Final Report

Calibration-Round-Robin

CaRo 11

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1. Conclusion

According to international standards (e.g. ISO 9000, GLP), test equipment must be calibrated at intervals by comparison with a standard or a calibrated testing apparatus.
This calibration also applies to the 20-l-apparatus and the 1-m3-vessel for the determination of Pmax and Kmax and the apparatus for determination of the minimum ignition energy. The test procedure is an important part of this calibration. A general check at the component level is incomplete and hence inadmissible.

Unfortunately there are neither internationally recognized reference samples nor reference equipment available for the determination of these explosion characteristics. Therefore the following calibration method has been carried out successfully:
A dust has been selected, prepared and supplied to **57** test laboratories all over the world. The mean values of the explosion indices, measured by the participating laboratories, has been calculated as reference values. The testing laboratories have been informed about the evaluation with a certificate.

This report presents the results of this calibration method and describes the evaluation procedures. It also demonstrates that with this method it was possible to discover and rectify the cause of any errors with installations producing results differing widely from the reference values.

CaRo 11 - Reference values for the Explosion Indices Pmax and Kmax

Pmax	(bar)	**8.1** ± 10%	(7.3 ... 9.0)
Kmax	(bar·m/s)	**243** ± 10%	(219 ... 268)

CaRo 11 – Reference values for the Minimum Ignition Energy MIE

Es / 3	Es	Es • 3
0.5 mJ	**1.5 mJ**	**4.5 mJ**

Birsfelden, January 2012

Adolf Kühner AG
Christoph Cesana

1.1 Participants

For details see section "list of participants".

	Pmax, Kmax (69)		MZE (53)	
	20-l	1 m^3	MIKE	others
Austria	4		1	
Belgium	2		2	
Canada	1		1	
Czechoslovakia	1			
England	5		2	2
France	5		4	
Germany	10	3	15	1
Hungary			1	
India	1			
Italy	2		2	
Japan	1		2	
Poland	2			1
Switzerland	7		3	
U.S.A	25		16	
total:	**66**	**3**	**49**	**4**

This calibration round robin test „CaRo 11“ has been accepted world wide as the best and most reliable calibration method for this type of test equipment.

1.2 Test substance

For correct calibration the CaRo 11 test sample has been milled, homogenized and shipped in an air tight package. Therefore the sample has to be tested „as delivered“.

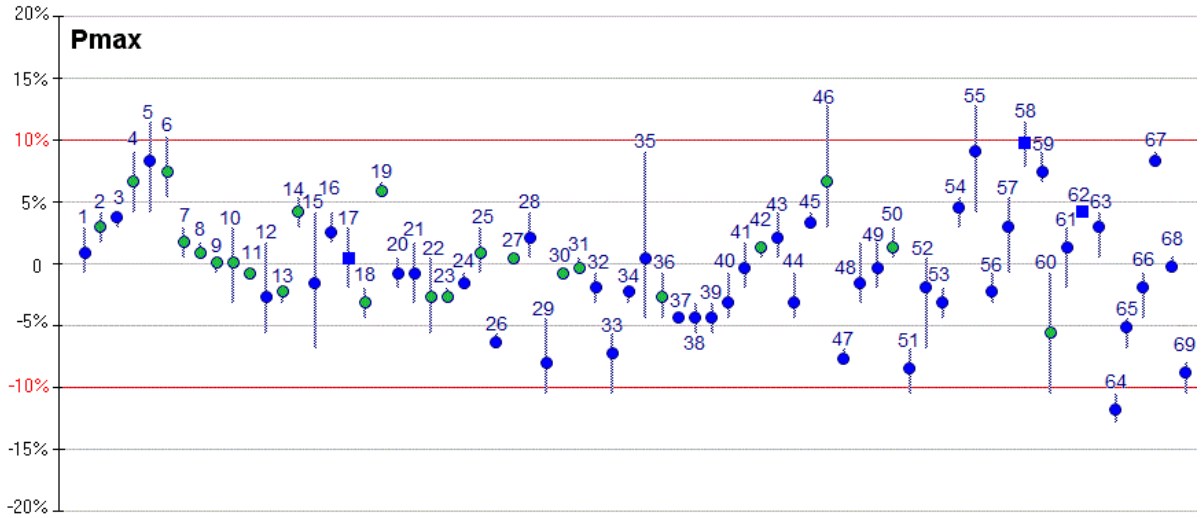
CaRo 11 = Niacin USP special (Nicotinic acid)

Particle size:

	d 10	**d 50 = median**	d 90
Sample 1	4 µm	**19 µm**	80 µm
Sample 2	4 µm	**19 µm**	83 µm
Sample 3	4 µm	**19 µm**	82 µm
Sample 4	4 µm	**19 µm**	80 µm

2. Explosion Indices Pmax, Kmax

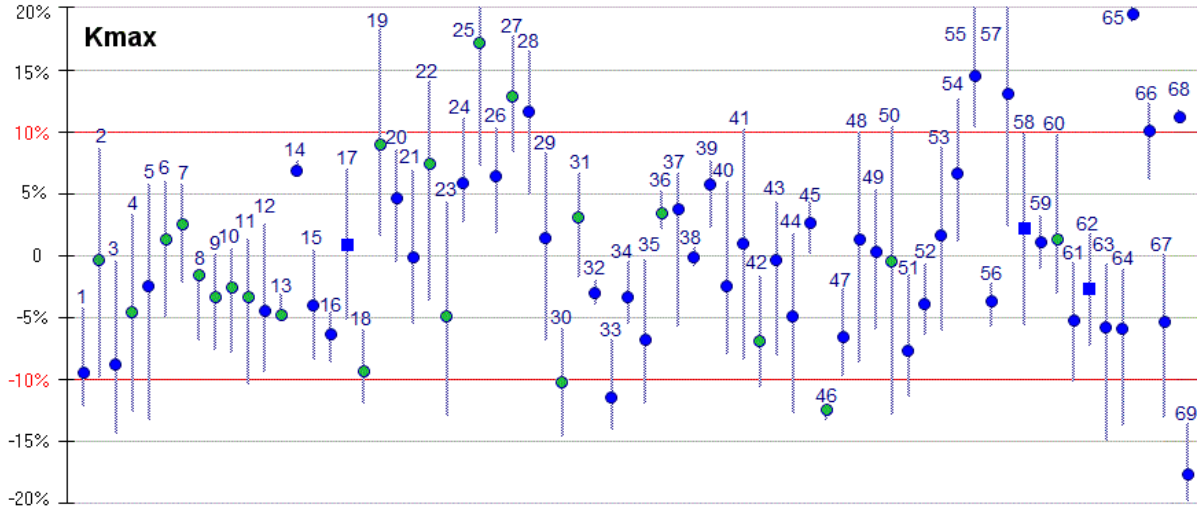
Pmax = 8.1 bar ± 10% (7.3 ... 9.0) by 505 g/m3



Sobbe 20-l Simex 20-l 1m^3

The individual results are drawn in relation to the arithmetic mean of all results and in chronological sequence (number of certificate).

Kmax = 243 bar·m/s ± 10% (219 ... 268) by 623 g/m3



Sobbe 20-l Simex 20-l 1m^3

The individual results are drawn in relation to the arithmetic mean of all results and in chronological sequence (number of certificate).

2.1 Test procedure:

The method for determination of Pmax, Kmax is described in the „Manual CaRo 11“.

2.2 Evaluation:

The explosion indices Pmax and (dP/dt)max are defined as the mean values of the maximum values of each series. Subsequently, the explosion index Kmax is calculated from the mean value (dP/dt)max.

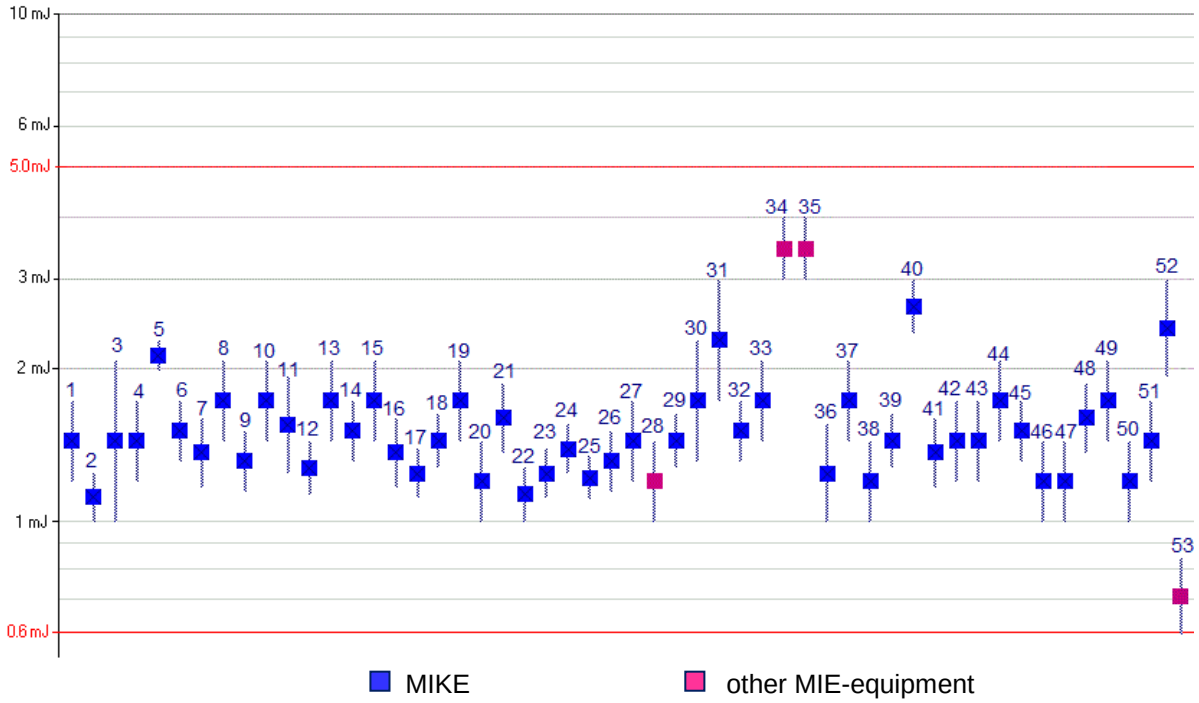
2.3 Scatter of Pmax and Kmax:

The maxima of each series must not deviate by more than **10%** of Pmax resp. Kmax.
Otherwise this series must be repeated!

2.4 Calculation of the reference values:

First the mean values of all test results (69) has been calculated. In a 2nd step all results outside of the tolerance band are excluded prior to the subsequent calculation of the mean value. Due to the large number of participants the mean values did not change.

3. Minimum Ignition Energy MIE



The individual results are drawn in chronological sequence (number of certificate).

3.1 Test procedure:

The method for determination of the MIE is described in the „Manual CaRo 11“.

3.2 Estimation of the statistical energy (Es):

The minimum ignition energy MIE lies, by definition, between two energy values:

$$E1 < MIE < E2$$

For the purpose of comparison between different apparatus, only one MIE value (Es) instead of the energy range (E1, E2) shall be used. This single value (Es) can be estimated by use of the probability of ignition as follows (EN 13821):

Provided that for the energy E2 a minimum of 5 dust concentrations evenly distributed are tested, the position of the MIE in the E1-E2 range can be estimated. At ignition energy E2, the number of dust concentrations with ignition, is divided by the total number of dust concentrations tested.

$$E_S = 10^{\log E_2 - \frac{I[E_2]\cdot(\log E_2 - \log E_1)}{(NI + I)\cdot[E_2]+1}}$$

where is: I[E2] = number of tests with ignition at the energy E2.
(NI+I)[E2] = total number of tests at the energy E2.

3.3 Criteria for conformity:

Conformity between two equipment (a, b) is given, when the Es-values differ less than a factor of 3 (EN 13821).

$$1/3 < Es(a) / Es(b) < 3$$

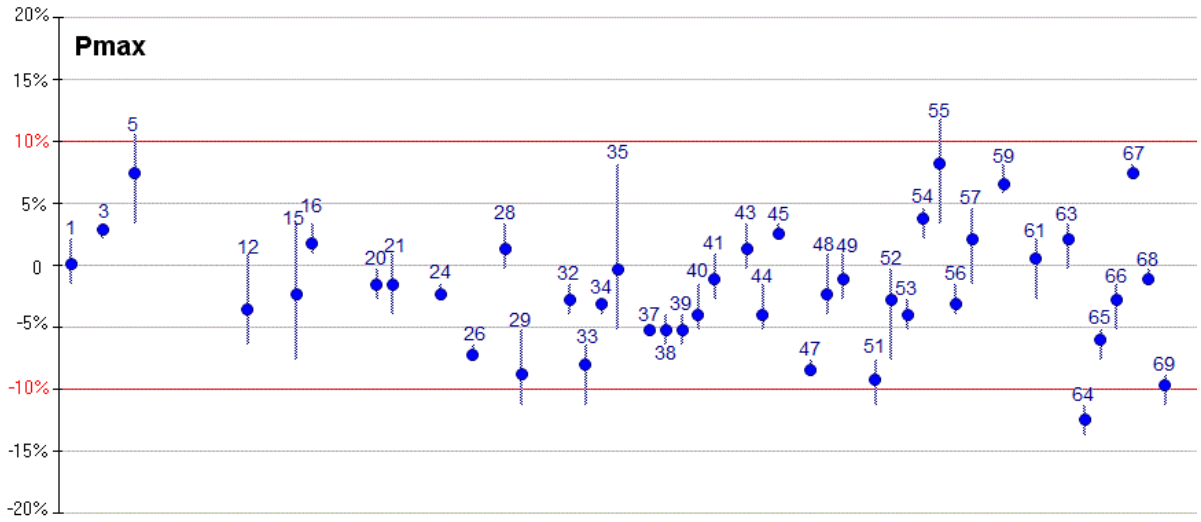
Accordingly:
Conformity in the CaRo 11 is given, when the Es-value of each equipment differ less than a factor of 3 to the mean (Es) of all equipment:

Es / 3	Es	Es • 3
0.5 mJ	1.5 mJ	4.5 mJ

4. Comparison Sobbe- und Simex-igniters

The Pmax-values of the two types of igniters are consistent within the measurement accuracy.

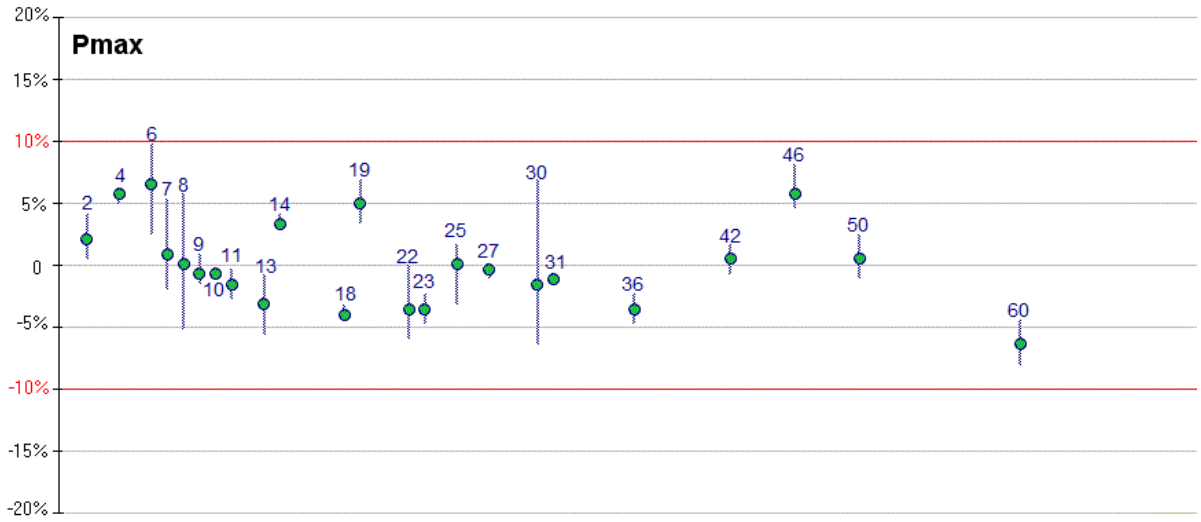
Sobbe - Pmax = 8.2 bar ± 10% (7.4 ... 9.1) by 449 g/m3



Sobbe 20-l

The individual Sobbe-results are drawn in relation to the arithmetic mean of all results and in chronological sequence (number of certificate).

Simex - Pmax = 8.1 bar ± 10% (7.3 ... 8.9) by 535 g/m3

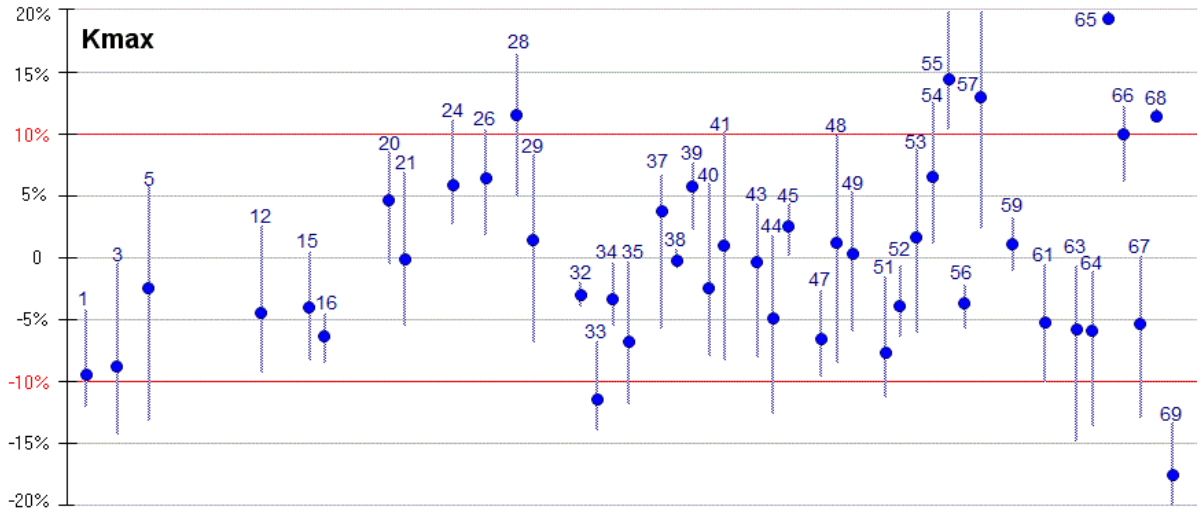


Simex 20-l

The individual Simex-results are drawn in relation to the arithmetic mean of all results and in chronological sequence (number of certificate).

The Kmax-values of the two types of igniters are consistent within the measurement accuracy.

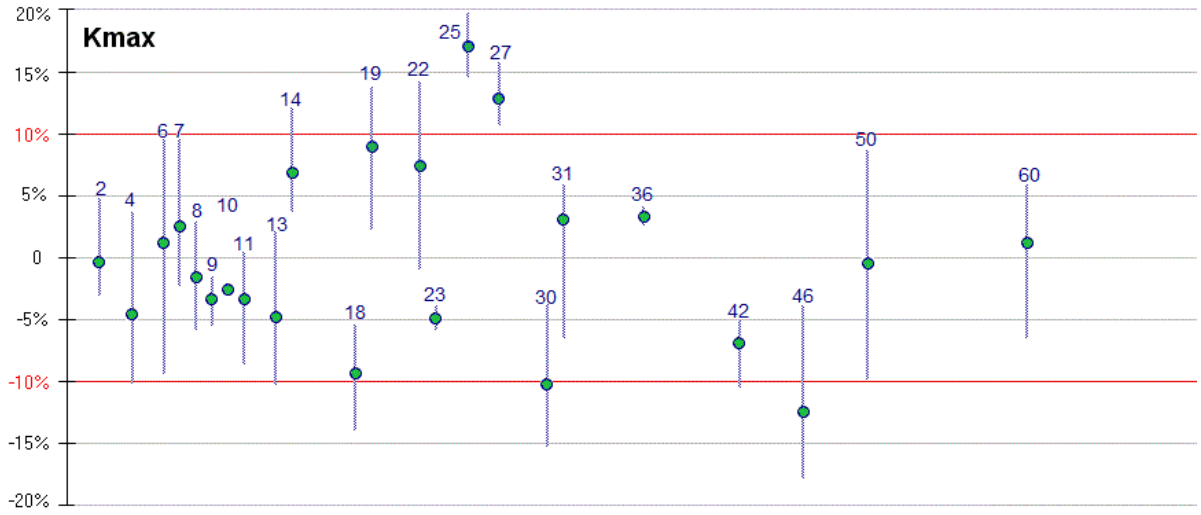
Sobbe - Kmax = 244 bar·m/s ± 10% (219 ... 268) by 549 g/m3



Sobbe 20-l

The individual Sobbe-results are drawn in relation to the arithmetic mean of all results and in chronological sequence (number of certificate).

Simex - Kmax = 243 bar·m/s ± 10% (219 ... 268) by 657 g/m3

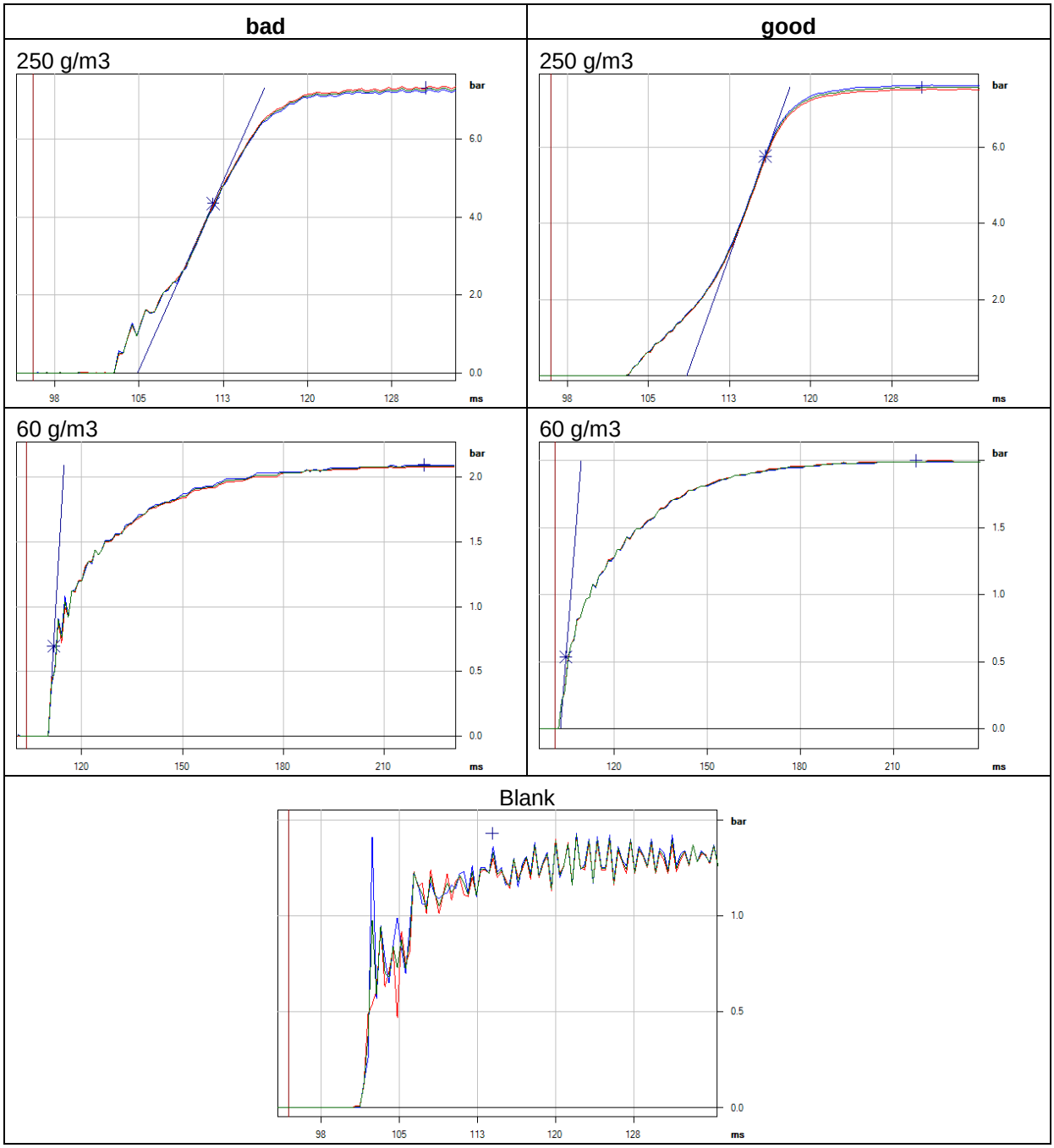


Simex 20-l

The individual Simex-results are drawn in relation to the arithmetic mean of all results and in chronological sequence (number of certificate).

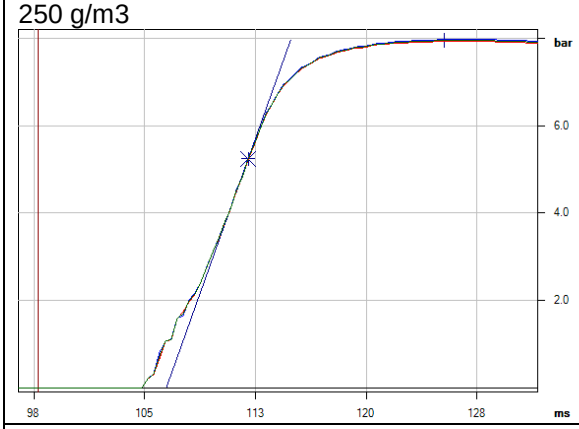
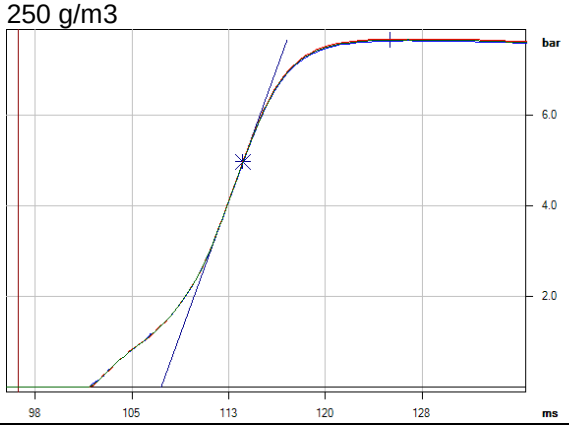
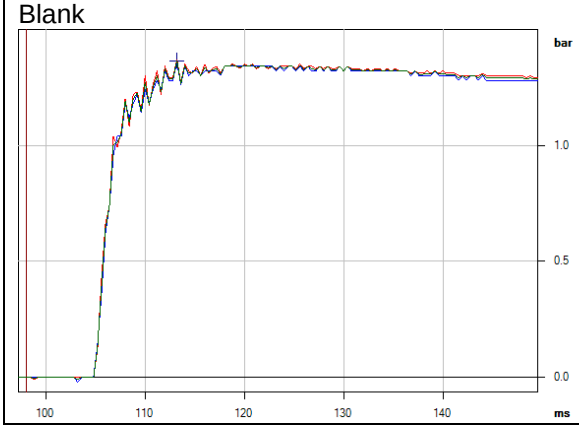
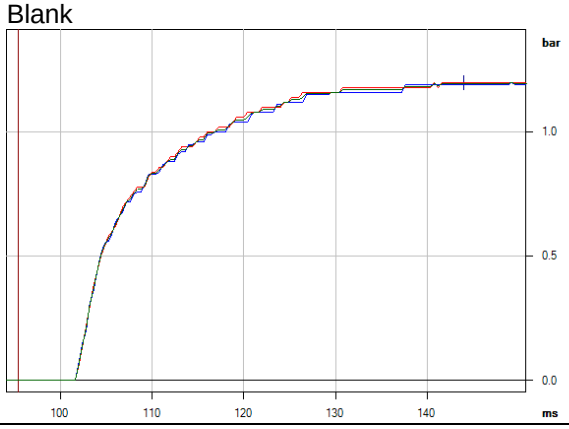
4.2 Problem by Simex- Igniters

Depending on the production batch of the igniters there was a much different burn behaviour observed. Pressure oscillations increase the turbulence and therefore the Kmax-value. Through the superimposed oscillation, the automatic evaluation is influenced or even wrong, that means the tangent has to be evaluated manually.



4.2 Problem by Sobbe- Igniters

As in 2001 Sobbe sent again some faulty igniters with pressure oscillations. Pressure oscillations increase the turbulence and therefore the Kmax-value. Through the superimposed oscillation, the automatic evaluation is influenced or even wrong, that means the tangent has to be evaluated manually.

bad	good
250 g/m3 	250 g/m3 
Blank 	Blank 

5. List of Participants

Country	Company Laboratory	E-Mail	Pmax Kmax	MIE
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Austria	FireX Greßlehner GmbH	dietmar.gresslehner@firex.at	✓	
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