Algorithm for methane number determination for natural gasses

Project Report

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1 Introduction

So far, DGC has calculated the methane number for the Danish natural gas quality using an algorithm developed by DGC. Since the introduction of gas from the Harald field and the ensuing changes to the Danish natural gas composition, the sphere of application of the algorithm has been exceeded.

This report describes a new algorithm for determination of the methane number for natural gasses.

On the basis of the new algorithm a program has been developed to calculate the methane number. The program together with a user manual can be requested from Danish Gas Technology Centre.

Per Gravers Kristensen, DGC, has developed the new algorithm and Jan Jensen, DGC, has performed quality assurance of the report.

Hørsholm, June 1999

Paw Andersen	Jan Jensen
Project Manager	Head of Department

2 Description of the algorithm

There is no present standard for determining the methane number for gas mixtures. Nevertheless, practically most of the recent work with gasses tendency for knocking refer to the very profound studies performed at AVL in the late sixties /1/. This new algorithm is also based on these AVL studies.

2.1 Background – the AVL studies

In the AVL work a test engine of the same type as the engines used for octane number determination was used to determine the gasses' relative tendency for knocking. As for petrol's octane number /2/, /3/ the scale for the gasses is relative. The definitions are that pure methane has a methane number of 100 and pure hydrogen has a methane number of 0.

The AVL study /1/ includes the components CH_4, C_2H_4, C_2H_6, C_3H_6, C_3H_8, n-C_4H_{10}, H_2, CO_2, N_2 and H_2S in binary and ternary component mixtures. In addition, some measurements have been made for a limited number of natural gasses. Primarily all the AVL /1/ data are available as ternary diagrams, as shown in Figure 2.1 and Figure 2.. For further information on the AVL studies see /1/.

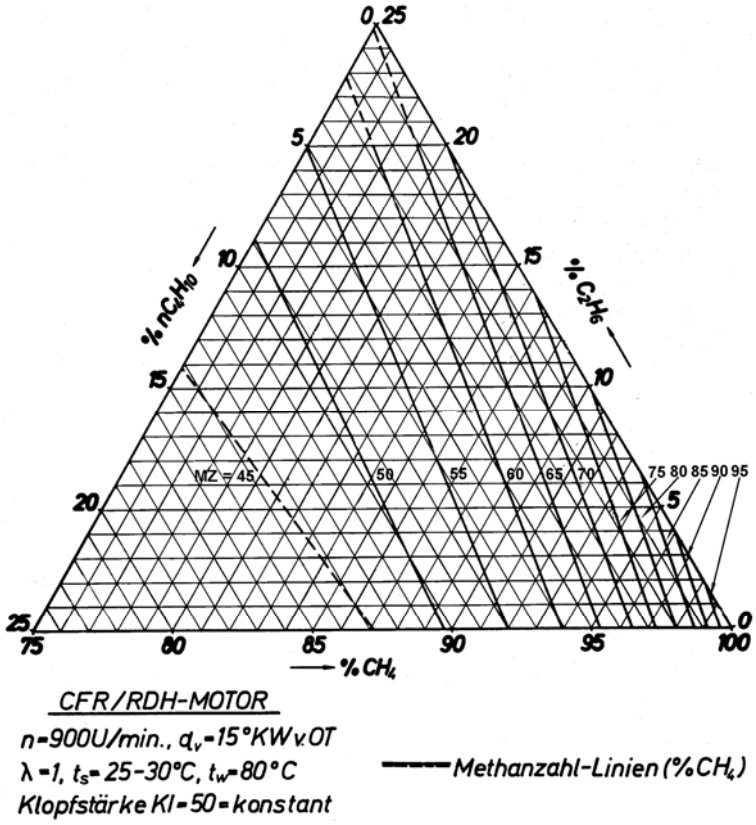

Figure 2.1. Methane number diagram for methane, ethane and butane /1/

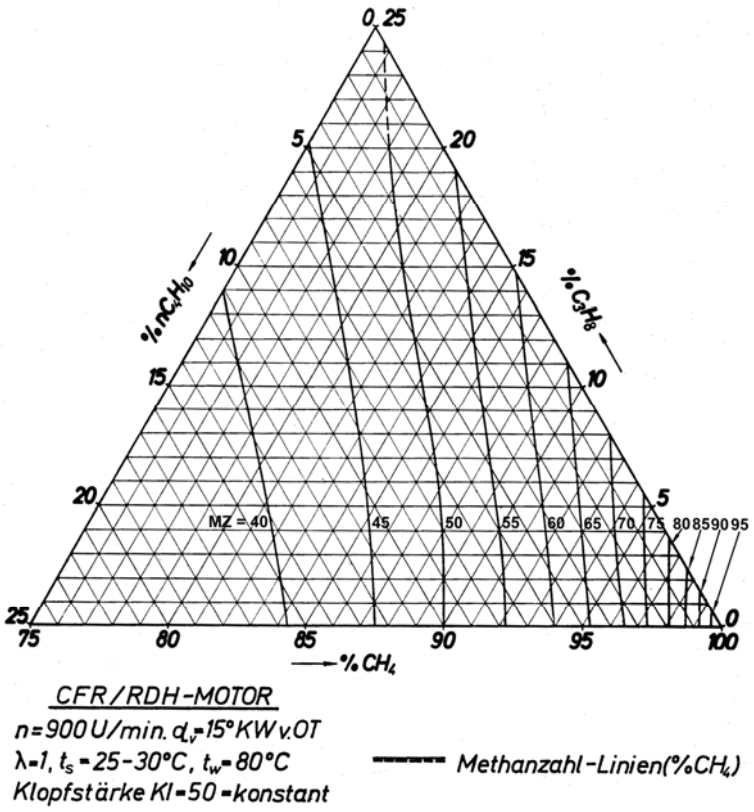

Figure 2.2. Methane number diagram for methane, propane and butane /1/

2.1.1 The AVL method

From all the experimental results, a procedure was developed to predict the methane number of a natural gas using the chemical composition of the gas. The procedure is:

1. The main components of the gas are determined. Inert gasses (CO_2 and N_2) are neglected at first.
2. The reduced gas (no inert gasses) is converted to 100% by volume.
3. The resulting mixture is divided into two fractions.
4. These two fractions are again normalised into 100% by volume.
5. The methane number of each of the two mixtures is determined using the diagrams.
6. If the difference between the two methane numbers found is greater than five, go back to step 3 and try again with two new fractions. When the difference is smaller than five, the methane number for the mixture without inert gasses can be determined using (Eq. 2.1).

$$MN' = \frac{1}{100} \cdot \sum_{i=1}^{n} y_i \cdot MN_i \qquad \textit{(Eq. 2.1)}$$

Where: MN' is the methane number for the gas free of inert gasses
MN_i is the methane number of component group i
Y_i is the share of component group i in the total mixture in percentage by volume

7. Finally, the influence from the inert gasses (*MN´´*) has to be taken into account. The influence from CO_2 and N_2 is found by using the diagram shown in Figure 2., where the total share of gas not containing inert gasses is considered as methane. In the AVL procedure the inert gasses CO_2 and N_2 are neglected, if their volume concentrations do not exceed two and nine percent, respectively.
8. The total methane number can then be determined by adding *MN´* and *MN´´*.

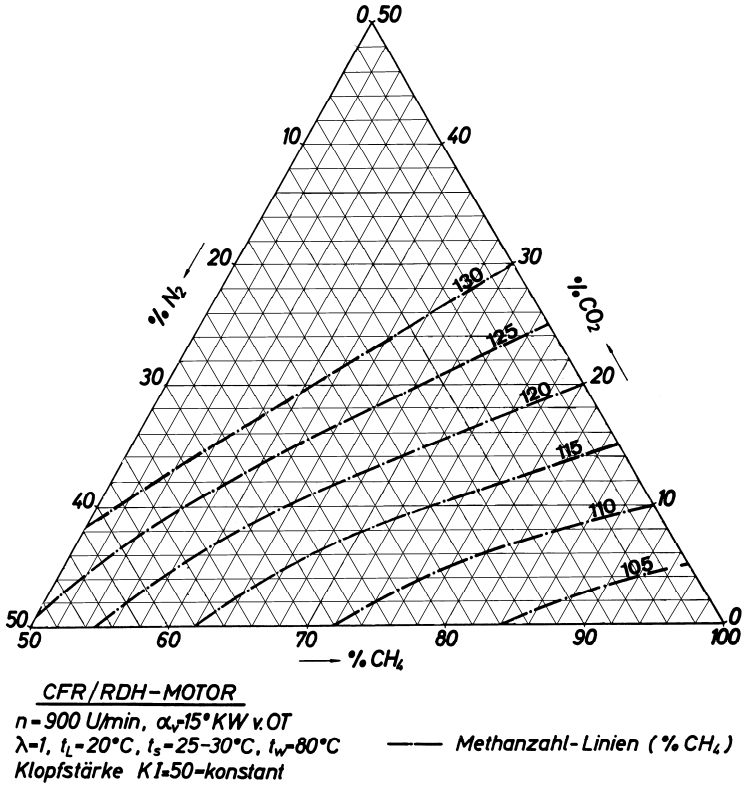

Figure 2.3. Methane number diagram for methane, carbon dioxide and nitrogen

2.2 The algorithm

As previous mentioned the new DGC algorithm is based on the AVL studies. The new algorithm also determines the methane number (MN) for a gas in two steps. First, the methane number for the gas free of inert gasses is determined, then the contribution from the inert gasses. Finally, the total methane number is found as:

$$MN = MN_{Without\ inert\ gasses} + MN_{Inert\ gasses} \qquad \textit{(Eq. 2.2)}$$

Where: MN *is the total methane number*

$MN_{Without\ inert\ gasses}$ *is the methane number of the gas free of inert gasses*

$MN_{Inert\ gasses}$ *is the supplement to the total methane number from the inert gasses*

Below follows a description of the assumptions made in the algorithm, and how the methane number is actually calculated.

2.2.1 Calculation of the methane number without inert gasses

To cover as large a spectrum as possible of the most common natural gasses, the two ternary AVL diagrams shown in Figure 2.1 and Figure 2. are used as the basis for determining the methane number for the gas free of inert gasses.

The formulaes developed to calculate the methane number are based on the assumption that the methane number curves in Figure 2.1 and Figure 2. can be represented as straight lines.

Normally, natural gasses contain methane, ethane, propane, butane, pentane, hexane and higher hydrocarbons, carbon dioxide, nitrogen and hydrogen sulphide etc. Because the ALV /1/ study does not include higher hydrocarbons than n-C_4H_{10}, all hydrocarbons higher than C_3H_8 are calculated as n-C_4H_{10}. The content of hydrogen sulphide in Danish natural gas is normally very low and is, therefore, neglected. Then the gas is represented as $G(X_1, X_2, X_3, X_4)$ where X_1 is the CH_4 concentration, X_2 is the C_2H_6 concentration, X_3 is the C_3H_8 concentration and X_4 is the concentration of n-C_4H_{10}, i-C_4H_{10} and higher hydrocarbons. Then, using the assumption that the methane number curves in Figure 2.1 and Figure 2. can be represented as straight lines, we have:

$$\begin{aligned} &A:(X_{1A}, X_{2A}, 0, X_{4A}):MN=AB \\ &B:(X_{1B}, X_{2B}, 0, X_{4B}):MN=AB \\ &C:(X_{1C}, 0, X_{3C}, X_{4C}):MN=CD \\ &D:(X_{1D}, 0, X_{3D}, X_{4D}):MN=CD \end{aligned} \qquad \textit{(Eq. 2.3)}$$

Where *A is the starting point of the MN curve in CH_4, C_2H_6, C_4H_{10} diagram*
B is the ending point of the MN curve in CH_4, C_2H_6, C_4H_{10} diagram
C is the starting point of the MN curve in CH_4, C_3H_8, C_4H_{10} diagram
D is the ending point of the MN curve in CH_4, C_3H_8, C_4H_{10} diagram
X_{1*} is the concentration of CH_4
X_{2*} is the concentration of C_2H_6
X_{3*} is the concentration of C_3H_8
X_{4*} is the concentration of C_4H_{10}

Generating two mixtures: E, a mixture of A and B, and F, a mixture of C and D:

$$\begin{aligned} E&: \in AB \qquad Parameter\,\alpha \\ F&: \in BC \qquad Parameter\,\beta \end{aligned} \qquad \textit{(Eq. 2.4)}$$

Mixing our gas G(X_1, X_2, X_3, X_4) as fractions of E and F we obtain:

$$G = X \cdot E + (1 - X) \cdot F \qquad \textit{(Eq. 2.5)}$$

and

$$MN(G) = MN(E) + X \cdot \left[MN(F) - MN(E)\right] \qquad \textit{(Eq. 2.6)}$$

where:

$$\begin{aligned} MN(E) &= AB \\ MN(F) &= CD \end{aligned} \qquad \textit{(Eq. 2.7)}$$

Solving this for X, gives the general solution shown in (Eq. 2.6). In Appendix A1 the derivation of (Eq. 2.6) is given.

$$X = \frac{X_1 - \dfrac{X_{2A}X_{1B} - X_{2B}X_{1A} - X_2(X_{1B} - X_{1A})}{X_{2A} - X_{2B}} - \dfrac{X_3(X_{1D} - X_{1C})}{X_{3D} - X_{3C}}}{\dfrac{(X_{3D}X_{1C} - X_{3C}X_{1D})}{X_{3D} - X_{3C}} - \dfrac{(X_{2A}X_{1B} - X_{2B}X_{1A})}{X_{2A} - X_{2B}}} \qquad \textit{(Eq. 2.8)}$$

2.2.2 Correction for inert gasses, CO_2 and N_2

As previously mentioned, inert gasses increase the methane number. The only inert gasses that are taken into account are CO_2 and N_2. To determine the contribution from the inert gasses CO_2 and N_2, the AVL diagram shown in Figure 2. is used. It has been found that the increased knocking resistance due to CO_2 and N_2 can be calculated using a tertiary interpolation expression of the form:

$$MZ_{C02\&N2} = 100 - \left(\begin{array}{l} [\%CH_4]^3 \cdot R_{111} + [\%CH_4]^2 \cdot [\%CO_2] \cdot R_{112} + \\ [\%CH_4]^2 \cdot [\%N_2] \cdot R_{113} + \\ [\%CH_4] \cdot [\%CO_2]^2 \cdot R_{122} + \\ [\%CH_4] \cdot [\%CO_2] \cdot [\%N_2] \cdot R_{123} + \\ [\%CH_4] \cdot [\%N_2]^2 \cdot R_{133} + \\ [\%CO_2]^3 \cdot R_{222} + [\%CO_2]^2 \cdot [\%N_2] \cdot R_{223} + \\ [\%CO_2] \cdot [\%N_2]^2 \cdot R_{233} + [\%N_2]^3 \; R_{333} + \\ [\%CH_4]^2 \cdot R_{11} + [\%CH_4] \cdot [\%CO_2] \cdot R_{12} + \\ [\%CH_4] \cdot [\%N_2] \cdot R_{13} + [\%CO_2]^2 \cdot R_{22} + \\ [\%CO_2] \cdot [\%N_2] \cdot R_{23} + [\%N_2]^2 \cdot R_{33} + K \end{array} \right) \quad \textit{(Eq. 2.9)}$$

Where: $MN_{CO2\&N2}$ *is the increase in the methane number caused by* CO_2 *and* N_2
$\%CH_4$ *is the content of* CH_4, C_2H_6, C_3H_8, C_4H_{10} *in volume percentage of the gas*
$\%CO_2$ *is the content of* CO_2 *in volume percentage of the gas*
$\%N_2$ *is the content of* N_2 *in volume percentage of the gas*

R_{111}, R_{112}, R_{113}, R_{122}, R_{123}, R_{133}, R_{222}, R_{223}, R_{233}, R_{333}, R_{11}, R_{12}, R_{13}, R_{22}, R_{23}, R_{33} *and K are constants where:*

R_{111}	= 52.25	R_{112}	= 148.40	R_{113}	= 153.84
R_{122}	= 18.68	R_{123}	= -237.05	R_{133}	= 9.03
R_{222}	= 48.33	R_{223}	= 64.18	R_{233}	= 440.32
R_{333}	= -190.89	R_{11}	= 29.69	R_{12}	= 102.83
R_{13}	= 161.54	R_{22}	= 158.93	R_{23}	= 517.88
R_{33}	= 302.83	K	= 18.06		

2.2.3 Limits of the algorithm

The available data that provides the basis for the algorithm also provides the limits of the algorithm. The calculations can only be made for gasses with a methane number higher then 45 (without inert gasses). The concentration of CO_2 cannot be higher than 30 vol% and the concentration of N_2 cannot be higher than 50 vol%. In *Figure 2.4 - Figure 2.7* the limits of the calculation of the methane number without inert gasses are shown.

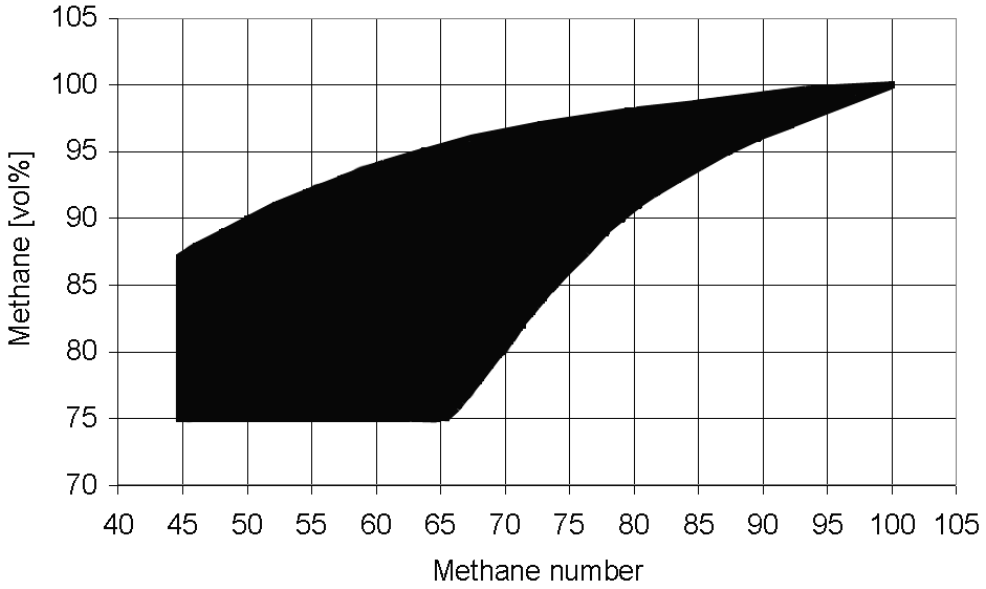

Figure 2.4. The possible methane concentrations in the new algorithm as a function of the methane number

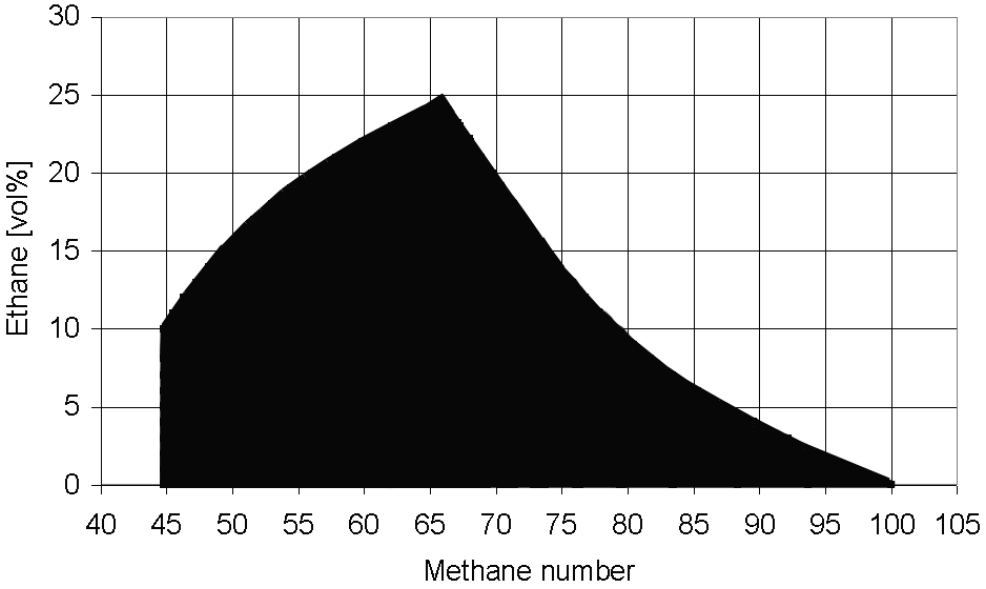

Figure 2.5. The possible ethane concentrations in the new algorithm as a function of the methane number

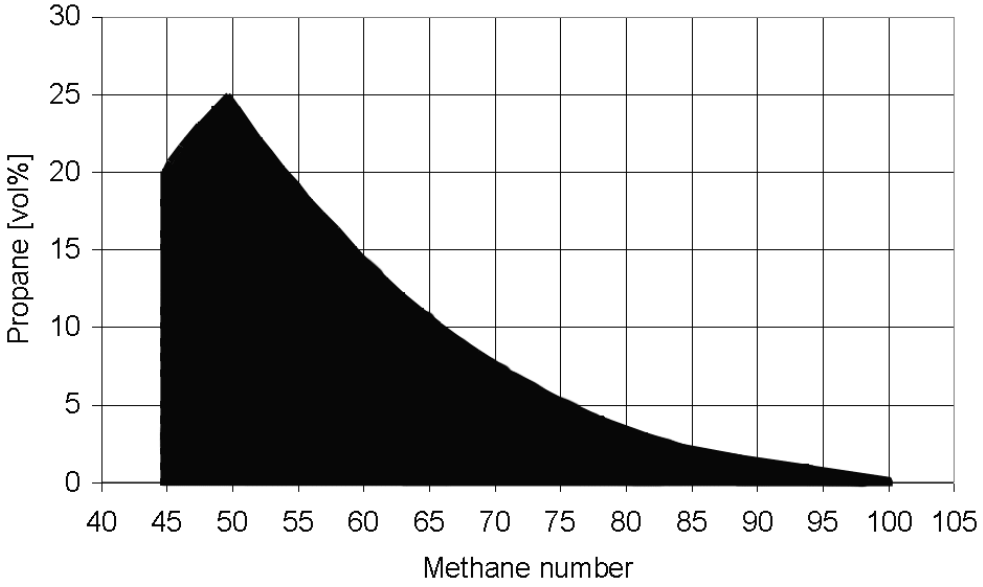

Figure 2.6. The possible propane concentrations in the new algorithm as a function of the methane number

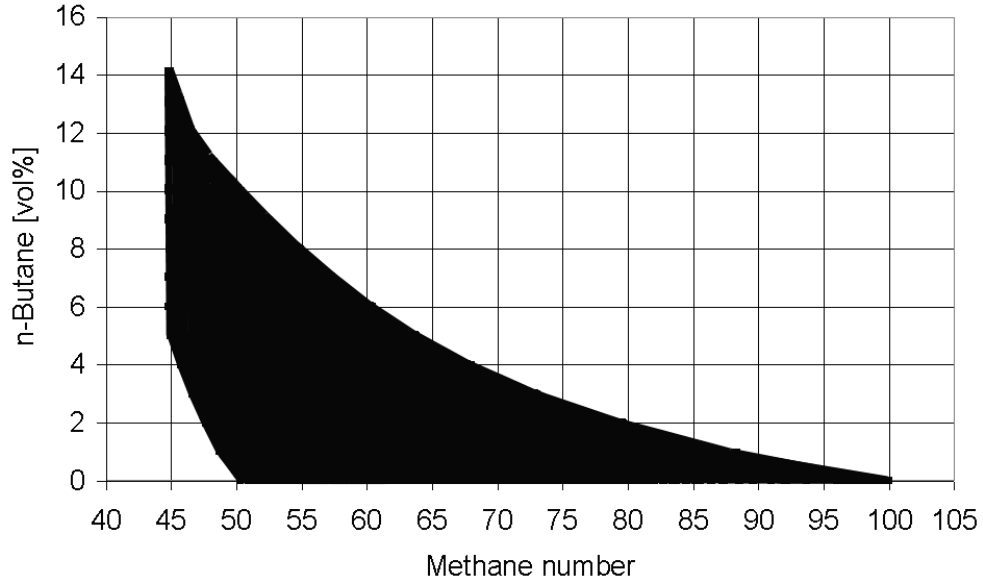

Figure 2.7. The possible n-butane (and higher hydrocarbons) concentrations in the new algorithm as a function of the methane number

2.3 Uncertainties

The uncertainties on the methane number of the AVL studies are ±2 /1/. From the test of the new algorithm, see Chapter 3, it is found that the new algorithm in the worst case differs 1.03 from the AVL data. Hence it can be concluded that the uncertainty of the new algorithm is approximately ±3.

3 Results

The error between readings in Figure 2.1 and calculated methane number of the responding gas is shown in Figure 3.8. The maximum error is less than 0.8. The error varies from –0.9% to 0.3%.

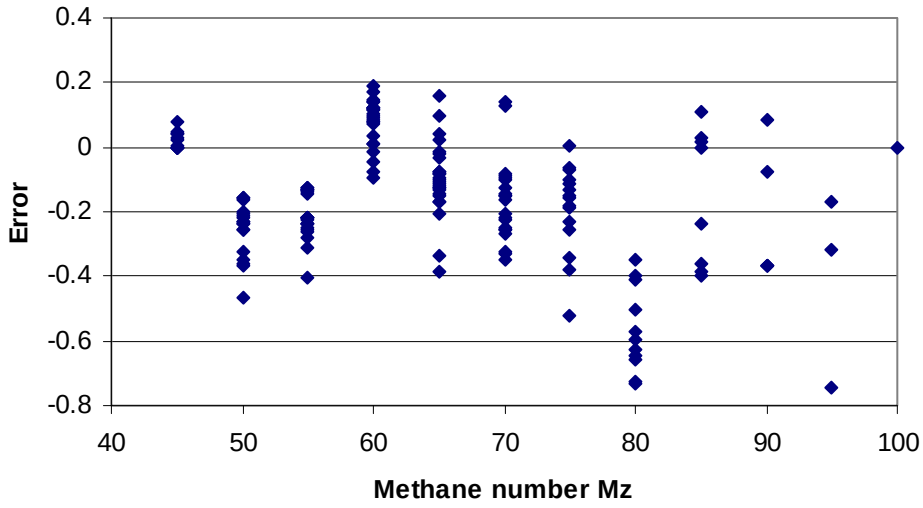

Figure 3.8. Error between readings in Figure 2.1 and calculated methane numbers

The error between readings in Figure 2. and calculated methane number of the responding gas is shown in Figure 3.9. The maximum error is 1.03. The error varies from –0.6% to 2.2%.

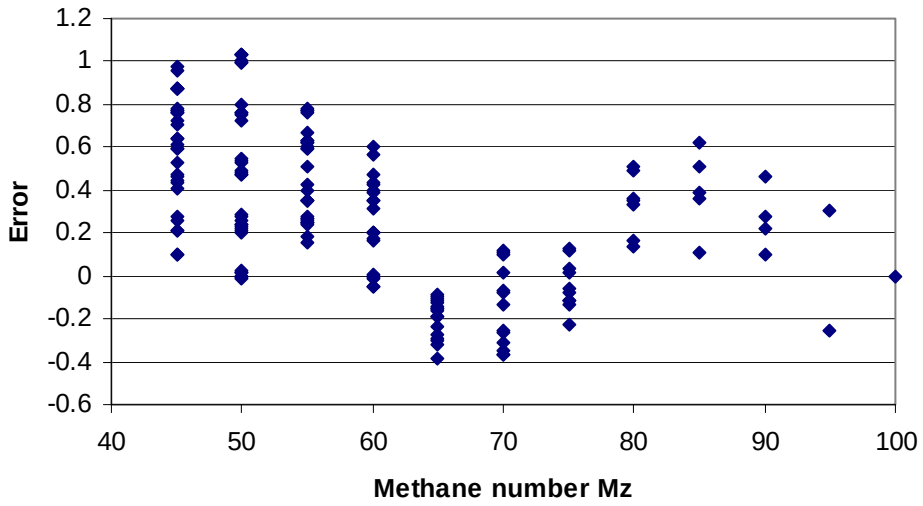

Figure 3.9. Error between readings in Figure 2. and calculated methane numbers

The above results show that the errors introduced by the assumptions that the methane number curves in Figure 2.1 and Figure 2. can be represented as straight lines is very small.

Table 3.1 shows five different gas compositions and their methane numbers as calculated by AVL /1/ and as calculated by using the new DGC algorithm. The table shows good agreement between the results.

CH_4	C_2H_6	C_3H_8	i-C_4H_{10}	n-C_4H_{10}	i-C_5H_{12}	n-C_5H_{12}	C_6 +	CO_2	N_2	MN AVL	MN DGC
69.00	20.00	11.00								54.80	55.9
65.00	18.50	11.00		5.50						48.25	48.4
96.88	1.42	0.37	0.08	0.10	0.04	0.03	0.04	0.19	0.64	90.65	90.8
97.27	1.17	0.32	0.08	0.09	0.04	0.03	0.18	0.20	0.62	91.3	90.3
95.21	2.47	0.70	0.13	0.19	0.08	0.06	0.23	0.29	0.56	84.8	83.2

Table 3.1. Different gas compositions and their respective methane number calculated by AVL/1/ and the new DGC algorithm

In combination with work done in the European Gas Research Group (GERG), different methods for calculating the methane number have been compared. In Table 3.2 the results of eight different methods and the new DGC algorithm are shown for a number of different European gas qualities. The table shows a very large variation in the results. There is good agreement between the new DGC algorithm and method 8. One of the reasons for the small difference between method 8 and the new DGC algorithm is that method 8 does not take N_2 and CO_2 into account, if the content is below 9 vol% and 2 vol%, respectively. The new DGC algorithm always takes N_2 and CO_2 into account to keep the continuity.

	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6	Method 7	Method 8	DGC		
									MN without CO2 and N_2 correction	CO2 and N2 correction	MN
Gas 1	84	85	80	82	83	91	81	84.3	**83.5**	**1.0**	**84.6**
Gas 2	72	79	76	77	79	88	70	79.9	**76.7**	**2.9**	**79.5**
Gas 3	85	86	81	83	85	92	82	85.3	**84.6**	**1.6**	**86.1**
Gas 4	78	75	75	73	76	83	73	76.1	**73.7**	**2.6**	**76.2**
Gas 5	73	70	68	70	71	79	69	71.3	**68.7**	**2.9**	**71.6**
Gas 6	82	83	78	80	82	90	82	82.1	**80.8**	**1.7**	**82.5**
Gas 7	66	67	64	63	68	71	68	66.5	**68.8**	**0.0**	**68.8**
Gas 8	75	73	72	70	72	80	73	71.7	**72.6**	**0.2**	**72.8**
Gas 9	79	80	79	77	80	88	75	79.7	**78.4**	**2.5**	**80.9**
Gas 10	81	80	79	75	78	84	79	78.8	**78.8**	**0.3**	**79.1**
Gas 11	71	84	85	82	86	85	75	87.6	**82.5**	**4.7**	**87.2**
Gas 12	91	93	87	88	90	95	88	90.7	**91.8**	**0.1**	**91.9**
Gas 13	90	93	91	90	91	97	94	91.5	**92.1**	**0.9**	**93.0**
Gas 14	68	68	64	68	64	74	66	63.9	**64.4**	**0.1**	**64.1**
Gas 15	68	67	66	66	66	73	67	65.4	**66.3**	**0.1**	**66.5**
Gas 16	67	87	85	86	90	98	77	92.0	**86.0**	**5.7**	**91.8**
Gas 17	75	77	75	75	78	86	73	77.5	**75.8**	**2.6**	**78.4**
Gas 18	70	80	81	81	85	94	75	88.6	**78.6**	**7.5**	**86.1**
Gas 19	95	99	94	96	99	100	96	96.8	**99.2**	**0.1**	**99.3**
Gas 20	93	96	94	94	95	99	96	94.4	**96.0**	**0.4**	**96.4**
Gas 21	84	86	83	83	84	92	81	84.7	**83.7**	**1.6**	**85.3**
Gas 22	67	72	69	70	72	81	68	72.4	**70.7**	**2.0**	**72.8**
Gas 23	74	70	71	70	71	79	69	69.0	**69.5**	**1.3**	**70.7**
Gas 24	74	73	69	68	71	79	74	72.4	**73.0**	**0.3**	**73.3**
Gas 25	77	76	74	71	75	81	74	75.5	**75.8**	**0.2**	**76.0**
Gas 26	76	75	74	70	74	81	74	74.1	**74.7**	**0.2**	**74.9**
Gas 27	76	74	74	70	74	80	74	73.8	**74.4**	**0.2**	**74.6**
Gas 28	83	83	78	76	81	88	79	82.8	**82.3**	**0.4**	**82.4**
Gas 29	94	98	94	96	96	100	96	96.3	**98.7**	**0.5**	**99.2**
Gas 30	90	98	94	95	98	100	94	96.2	**97.4**	**1.2**	**98.6**
Gas 31	90	93	91	88	89	96	91	90.8	**92.2**	**0.2**	**92.3**
Gas 32	77	76	74	71	75	82	75	75.7	**75.8**	**0.3**	**76.1**
Gas 33	78	84	76	72	76	92	75	84.6	**81.8**	**2.7**	**84.5**
Gas 34	82	85	77	79	78	91	81	83.4	**82.4**	**1.2**	**83.6**
Gas 35	66	70	69	70	71	80	68	71.7	**70.0**	**2.1**	**72.1**

Table 3.2. Methane numbers of different European gas qualities calculated by different methods

In Figure 3.10 the new DGC algorithm is compared with the old DGC algorithm using the data for the Danish natural gas quality from January 1995 to September 1998. There is very good agreement between the two algorithms for gasses with a knocking resistance smaller than approximately 72.5.

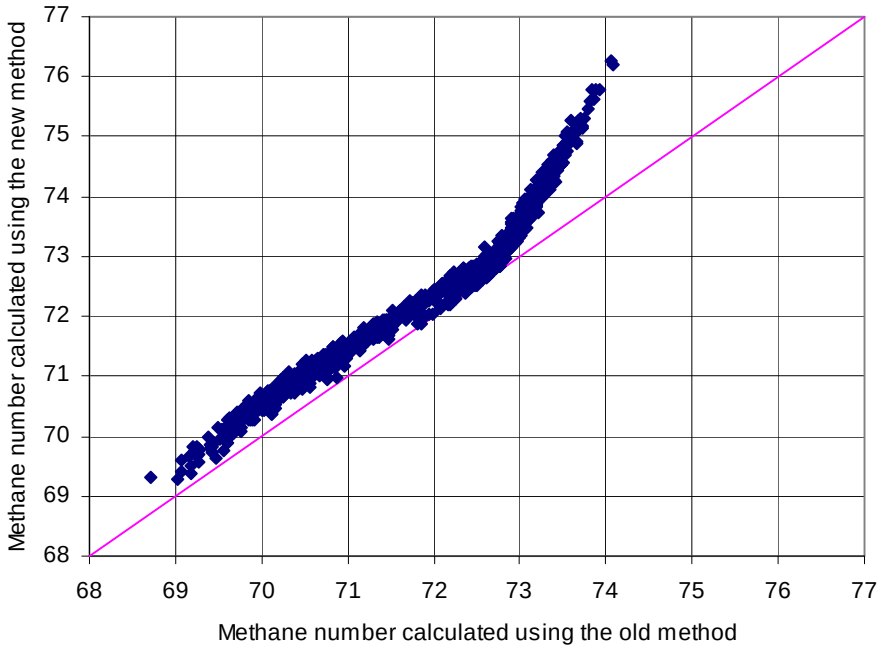

Figure 3.10. The new method versus the old method.

In Figure 3.10 all the methane number calculations are shown, whereas Figure 3.11 only shows the data where the old algorithm is valid. It is seen that there are no results for methane numbers less than 70.5 after the old method or 71 after the new method.

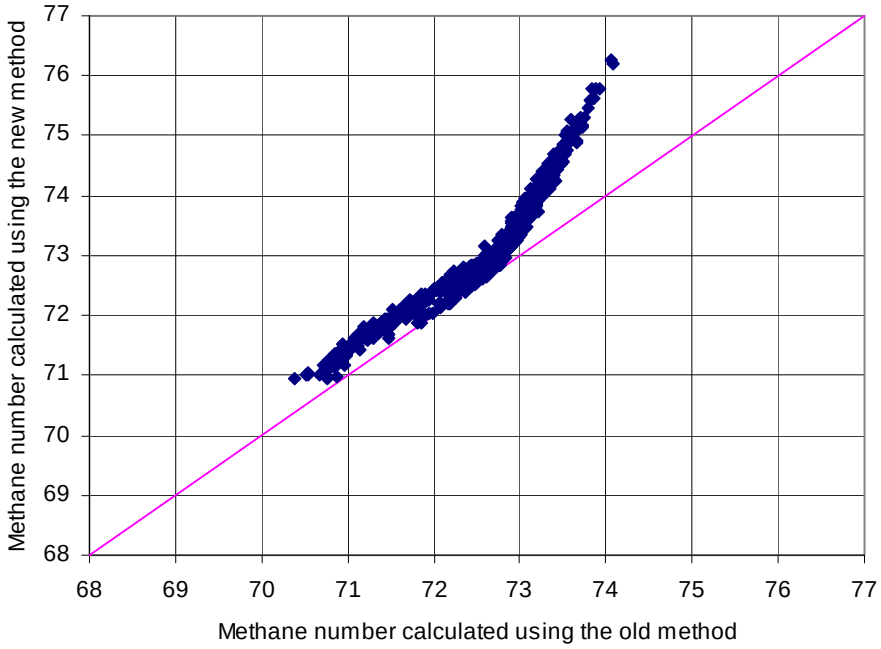

Figure 3.11. The new method versus the old method. Only data where the old algorithm is valid.

The old algorithm has a tendency of underestimating the methane number for gasses with a high methane number. The old algorithm is not valid if the methane number of the gas is higher than approximately 79. In Figure 3.12 the possible methane concentrations in the old algorithm are shown.

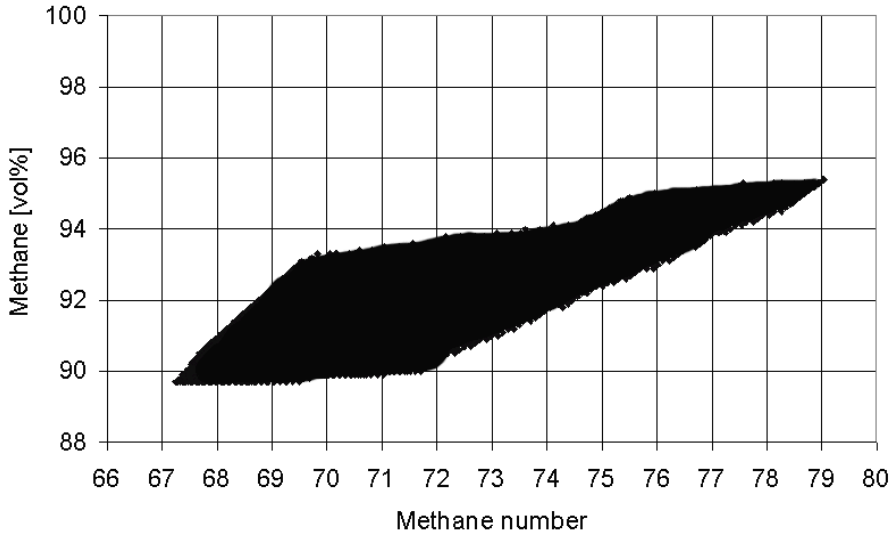

Figure 3.12. The possible methane concentrations in the old algorithm

4 Conclusions

The purpose of developing a new algorithm for determining the methane number of natural gasses has been fulfilled. The new algorithm is in good agreement with the AVL /1/ data, the calculated results only vary approximately ± 1 around the AVL data.

There is good agreement between the old algorithm for gasses with methane numbers lower than 72.5. The new algorithm gives results that are approximately 0.5 higher than the old method.

Compared with other methods there is good agreement with some of the methods. In general, however, there is a very large variation between the methods.

The new algorithm has some limits given by the available data used as basis for the algorithm. The calculations can only be made for gasses with a methane number higher than 45 (without inert gasses). The concentration of CO_2 cannot be higher than 30 vol%, and the concentration of N_2 cannot be higher than 50 vol%.

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6 Principle for calculating the methane number of natural gasses

This Appendix describes how the equation (EQ 2.3) is found.

The gas is represented as $G(X_1, X_2, X_3, X_4)$, where X_1 is the CH_4 concentration, X_2 is the C_2H_6 concentration, X_3 is the C_3H_8 concentration, and X_2 is the concentration of n-C_4H_{10} and higher hydrocarbons. Using the assumption that the methane number curves in Figure 2.1 and Figure 2. can be represented as straight lines we have:

$$\begin{aligned} &A:(X_{1A}, X_{2A}, 0, X_{4A}):MZ=AB \\ &B:(X_{1B}, X_{2B}, 0, X_{4B}):MZ=AB \\ &C:(X_{1C}, 0, X_{3C}, X_{4C}):MZ=CD \\ &D:(X_{1D}, 0, X_{3D}, X_{4D}):MZ=CD \end{aligned} \qquad \textit{(Eq A 1)}$$

Where A is the starting point of the MN curve in CH_4, C_2H_6, C_4H_{10} diagram
B is the ending point of the MN curve in CH_4, C_2H_6, C_4H_{10} diagram
C is the starting point of the MN curve in CH_4, C_3H_8,C_4H_{10} diagram
D is the ending point of the MN curve in CH_4, C_3H_8, C_4H_{10} diagram
X_{1*} is the concentration of CH_4
X_{2*} is the concentration of C_2H_6
X_{3*} is the concentration of C_3H_8
X_{4*} is the concentration of C_4H_{10}

Then generating two mixtures E and F

where: E: $\in$ AB parameter α

F: $\in$ CD parameter β

where it is valid that:

$$\begin{aligned} &G=X\cdot E+(1-X)\cdot F \\ &MZ(G)=MZ(E)+X\cdot\left[MZ(F)-MZ(E)\right] \end{aligned} \qquad \textit{(Eq A 2)}$$

Setting:

$$\alpha=\frac{\frac{X_2}{X-1}+X_{2A}}{X_{2A}-X_{2B}} \qquad \textit{(Eq A 3)}$$

and:

$$\beta = \frac{\frac{X_3}{X} - X_{3C}}{X_{3D} - X_{3C}} \qquad \textit{(Eq A 4)}$$

then:

$$(1-\alpha) = \frac{-X_{2B} - \frac{X_2}{(X-1)}}{X_{2A} - X_{2B}} \qquad \textit{(Eq A 5)}$$

and:

$$(1-\beta) = \frac{-X_{3D} - \frac{X_3}{X}}{X_{3D} - X_{3C}} \qquad \textit{(Eq A 6)}$$

Using the above we get:

$$X_1 = (1-X)\left[(1-\alpha)X_{1A} + \alpha X_{1B}\right] + X\left[(1-\beta)X_{1C} + \beta X_{1D}\right] \qquad \textit{(Eq A 7)}$$

Equation (Eq A 7) is solved for X by inserting α and β

$$X_1 = (1-X)\left[\frac{-X_{2B} - \frac{X_2}{(X-1)}}{X_{2A} - X_{2B}} X_{1A} + \frac{\frac{X_2}{X-1} + X_{2A}}{X_{2A} - X_{2B}} X_{1B}\right] + X\left[\frac{X_{3D} - \frac{X_3}{X}}{X_{3D} - X_{3C}} X_{1C} + \frac{\frac{X_3}{X} - X_{3C}}{X_{3D} - X_{3C}} X_{1D}\right] \qquad \textit{(Eq A 8)}$$

⇓

$$X_1 = (1-X)\left[\frac{X_{2A}X_{1B} - X_{2B}X_{1A} + \frac{X_2(X_{1B}-X_{1A})}{X-1}}{X_{2A}-X_{2B}}\right] + X\left[\frac{X_{3D}X_{1C} - X_{3C}X_{1D} + \frac{X_3(X_{1D}-X_{1C})}{X}}{X_{3D}-X_{3C}}\right] \qquad \textit{(Eq A 9)}$$

$\Downarrow$

$$X_1 = \frac{X_{2A}X_{1B} - X_{2B}X_{1A} - X_2(X_{1B}-X_{1A})}{X_{2A}-X_{2B}} - \frac{X(X_{2A}X_{1B} - X_{2B}X_{1A})}{X_{2A}-X_{2B}} + \frac{X_3(X_{1D}-X_{1C})}{X_{3D}-X_{3C}} + \frac{X(X_{3D}X_{1C} - X_{3C}X_{1D})}{X_{3D}-X_{3C}} \qquad \textit{(Eq A 10)}$$

$\Downarrow$

$$X_1 = X\left[\frac{(X_{3D}X_{1C} - X_{3C}X_{1D})}{X_{3D}-X_{3C}} - \frac{(X_{2A}X_{1B} - X_{2B}X_{1A})}{X_{2A}-X_{2B}}\right] + \frac{X_{2A}X_{1B} - X_{2B}X_{1A} - X_2(X_{1B}-X_{1A})}{X_{2A}-X_{2B}} + \frac{X_3(X_{1D}-X_{1C})}{X_{3D}-X_{3C}} \qquad \textit{(Eq A 11)}$$

$\Downarrow$

$$X = \frac{X_1 - \frac{X_{2A}X_{1B} - X_{2B}X_{1A} - X_2(X_{1B}-X_{1A})}{X_{2A}-X_{2B}} - \frac{X_3(X_{1D}-X_{1C})}{X_{3D}-X_{3C}}}{\frac{(X_{3D}X_{1C} - X_{3C}X_{1D})}{X_{3D}-X_{3C}} - \frac{(X_{2A}X_{1B} - X_{2B}X_{1A})}{X_{2A}-X_{2B}}} \qquad \textit{(Eq A 12)}$$

7 Prediction principle of methane numbers for a natural gas step by step

1. The Natural gas analysis is put into a table of the above format. The H_2S and odorant (THT) are only present in small quantities, and therefore not used in the calculation. The Danish gas is normally analysed as a C_{6+} result.

2. The sum of hydrocarbon components is added up and the number is out into table at the C_{1+} place. N_2 and CO_2 are kept as before. The result is used in combination with Figure A2.3 to find a methane number addition due to the content of inert gases (N_2 and CO_2).

3. The C_{4+} fraction is calculated as the sum of all C_4, C_5 and the C_{6+} fraction. Inert components are not considered.

4. Step 5 to 7 is the most difficult steps to perform, and they are performed by trial and error, until an acceptable result is achieved. The aim is to divide the mixture calculated in step 3 into two new mixtures, called Mix I and Mix II.

5. Put all of the C_2H_6 into Mix I, and all the C_3H_8 into Mix II. The remaining two components from step 3, CH_4 and the C_{4+} are divided into the two mixtures, Mix I and Mix II

6. Calculate the relative composition of Mix I and Mix II, as shown in Table A2.2. Read the methane number for Mix I in Figure 2.1, and the methane number for Mix II in Figure A2.2.

7. Compare the obtained methane numbers for Mix I and Mix II. If the difference is 5 or above, repeat from step 5 again.

8. Find the methane number for the composition determined in step 2 by the use of Figure A2.3.

9. Finally calculate the methane number as shown in Table A2.3 by adding up the results from Mix I and II using the weight factors, and add the effect of inert. The result is 70.7 in methane number.

Table A2.1: Calculations for methane number determination.

Step #	1	2	3	5-7	5-7
Components volume parts of 100	Analysis (average 1998)	C_{1+} and inert	C_{4+} without inert	Mix I	Mix II
CH_4	88.15	-	88.15	42.50	45.65
C_{1+}	-	98.473			
C_2H_6	6.35	-	6.35	6.35	0
C_3H_8	2.77	-	2.77	0	2.77
i-C_4H_{10}	0.55	-	-	-	-
n-C_4H_{10}	0.41	-	-	-	-
C_{4+}	-	-	1.203	0.600	0.603
i-C_5H_{12}	0.075	-	-	-	-
n-C_5H_{12}	0.110	-	-	-	-
C_{6+}	0.058	-	-	-	-
N_2	0.342	0.342	-	-	-
CO_2	1.18	1.18	-	-	-
Total	99.995	99.995	98.473	49.45	49.023

Table A2.2: Step 6 details

Component	Mix I	Mix II	Mix I, relative	Mix II, relative
CH_4	42.50	45.65	85.95	93.12
C_2H_6	6.35	0.00	12.84	0.00
C_3H_8	0.00	2.77	0.00	5.65
C_{4+}	0.600	0.603	1.21	1.23
Total	49.45	49.023	100.00	100.00
Methane number (MN) from Figure 2.1 and Figure 2.2			70	69

Table A2.3: Step 9 in the methane number determination

	Formula	With example numbers	Result
Add Mix I and Mix II	(MN mix I×Total Mix I + MN mix II×Total Mix II) /(Total Mix I + Total Mix II)	(70×49.45 + 69×49.023) /(49.45+49.023)	69.50
C_{1+} and inert	From step 8, Figure A2.3		101.2
Methane number	Add Mix I and Mix II + (C_{1+} and inert – 100)	69.5+(101.2 - 100)	70.7

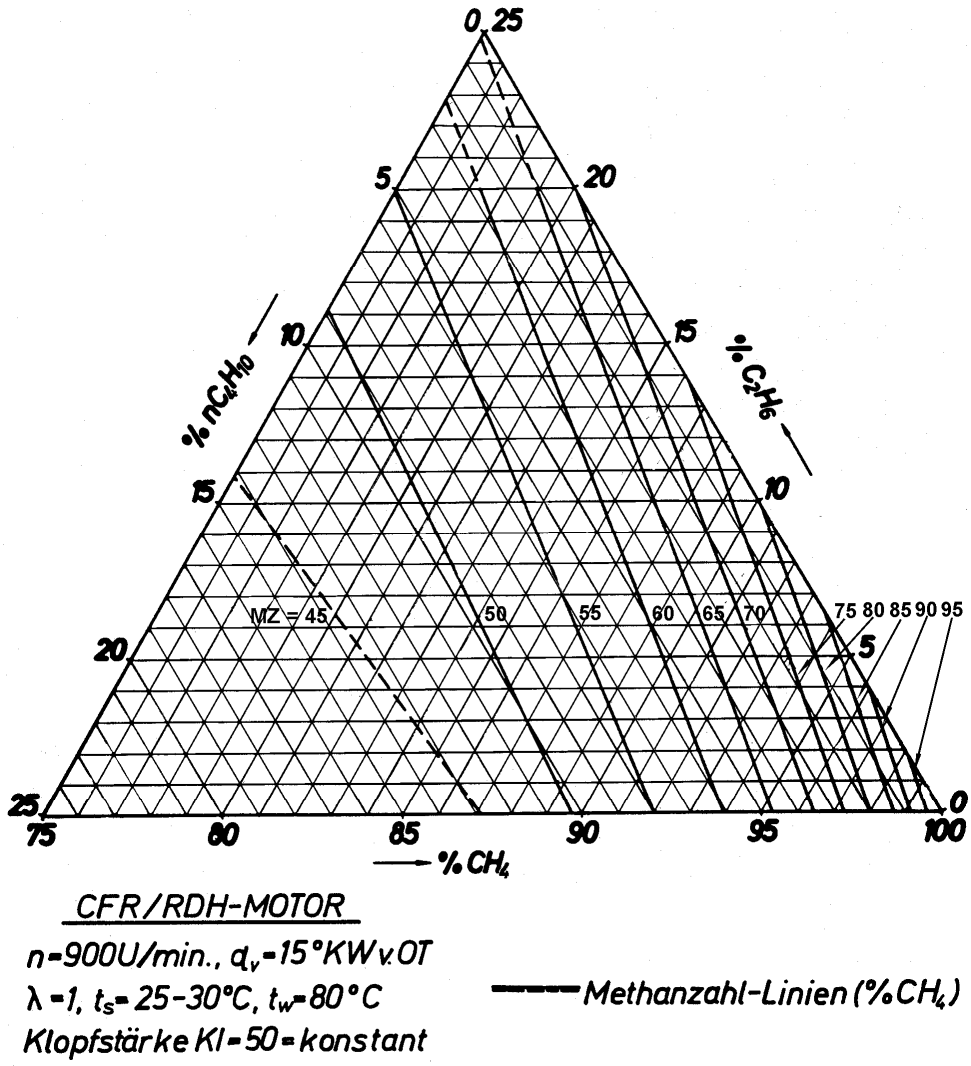

Figure A2.1: Methane numbers for CH_4, C_2H_6, C_4H_{10} mixtures.

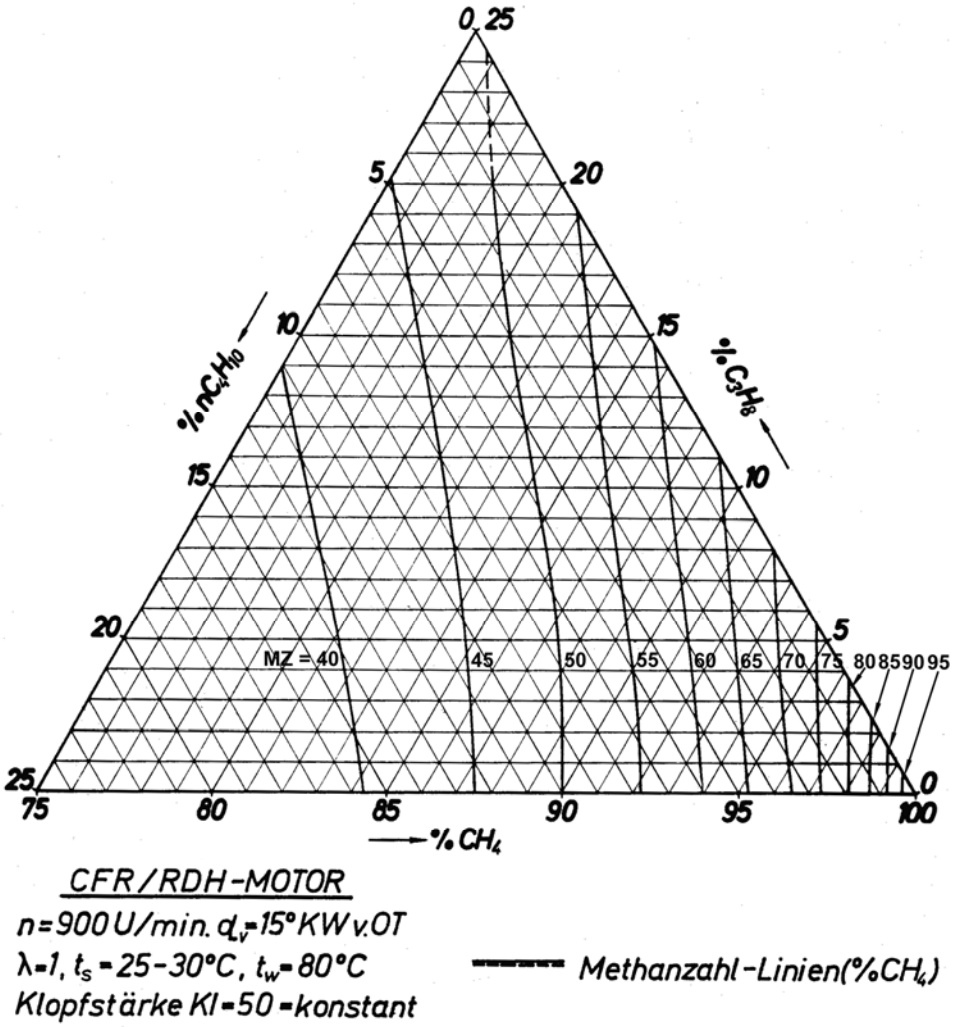

Figure A2.2: Methane numbers for CH_4, C_3H_8, C_4H_{10} mixtures.

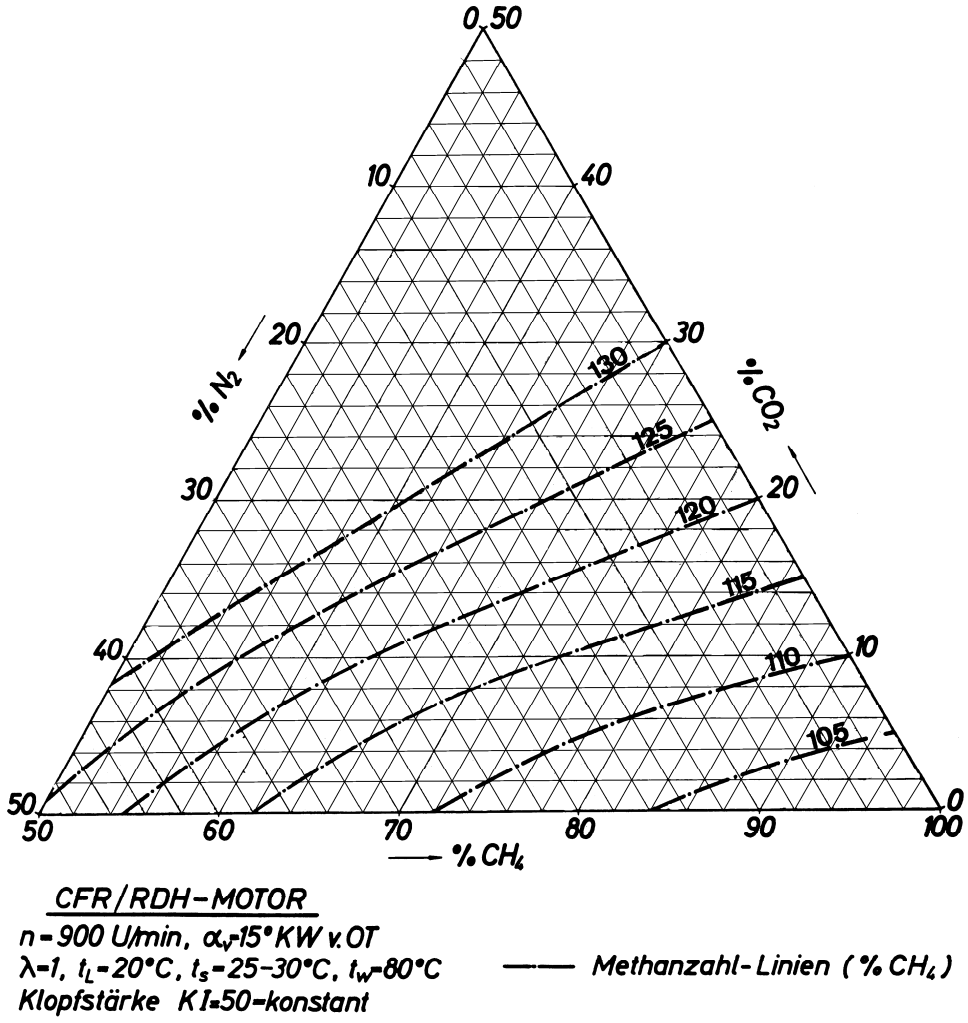

Figure A2.3: Influence of inert.