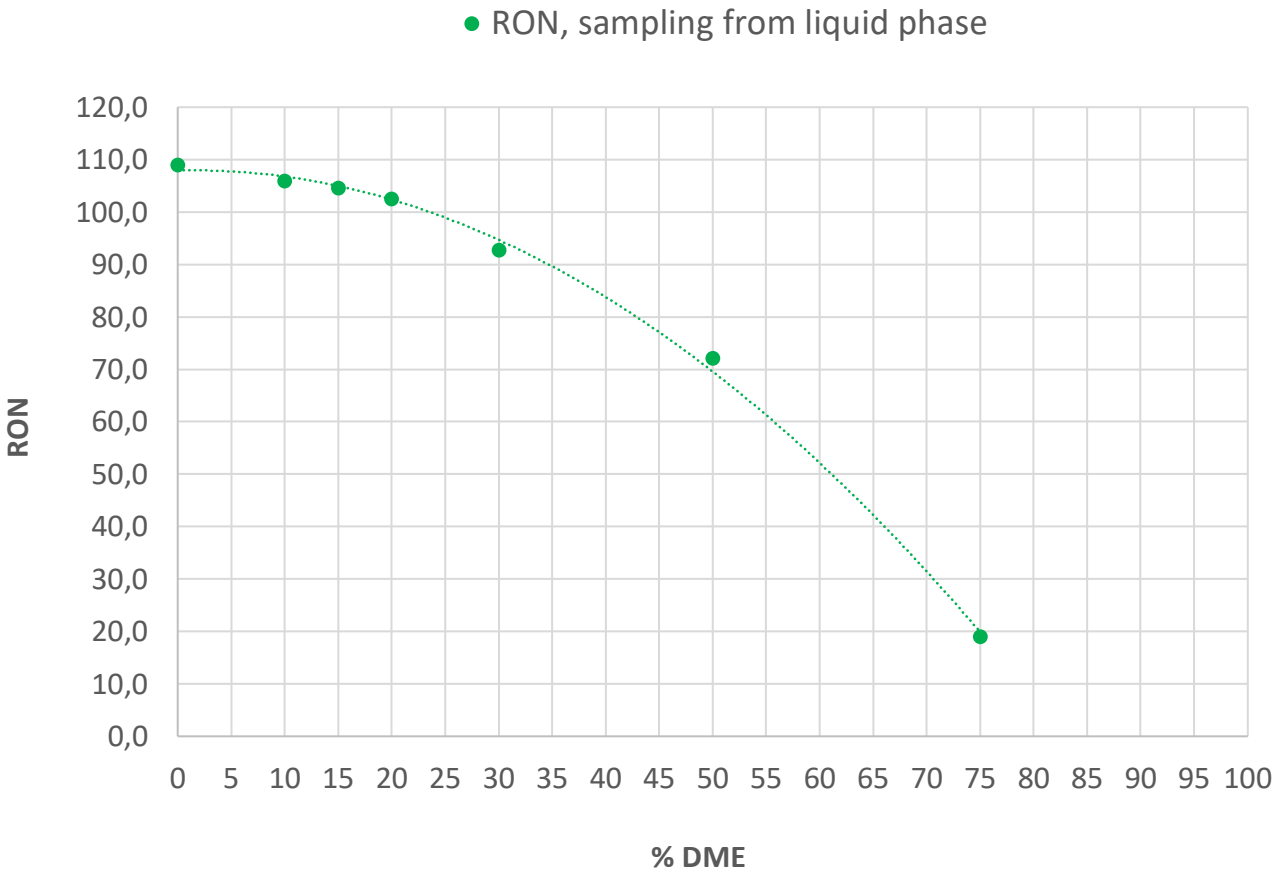
- fitting: 2nd order polynomial
- Up to ~25% DME the MON requirement according to EN 589 (89,0 MON minimum) is satisfied
- MON of pure DME is not measurable (too low) with the method
- The MON value of 75/25 blend is an extrapolation (see next slide)

DME (% m/m)	0	10	15	20	30	50	75
Propane (% m/m)	100	90	85	80	70	50	25
MON	**96,0**	**92,7**	**91,7**	**90,8**	**86,2**	**71,4**	**28,1**

Results


MON: Dial Indicator Readings vs ON
120
100
80
60
40
20
0
0,300
0,400
0,500
0,600
0,700
0,800
0,900
1,000
DME/propane = 75/25

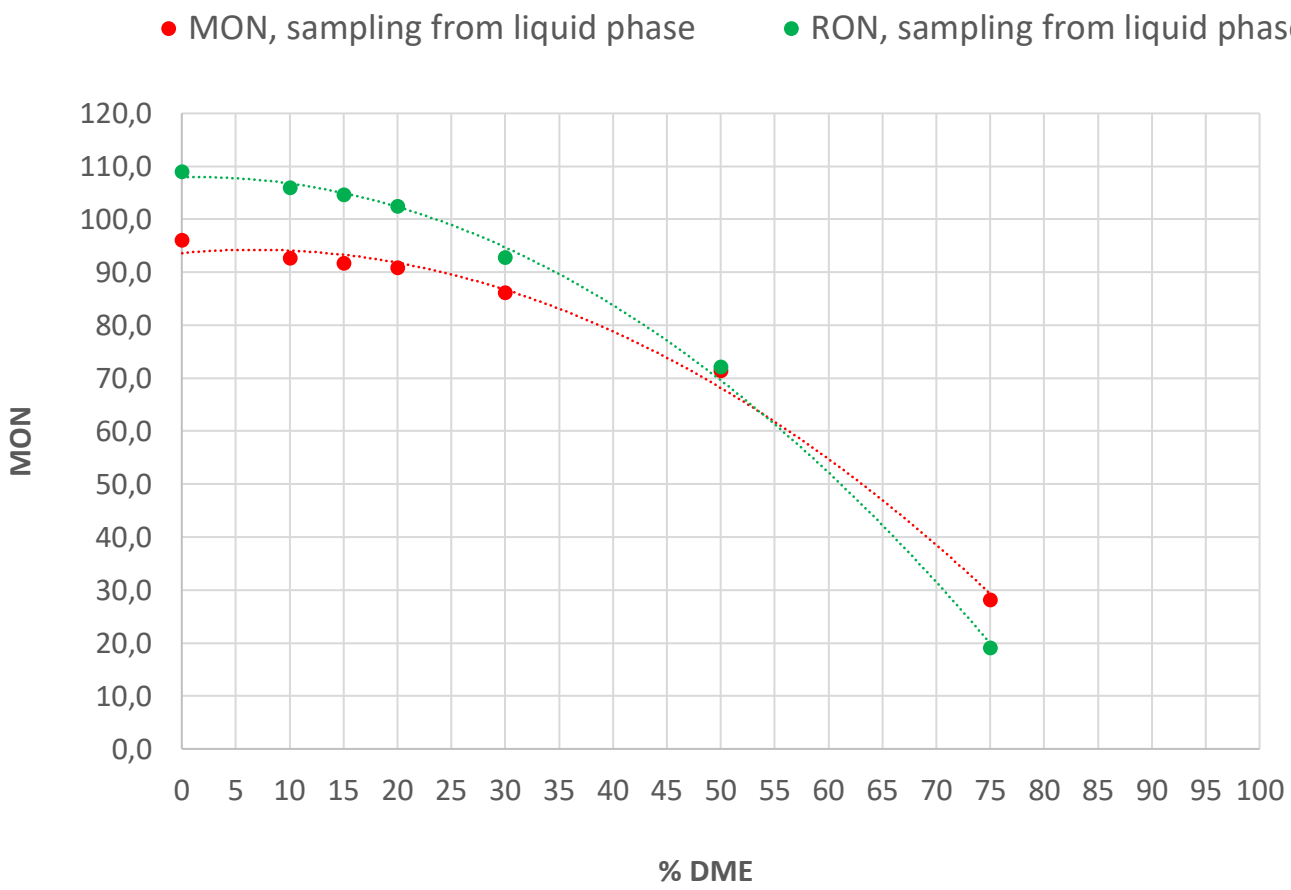
Results



DME (% m/m)	0	10	15	20	30	50	75
Propane (% m/m)	100	90	85	80	70	50	25
RON	**109,0**	**106,0**	**104,6**	**102,5**	**92,8**	**72,1**	**19,1**

- fitting: 2nd order polynomial
- Up to ~20% DME the RON values is > 100
- RON of pure DME is not measurable (too low) with the method
- The RON value of 75/25 blend is an extrapolation

Results



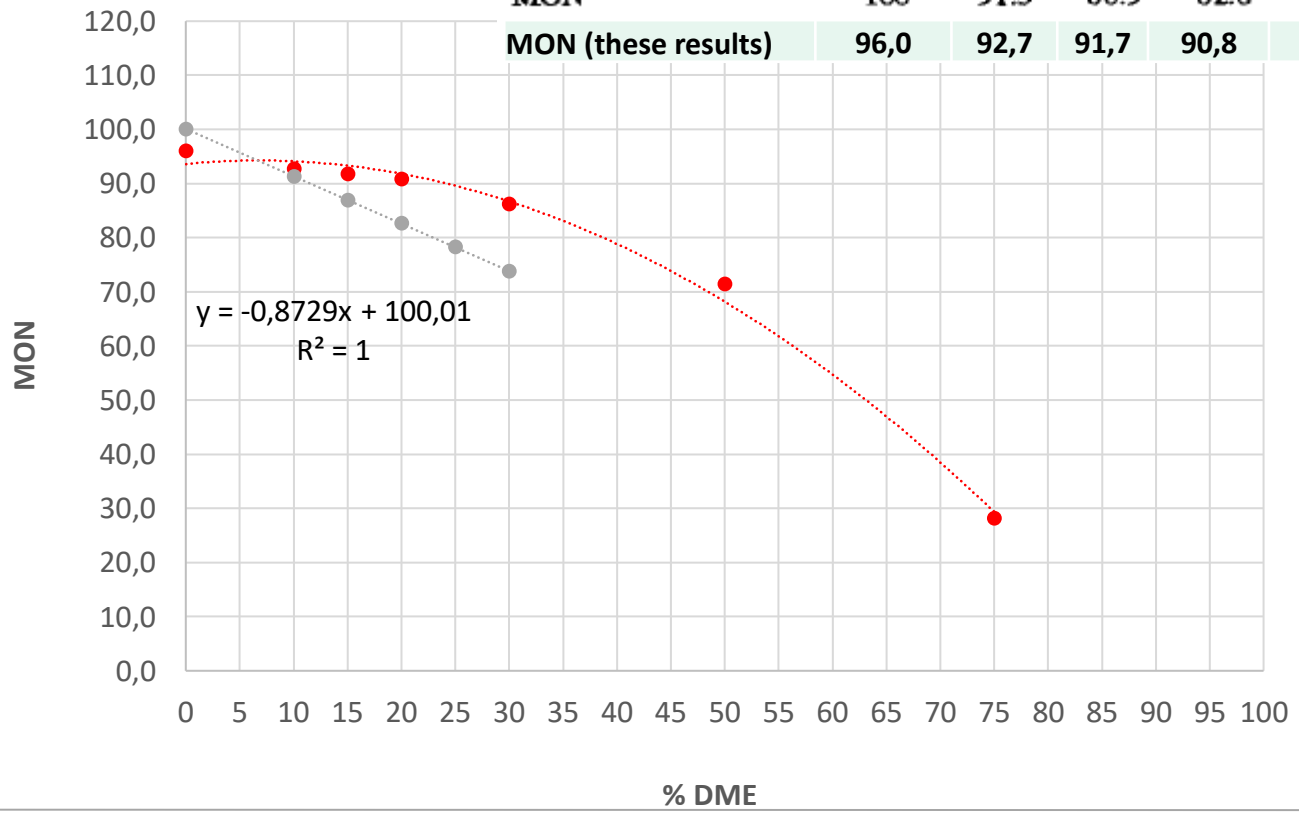
- The fuel sensitivity (RON-MON) decreases as % DME increases
- With the 50/50 blend the two values are almost equal
- DME > 50% MON > RON

Results – comparison with Amoco patent (May 1997)

TABLE A-continued

OCTANE NUMBERS OF SEVERAL BLENDS

Dimethyl Ether (weight percent)		10	15	20	25	30
Propane (weight percent)	100	90	85	80	75	70
MON	100	91.3	86.9	82.6	78.2	73.8
MON (these results)	**96,0**	**92,7**	**91,7**	**90,8**	**-**	**86,2**



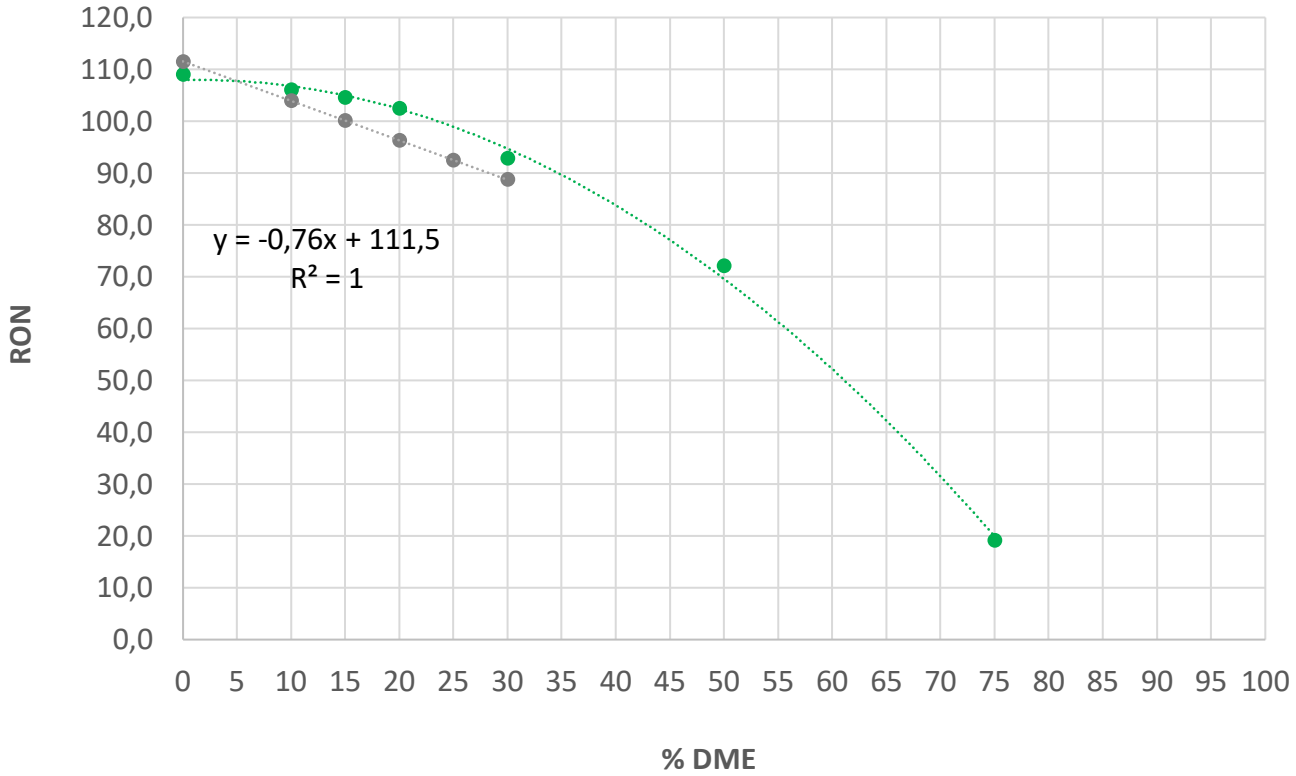
- Linear (Amoco) vs polynomial fitting
- The Amoco 100% propane result is not in line with ASTM

Results – comparison with Amoco patent (May 1997)

TABLE A

OCTANE NUMBERS OF SEVERAL BLENDS

Dimethyl Ether (weight percent)		10	15	20	25	30
Propane (weight percent)	100	90	85	80	75	70
RON	111.5	103.9	100.1	96.3	92.5	88.7
RON (these results)	**109,0**	**106,0**	**104,6**	**102,5**	**-**	**92,8**



- Linear (Amoco) vs polynomial fitting
- The delta between the two data set is lower compared to the one observed with MON

Results

Conclusions

- The 20/80 DME/propane blend has been identified as the blend to be tested for automotive testing (WP2):

DME (% m/m)	0	10	15	**20**	30	50	75
Propane (% m/m)	100	90	85	**80**	70	50	25
MON	96,0	92,7	91,7	**90,8**	86,2	71,4	28,1
RON	109,0	106,0	104,6	**102,5**	92,8	72,1	19,1
Vapour pressure at -10°C	244,7	228,6	220,6	**212,6**	196,6	164,5	124,4