C3 WP3: Methane Number Standardised Method

*(**VSL,** NPL, PTB, SP, Shell, REG(TUBS))*

Start month: Jun 2014, end month: Sep 2016

The methane number (MN) is a parameter that is representative for the knocking behaviour of fuel gases. Pure methane has a MN of 100, whereas pure hydrogen has an MN of 0. A binary mixture of hydrogen and methane with a volume fraction of 75 % methane has an MN 75. A comprehensive approach to the development of a correlation between the natural gas composition and the MN dates back to the early 1970s [11]. This work is still the basis for the current practice in determining the MN. One of the shortcomings of this work is that the number of components considered is quite limited. Furthermore, there are issues with the metrological traceability of the gas mixtures used for the tests leading to the correlation, and there is no evaluation of measurement uncertainty. As the MN is used in conformity assessment, the metrological aspects need urgent attention.

The aim of this work package is to provide a metrological framework for the development of LNG as a transport fuel, which is one of the pillars of the EU clean fuel strategy. Currently, there is a lack of commonly agreed measurement practices and no metrological framework. A crucial element for the roll-out of LNG as transport fuel is the development of a harmonised method and related measurement technology for the determination of the MN, including a correlation of the methane number with LNG composition. LNG composition can differ from that of natural gas by increased contents of higher hydrocarbons, These hydrocarbons have a suppressing effect on the MN, but because of the ageing of LNG in storage tanks (the boil off contains mostly methane and nitrogen), there is an accumulation of heavier hydrocarbons.

The work of this technical work package will lead to the submission for publication of at least two peer reviewed paper. These papers are included in WP5 as D5.1.7, however the resource is included in this WP.

C3.a Description of Work

Task 3.1: Definition of an approach for the calculation of the MN from the LNG composition (**VSL**, NPL, PTB, REG(TUBS), Shell)

(Start Jun 2014, end Sep 2014)

The aim of the Task is to develop an approach for the calculation of the methane number (MN) from the LNG composition. A potentially suitable correlation between the MN and LNG composition comes from MWM [10], which is an extension of the well-known AVL method [11]. The AVL method is widely used, but has the disadvantage that it covers only hydrocarbons up to C_4 (butane). The MWM method covers hydrocarbons up to C_7, and therefore is of much more use in relation to LNG. The heavier hydrocarbons have a detrimental effect on the MN as they tend to accumulate in LNG during storage. Activities to introduce the MWM method into a European standard are presently underway. However, the method has been developed mainly with focus on engines designed for lean mixtures (large Air Fuel Ratio) and not on current supercharged automotive engines that run on stoichiometric mixtures (mixtures with exactly enough air to completely burn all of the fuel.). Therefore further validation is necessary.

Description of activities:

- VSL with input from NPL, PTB, REG(TUBS) and Shell will conduct a literature review of experimental and theoretical work on the correlation between the MN and LNG composition. This review will include acquiring data from the automotive and engine industry and Rapid Compression Machine (RMC) data. The data will then be down selected for that which is relevant for the calculation of the MN from the LNG composition. This will be recorded in a document. (VSL, NPL, PTB, REG(TUBS), Shell) (D3.1.1)
- Using information from the previous activity, NPL with input from VSL, PTB and REG(TUBS) will develop an algorithm for the calculation of the MN from the LNG composition, including the calculation of measurement uncertainty. (NPL, VSL, PTB, REG(TUBS)) (D3.1.2)

Major facilities to be used: none

Task 3.2: Development of an experimental programme for the calculation of the MN from the LNG composition (VSL, NPL, PTB, REG(TUBS))

(Start Aug 2014, end May 2015)

The aim of this task is to develop an experimental validation program for the calculation of the MN from the LNG composition based on the algorithm produced in Task 3.1. The number and composition of the gas mixtures to be used in the validation tests will be decided and a validation protocol developed for use in Task 3.3.

Description of the activities:

- VSL with input from NPL, PTB and REG(TUBS) will develop an experimental program and validation protocol for the validation of the calculation of the MN from the LNG composition based on the algorithm from D3.1.2. (VSL, NPL, PTB and REG(TUBS)) (D3.2.1)
- In order to perform the validation, VSL with support from NPL, PTB and REG(TUBS) will determine the number and composition of the gas mixtures to be used in the validation tests, i.e. a set of characterised gas mixtures with traceable composition. They will then ensure the provision and certification/characterisation of the chosen set of gas mixtures of hydrogen in methane and LNG compositions. The set will include at least 4 gas mixtures. (VSL, NPL, PTB, REG(TUBS)) (D3.2.2)

Major facilities to be used: none

Task 3.3: Experimental work with RCM & SI engines (PTB, REG(TUBS))

(Start Sep 2014, end May 2016)

The aim of this task is the determination of knocking resistance for a set of characterised LNG samples, using the set of gas mixtures produced in D3.2.2 with two different experimental techniques. Firstly, ignition delay times (a measure for knock propensity) will be measured using a RMC [15,16]. Secondly, SI engine measurements will be performed to determine the service methane number as a function of gas composition. The data from the two experimental techniques will then be compared to results reported in current literature and with other methods used for calculating the MN, such as the MWM method.

Description of activities:

- REG(TUBS) will perform SI engine experiments to determine the service methane number as a function of gas composition with two different engine types:
  - SI engine experiments with engine A: REG(TUBS) will perform experiments with a state of the art, λ=1 turbocharged SI engine with at least 4 gas mixtures and a wide range of operating parameters including engine speed, supercharging pressure, equivalence ratio, ignition timing, effective and geometric compression ratio, using the D3.2.2 samples and following the D3.2.1 validation protocol. (REG(TUBS)) (D3.3.1)
  - SI engine experiments with engine B: REG(TUBS) will perform experiments with a state of the art, λ=1 turbocharged SI engine with at least 4 gas mixtures and a wide range of operating parameters including engine speed, supercharging pressure, equivalence ratio, ignition timing, effective and geometric compression ratio, using the D3.2.2 samples and following the D3.2.1 validation protocol. (REG(TUBS)) (D3.3.2)
- PTB will measure ignition delay times using a RCM with the set of gas mixtures. PTB will begin by making LNG sample preparation hardware modifications to a RCM for LNG investigations (e.g fuel delivery, combustion chamber). Using the modified RCM, PTB will then perform measurements with the D3.2.2 samples and will determine the uncertainties for ignition delays over a range of gas compositions, temperatures and pressures decided in the D3.2.1 validation protocol. The RCM experiments will be done in the temperature range of 500-900 K, with pressures of 20 bar and phi= 0.4 – 1.25. (PTB) (D3.3.3)
- PTB and REG(TUBS) will compare the results from D3.3.1, D3.3.2 and D3.3.3 with results reported in current literature and with other methods used for calculating the MN, such as the MWM method . They will then produce a report on the results of the Task and the determination of knocking resistance for characterised LNG samples using SI engine and RCM techniques. (PTB, REG(TUBS) (D3.3.4)

Major facilities to be used:

SI-Engines (REG(TUBS))

Rapid Compression Machine (PTB)

Task 3.4: Correlation and validation for the calculation of the MN from the LNG composition (VSL, NPL, PTB, SP, REG(TUBS), Shell)

(Start May 2015, end Sep 2016)

The aim of this task is to validate the algorithm from D3.1.2 based on the experimental results from Task 3.3 in order to provide a validated model for the calculation of the MN from the LNG composition. The uncertainty of the calculation of the MN, as well as the correlation of the MN to the LNG composition, will also be determined.

Description of activities:

- NPL, with input from VSL, PTB, SP, REG(TUBS) and Shell will examine the correlation between the MN and LNG composition using the results from D3.3.1 – D3.3.3 and the literature review D3.1.1. From this NPL, with input from VSL, PTB, SP, REG(TUBS) and Shell will revise the algorithm D3.1.2, to produce an updated model for the calculation of the MN from the LNG composition. (NPL, VSL, PTB, SP, REG(TUBS), Shell) (D3.4.1)
- Using input from the previous activity, NPL, with support from VSL, PTB, SP, REG(TUBS) and Shell will evaluate the measurement uncertainty for the calculation of the MN from the LNG composition using the updated model D3.4.1 and the correlation of the MN with the LNG composition. (NPL, VSL, PTB, SP, REG(TUBS), Shell) (D3.4.2).
- Using the updated model D3.4.1, the calculated uncertainties from D3.4.2 and the report from D3.3.4, VSL together with NPL, PTB and REG(TUBS) will make any necessary final revisions to the model for the calculation of the MN from the LNG composition. They will then produce a report on the validation of a calculation for the MN from the LNG composition and the correlation of the MN to the LNG composition. (VSL, NPL, PTB, REG(TUBS) (D3.4.3)

Major facilities to be used: none

C3.b Labour Resources for WP3

	1- VSL	2- CESAME	3- CMI	4- FORCE	5- INRIM	6- JV	7- NPL	8- PTB	9- SP	10- Shell	11- REG(RUB)	12- REG(TUBS)	TOTAL
WP3	5.6						6.0	9.0	1.0	1.0		14.0	36.6

C3.c Summary of Deliverables for WP3

Deliverable number	**Deliverable description**	**Participants (Lead in bold)**	**Deliverable type**	**Delivery date**	**Dependent on**
3.1.1 (REG(TUBS) D1)	Literature review on the correlation between the MN and LNG composition	**VSL**, NPL, PTB, REG(TUBS), Shell	Document	Jul 2014	
3.1.2 (REG(TUBS) D2)	Algorithm for the MN calculation from the LNG composition	**NPL,** VSL, PTB, REG(TUBS)	Algorithm	Sep 2014	D3.1.1

3.2.1 (REG(TUBS) D3)	Validation protocol for the calculation of the MN from the LNG composition	**VSL**, NPL, PTB, REG(TUBS)	Protocol	Sep 2014	D3.1.2
3.2.2 (REG(TUBS) D4)	Set of at least 4 characterised gas mixtures with traceable composition	**VSL**, NPL, PTB, REG(TUBS)	Samples	Nov 2014, May 2015	D3.2.1
3.3.1 (REG(TUBS) D5)	Service methane number as a function of gas composition for test engine A for well-defined LNG samples over a complete operating range	**REG(TUBS)**	Datasets	May 2015	D3.2.1, D3.2.2
3.3.2 (REG(TUBS) D6)	Service methane number as a function of gas composition for test engine B for well-defined LNG samples over a complete operating range	**REG(TUBS)**	Datasets	Sep 2015	D3.2.1, D3.2.2
3.3.3	Ignition delay measurements using an RCM for well-defined LNG samples	**PTB**	Datasets	Nov 2015	D3.2.1, D3.2.2
3.3.4 (REG(TUBS) D7)	Report on the determination of knocking resistance for characterised LNG samples using SI engine and RCM techniques	**PTB**, REG(TUBS)	Report	May 2016	D3.3.1 to D3.3.3
3.4.1 (REG(TUBS) D8)	Updated model for the calculation of the MN from the LNG composition	**NPL,** VSL, PTB, SP, REG(TUBS), Shell	Model	Nov 2015	D3.1.1, D3.1.2, D3.3.1 to D3.3.3
3.4.2 (REG(TUBS) D9)	Measurement uncertainty for the calculation of the MN from the LNG composition	**NPL,** VSL, PTB, SP, REG(TUBS), Shell	Uncertainty budget	Jan 2016	D3.4.1
3.4.3	Report on the validation of a calculation for the MN from the LNG composition and the correlation of the MN to the LNG composition	**VSL**, NPL, PTB	Report	Sep 2016	D3.3.4, D3.4.1, D3.4.2

C4 WP4: Density, Enthalpy and Calorific Value

*(**PTB**, INRIM, NPL, VSL, REG(RUB))*

Start month: Jun 2014, end month: Feb 2017

The aim of this work package is to provide an improved model for LNG density prediction and uncertainty analysis. The work package consists of 4 Tasks. In Task 4.1 a LNG densimeter (developed as part of the preceding JRP, ENG03 LNG) will be further developed and density data of different LNG samples will be determined. A selected Equation of State (EoS) for LNG will be improved in Task 4.2. In Task 4.3 a LNG densimeter will be constructed which applies to speed of sound measurements and operates with an alternative physical principle compared to the densimeter in Task 4.1. Uncertainties and the traceability of enthalpy and calorific value calculations will be examined in Task 4.4.

The work of this technical work package will lead to the submission for publication of at least four peer reviewed paper. These papers are included in WP5 as D5.1.7, however the resource is included in this WP.