Calibration-Round-Robin CaRo 19
Final Report

1. Conclusion

According to international standards 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 must be calibrated at regular intervals (at least every 12 months, or following any significant maintenance or repair).
For this purpose, an international calibration round test (calibration round robin = CaRo) has been carried out periodically since 1993.

A dust has been selected, prepared and supplied to **58** test laboratories all over the world.
The mean values of the explosion indices, measured by the participating laboratories, have 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 procedure.

CaRo 19 – Reference values for the Explosion Indices Pmax and Kmax

Pmax (bar)	**8.2** ± 10% (7.4 ... 9.0)
Kmax (bar·m/s)	**243** ± 10% (218 ... 267)

CaRo 19 – Reference values for the Minimum Ignition Energy MIE

Es / 3	Es	Es • 3
0.6 mJ	**1.7 mJ**	**5.0 mJ**

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1.1 Participants:

Further details about participants who have agreed to a publication,
can be found in section 4.

	Pmax, Kmax (73)		MZE (73)	
	20-l	1 m3	MIKE	others
Australia	1		1	
Austria	2		1	
Belgium	1		1	
Czech Republic	1		1	
France	5		3	
Germany	18	3	16	
India			1	
Italy	2		3	
Japan	1		2	
Norway	2		1	
Poland	2			2
Romania	1			
South Africa	1			
Spain	1		1	
Sweden	1			1
Switzerland	3		5	
The Netherlands	1		1	
United Kingdom	4		2	3
USA	17	1	11	3
Total:	**64**	**4**	**50**	**9**

1.2 Test substance:

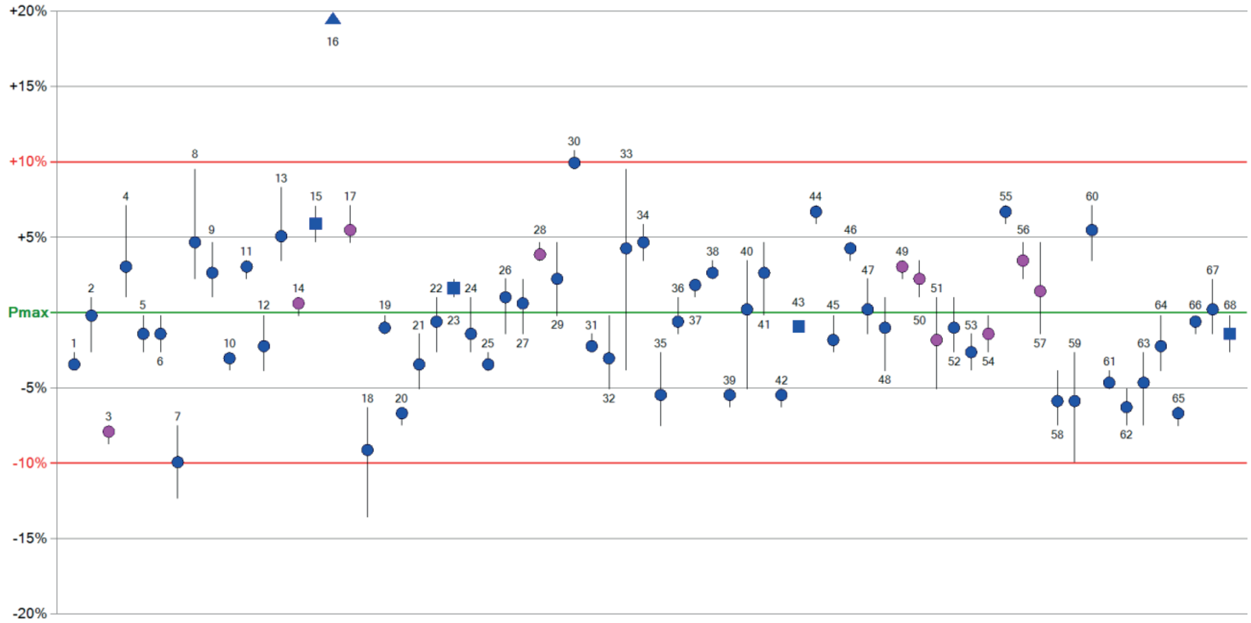
For correct calibration the CaRo 19 test sample has been milled, homogenized and shipped in an air tight package. Therefore the sample has to be tested „as delivered“.

CaRo 19 = **Niacin** CaRo Test Dust (Nicotinic acid)

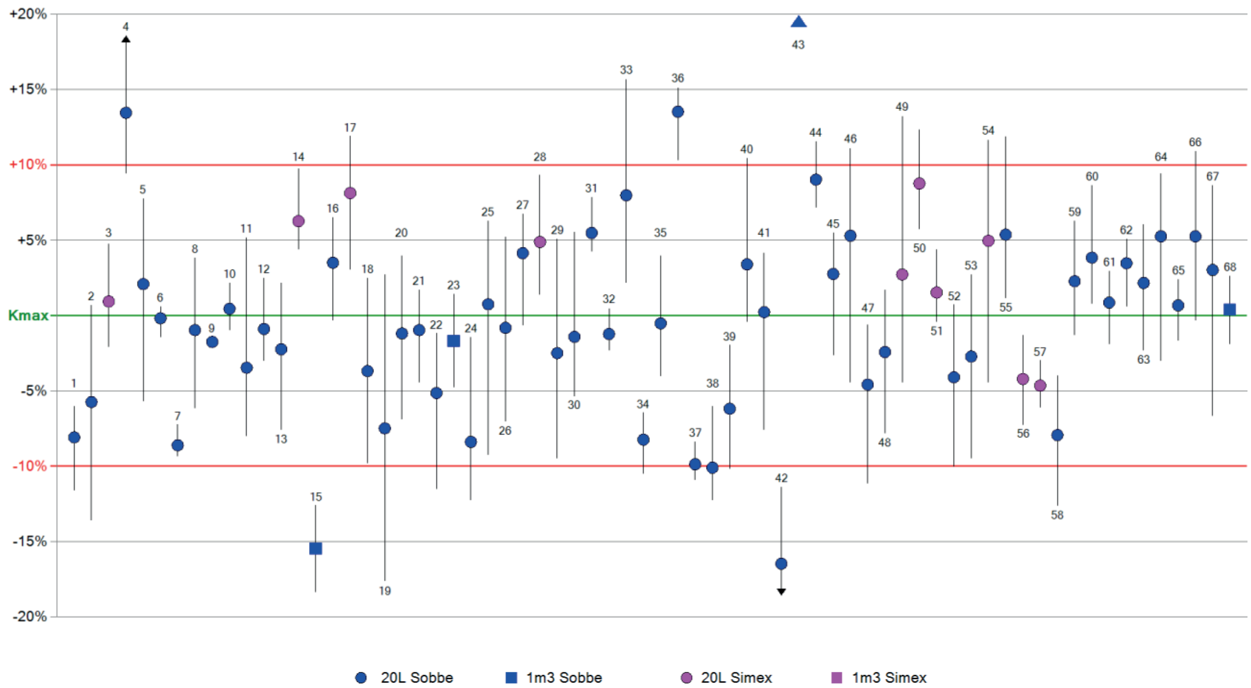
Particle size:	d 10 [µm]	**d 50 = median [µm]**	d 90 [µm]
Sample 1	4.6	**20.5**	77.7
Sample 2	4.6	**20.1**	76.3
Sample 3	4.6	**20.2**	76.4
Sample 4	4.7	**20.3**	76.8

2. Explosion Indices Pmax, Kmax

Pmax = 8.2 bar ±10% (7.4 ... 9.0) @ 527 g/m³



Kmax = 243 bar•m/s ±10% (218 ... 267) @ 699 g/m³



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 19“

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 value of all test results (68) has been calculated.
In a second 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.

2.5 Cause of errors:

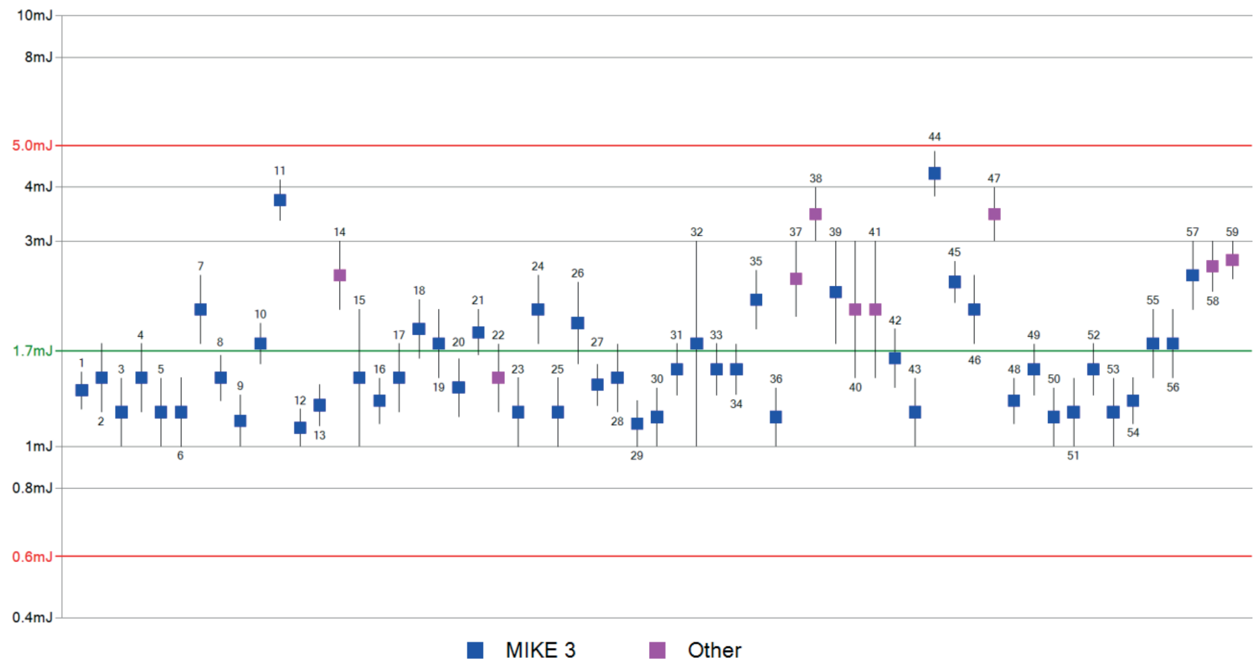
Some laboratories had to repeat the tests.
The reasons were:

a) Too high or too low initial pressure Pi.
The explosion indices Pmax and Kmax are direct proportional to the initial pressure Pi,
the pressure in the sphere at the moment of ignition.
This relation is linear up to an initial pressure of approx. 3 bar.

b) Too low Kmax values due to additional ignition delay time caused by a bad contact between ignition rod and the leads of the ignitors (inadequate cleaning).

c) Induced turbulences caused by pressure oscillations of the ignitors.

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 19“.

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 apparatuses, 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):

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

where is: I[E2] = number of tests with ignition at energy E2

(NI+I) [E2] = total number of tests at energy E2

3.3 Criteria for conformity:

Conformity in the CaRo 19 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
0.6 mJ	1.8 mJ	5.3 mJ

3.4 Cause of errors:

a) The use of synthetic air can increase the MIE.

b) Broken wires in high voltage and ground cable.

4. List of Participants

Country	Company Laboratory	E-Mail	Pmax Kmax	MIE
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USA	ioKinetic, LLC	barrett.c.iokinetic@iomosaic.com	✓	✓

5. Standards, History

5.1 Standards:

The following Standards have been applied:

EN 13821: Determination of minimum ignition energy of dust/air mixtures
EN 14034-1: Determination of max. explosion pressure Pmax …
EN 14034-2: Determination of max. rate of explosion pressure rise (dp/dt)max …
ASTM E1226: Standard Test Method for Explosibility of Dust Clouds
EN ISO/IEC 80079-20-2: … Material characteristics. Combustible dust methods

5.2 History:

Our previous world-wide round robin tests:

CaRo93: 77 apparatuses	CaRo05: 98 apparatuses	CaRo15: 131 apparatuses
CaRo96: 68 apparatuses	CaRo07: 77 apparatuses	CaRo17: 144 apparatuses
CaRo98: 63 apparatuses	CaRo09: 90 apparatuses	CaRo18: 41 apparatuses
CaRo00: 69 apparatuses	CaRo11: 122 apparatuses	
CaRo03: 93 apparatuses	CaRo13: 112 apparatuses	

➔ All final reports can be downloaded here: https://www.cesana-ag.ch/Calibration.shtml

References

Cesana Ch., Eiche M., Schwaninger M., 2019,
Quality Management in the Determination of Safety Characteristics, CET-Paper