

Calibration-Round-Robin CaRo21

Final Report

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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 **54** 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 21 – Reference values for the Explosion Indices Pmax and Kmax

Pmax (bar)	8.3 ± 10% (7.4 ... 9.1)
Kmax (bar·m/s)	249 ± 10% (224 ... 274)

CaRo 21 – Reference values for the Minimum Ignition Energy MIE

Es / 3	Es	Es · 3
0.5 mJ	1.5 mJ	4.6 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 (67)		MZE (58)	
	20-l	1 m3	MIKE	others
Australia	1		1	
Austria	2		1	
Belgium	1		1	
Brazil	1			
China			1	
Czech Republic	2	1	1	
France	3		3	
Germany	14	3	13	1
India			1	
Italy	2		2	
Japan	1		2	
Norway	1		1	
Poland	1	2		2
Romania	1			1
South Africa	2			
Spain	1		1	
Sweden	1			1
Switzerland	3		7	
The Netherlands	1		1	
United Kingdom	4		4	1
USA	17	2	10	2
Total:	59	8	50	8

1.2 Test substance:

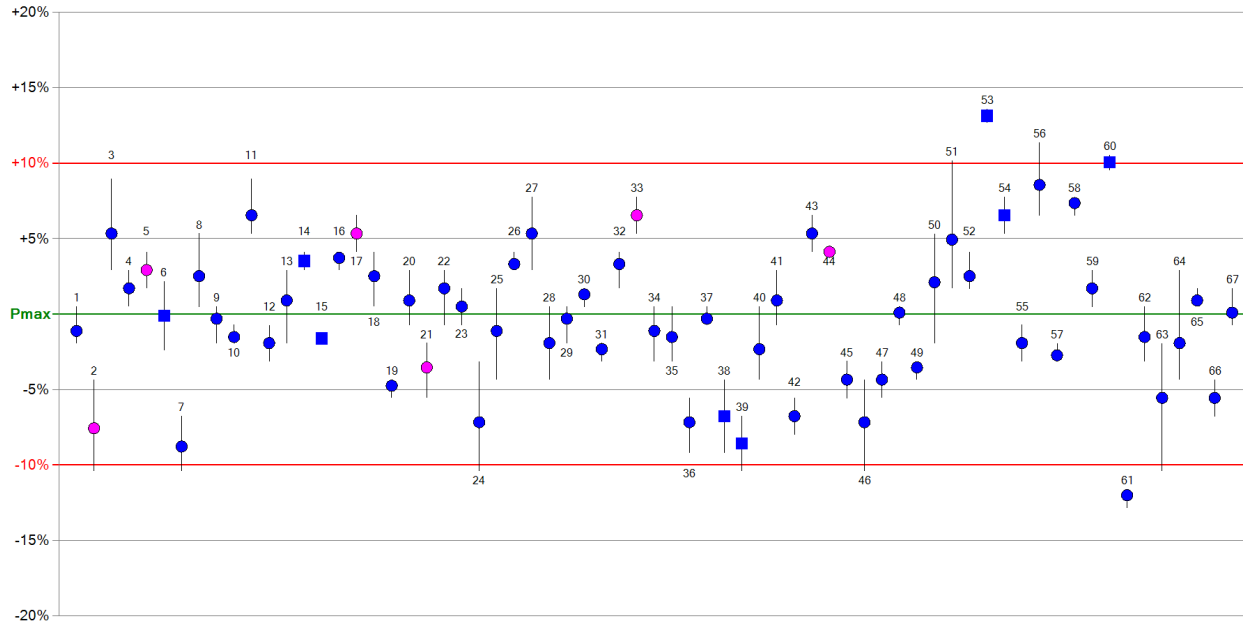
For correct calibration the CaRo 21 test sample has been milled, homogenized and shipped in an air tight package. Therefore the sample has to be tested „as delivered“.

CaRo 21 = Niacin CaRo Test Dust (Nicotinic acid)

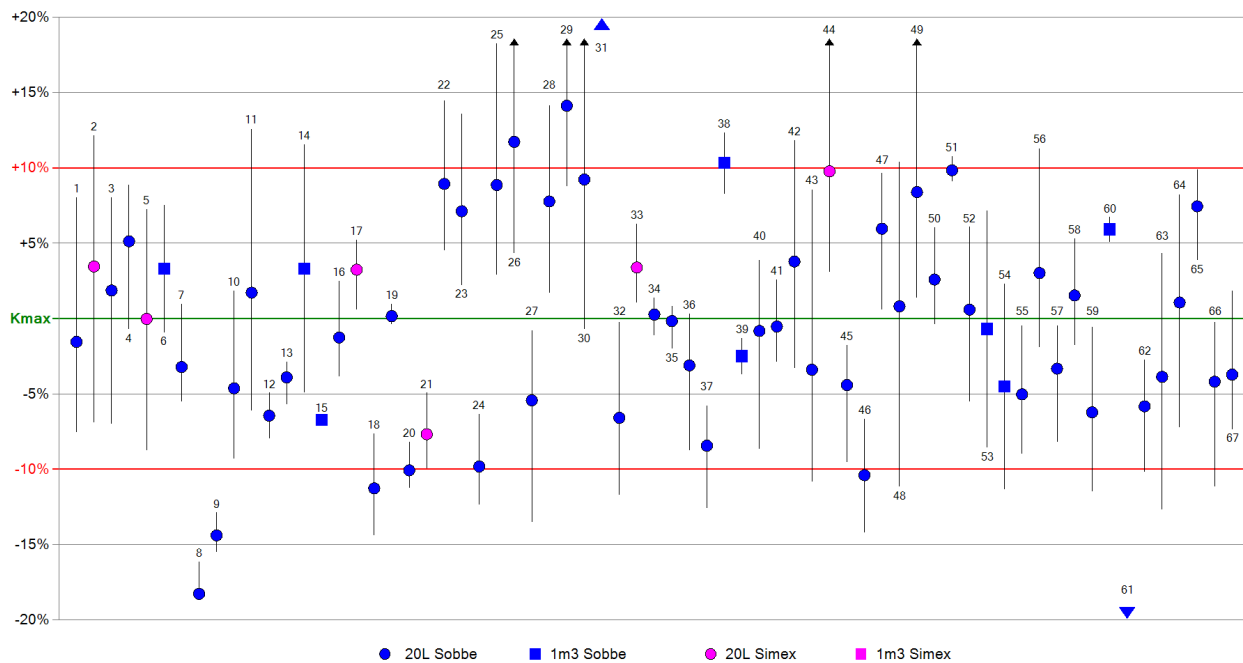
Particle size:	d 10 [µm]	d 50 = median [µm]	d 90 [µm]
Sample 1	4.78	19.34	69.07
Sample 2	4.76	19.54	71.03
Sample 3	4.90	19.80	67.97
Sample 4	4.86	19.40	67.46

2. Explosion Indices Pmax, Kmax

Pmax = 8.3 bar ±10% (7.4 ... 9.1) @ 582 g/m³



Kmax = 249 bar·m/s ±10% (224 ... 274) @ 725 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 „Instructions CaRo 21“

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 (67) 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.

2.5 Cause of errors:

Some laboratories had to repeat the tests.
The most common causes of errors known to us have been summarised in our new appendix on the 20-L apparatus (B000_080.pdf) in chapter 5.
This document and other revised documents can be found after updating the corresponding software (KSEP) as usual via the menu item "Help".

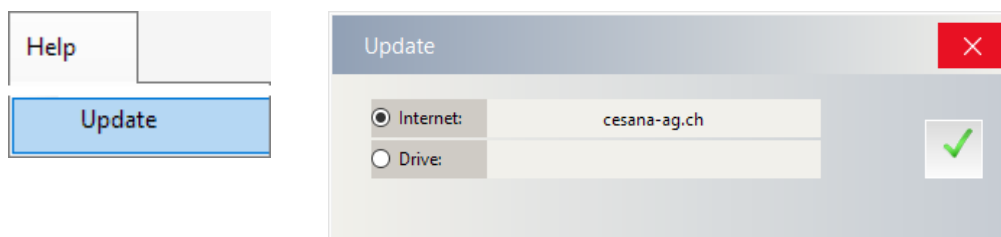
Update of software older than 2017

The former Kühner update server no longer exists! An update via the built-in update function is therefore no longer possible. Old software with the Kühner logo can only be updated as follows:

KSEP 7.x

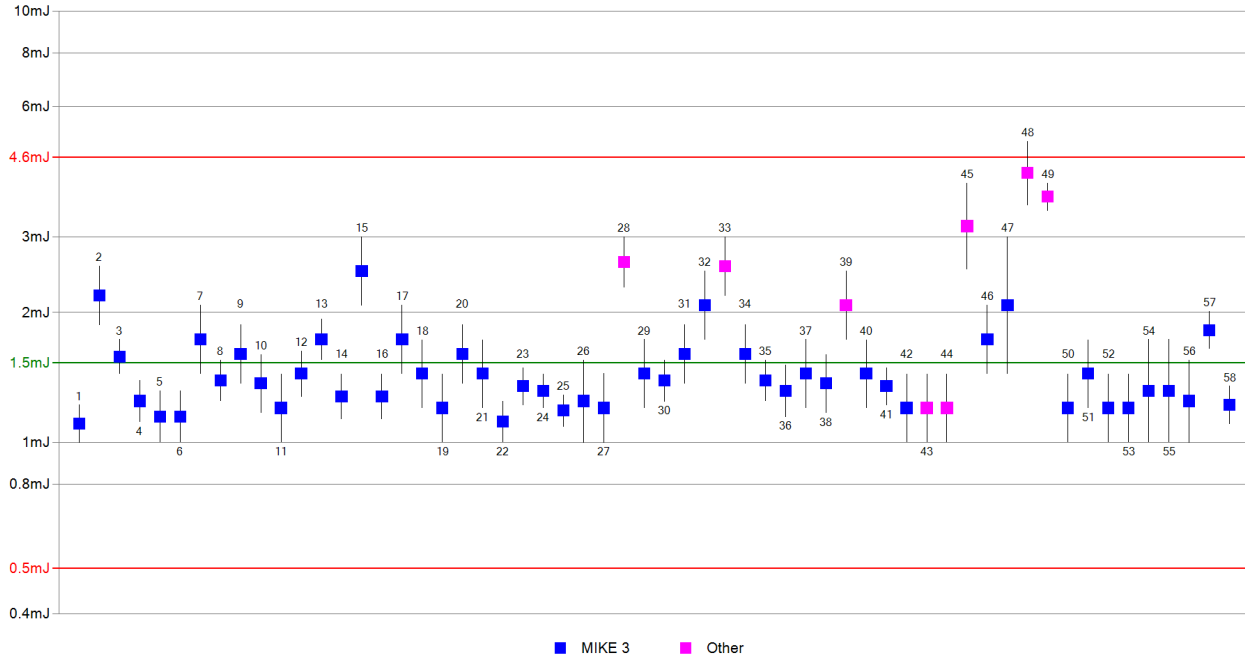
1. Load file: https://www.cesana-ag.ch/download/KSEP71_setup.msi
2. Run the file: KSEP71_setup.msi
3. Select the previous KSEP directory (Browse).
4. Start installation (if necessary select the option "Repair").
Your previous settings and data remain unchanged!

Update of software 2017 and newer



Select and start the update function: **Help / Update** (Internet: cesana-ag.ch)
Everything else happens automatically.

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 „Instructions CaRo 21“.

3.2 Estimation of the statistical energy (Es):

The minimum ignition energy MIE lies, by definition, between two energy values: $E_1 < MIE < E_2$

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):

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

where is: $I[E_2]$ = number of tests with ignition at energy E2
 $(N+1) [E_2]$ = total number of tests at energy E2

3.3 Criteria for conformity:

Conformity in the CaRo 21 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	4.6 mJ

4. List of Participants

Country	Company Laboratory	E-Mail	Pmax Kmax	MIE
Australia	Simtars – Resources Safety & Health Queensland (RSHQ)	sponcom.dust@simtars.com.au	✓	✓
Austria	AUVA	stp@auva.at	✓	✓
Austria	FireX Greßlehner GmbH	dietmar.gresslehner@firex.at	✓	
Belgium	Adinex N.V.	info@adinex.be	✓	✓
Brazil	IPT - Instituto de Pesquisas Tecnológicas	ricalca@ipt.br	✓	✓*
Czech Republic	VVUÚ, a.s.	mokosl@vuuu.cz	✓	✓
France	INERIS	ghislain.binotto@ineris.fr	✓	✓
France	SOLVAY	gilles.roman@solvay.com	✓	✓
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Germany	IFA - DGUV	sascha.hohmann@dguv.de	✓	✓
Germany	Inburex Consulting GmbH	rene.dworschak@inburex.com	✓	✓
Germany	Merck KGaA	thomas.keil@merckgroup.com		✓*
Germany	Wacker Chemie AG	alfred.augsberger@wacker.com	✓	✓

Country	Company Laboratory	E-Mail	Pmax Kmax	MIE
India	GVS Cibatech Private Limited	vijay.bhujle@cibatech.com		✓*
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Switzerland	TÜV SÜD Process Safety	delphine.berset@tuvsud.com	✓	✓
Switzerland	TÜV SÜD Schweiz AG	michael.durrer@tuvsud.com	✓	✓
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United Kingdom	BRE Global	lee.amendt@bregroup.com	✓	✓
United Kingdom	DEKRA Organisational & Process Safety	aidan.bushell@dekra.com	✓	✓

Country	Company Laboratory	E-Mail	Pmax Kmax	MIE
United Kingdom	Sigma-HSE (UK) Ltd	grogers@sigma-hse.com	✓	✓
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USA	Ashland LLC	tolechnowicz@ashland.com	✓	✓
USA	BASF Corporation	andrew.charlick@basf.com	✓	✓
USA	DEKRA Process Safety	don.churchwell@dekra.com	✓	✓
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USA	Exponent, Inc.	phenry@exponent.com	✓	✓
USA	Fauske & Associates, LLC	dastidar@fauske.com	✓	✓
USA	Firmenich, Inc.	peter.de.rege@firmenich.com	✓	✓
USA	IEP Technologies	john.lussier@hoerbiger.com	✓	✓

✓* result pending

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	CaRo19: 127 apparatuses
CaRo03: 93 apparatuses	CaRo13: 112 apparatuses	CaRo20: 41 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