Microwave Spectromter HK9

- Idea behind the spectromter concept; purpose and application
- Physical background
- Realisation (instrument, antennas, priliminary technical data)
- Specter 9 software for calibration
- Indoor tests on different products (tobacco, sand, Isopropanol2, sugar)
- Task list; field test on tobacco, temperature tests, etc.

Idea behind the spectromter concept

If it is required to measure materials that are baled or packed in boxes, the moisture and the density inside the bale or box are of interest.

Problems using phaseshift and attenuation of the µW signal:

- Phaseshift is only defined in a range of 0° to 360°
- Attenuation has a small measuring effect
- To detect density and moisture a combination of attenuation and phaseshift is needed

Idea behind the spectromter concept

Advantage using the absorption spectrum:

- no limitation in measuring range (0° to 360° phaseshift)
- As the interaction of material and water is frequency dependent,moisture and density can be measured

Remark: As the attenuation shows less measuring effect than the phase shift, the spectrometer is not usable for small quantities of materials with low moisture.

- Use frequency dependent attenuation instead of phase measurement

Physical background

The interacion of material and microwaves is specified by the dielectric constant of the material, epsilon.

epsilon = epsilon(real)+epsilon(imaginary)

epsilon(real) = reduction in wavelength

epsilon(imaginary) = angle of energy absorption

The loss tangent

tan(delta) = epsilon(imaginary)/epsilon(real)

describes the loss in dielectrics and is the attenuation measured by the HK9 instrument. The variation in tan(delta) relates to the moisture content and the bulk density of the material.

Physical background

The dielectric behaviour of material, especially of water, is frequency dependent . This factor enables us to generate a density-independent moisture signal.

Using a multilinear regression of the absorption spectrum makes it possible to distinguish between the attenuation caused by moisture and that caused by density.

The standarisation, used in the HK9 software, also helps generating a density-independent signal. The first derivation, dT/Lambda, of the spectrum is one of the possibilities the HK9 software offers.

HK9 Technical data (priliminary)

Housing: Aluminium; IP65; H*B*T = 230*200*110mm

Weight: about 5kg

Voltage: 115/230 VAC +/-15% 47-65 Hz

Power consumption: 50VA

Operating temperature: -20 – 85°C

Storage temperature:-30 – 95°C

Display: 2*24 character LCD, LED-backlight

Relay: AC 250VA, DC 30V 1A

Current output: 2 * 0/4 – 20mA active output, isolated, max. load 500 Ohm, moisture and density

HK9 Technical data (priliminary)

Current input: 0/4 – 20mA, not isolated, load 125 Ohm

COM ports: RS232; data output

RS232; bidirectional; calibration via SPECTER9

RS485; data output

2400 Baud to 115 kBaud;

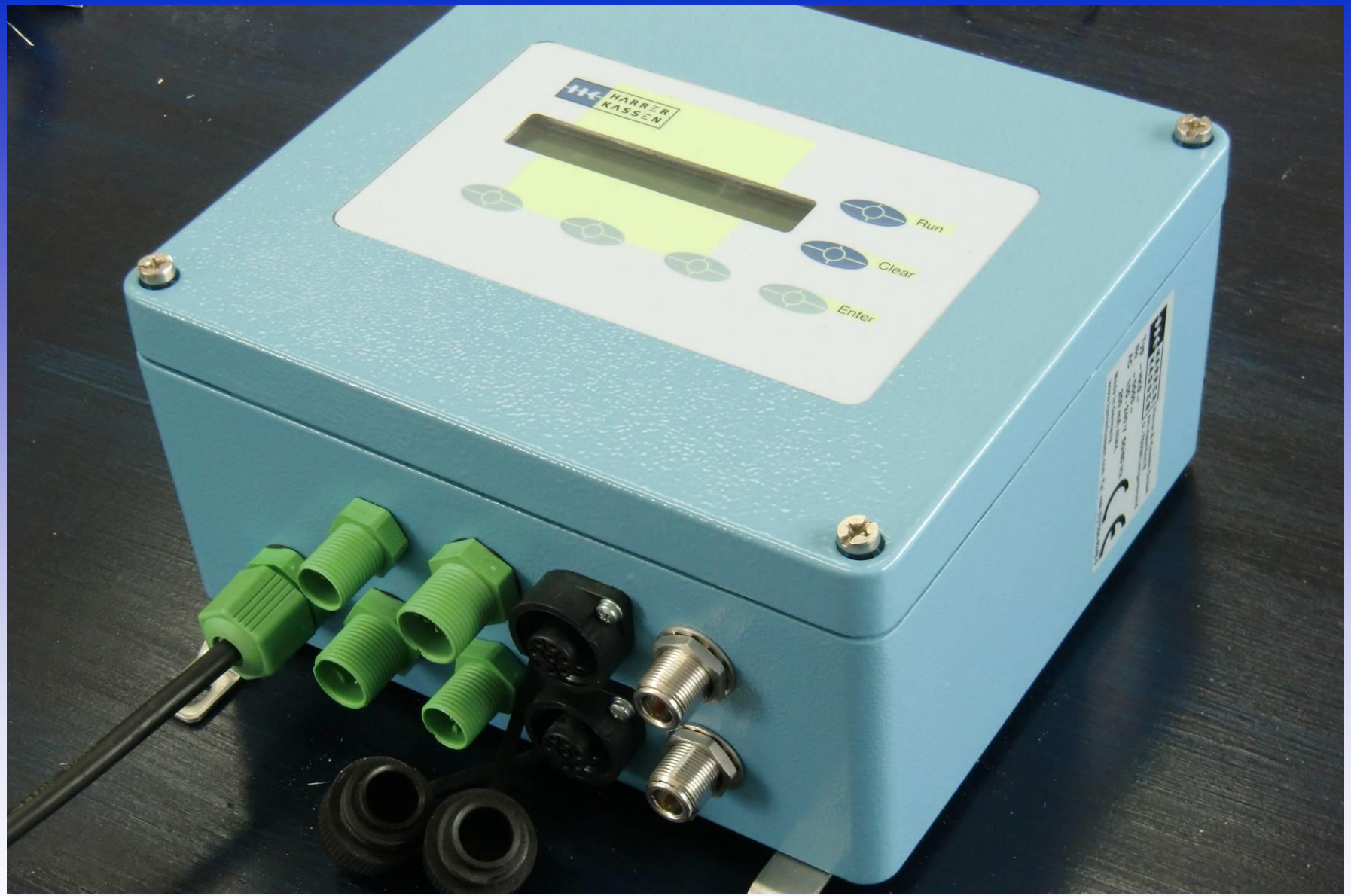
8 data bit, 1 stop bit, no parity

Digital inputs: Start/Stop; Product select

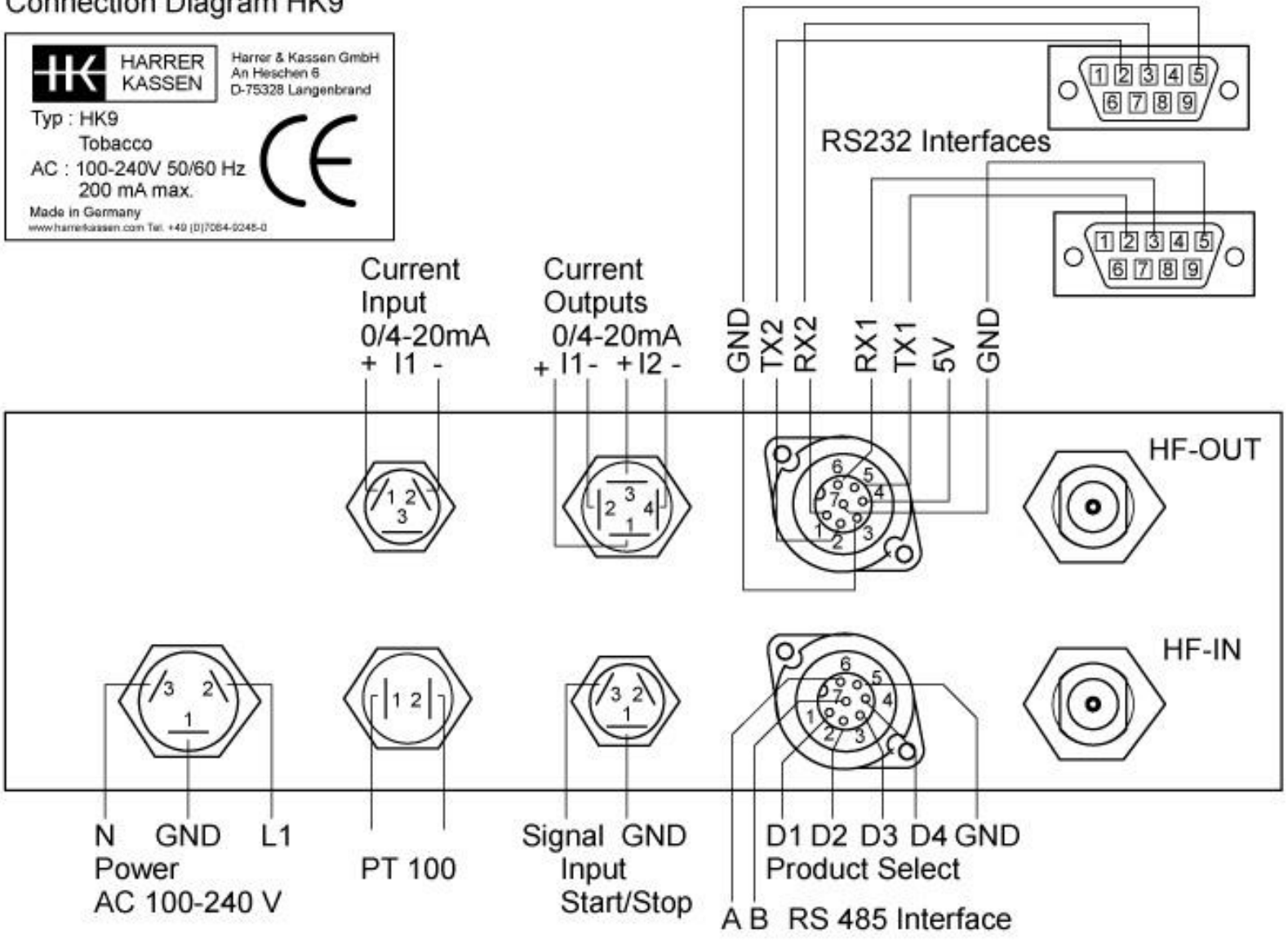
Microwave frequency: 1,5 GHz to 3,5 GHz; 50 steps

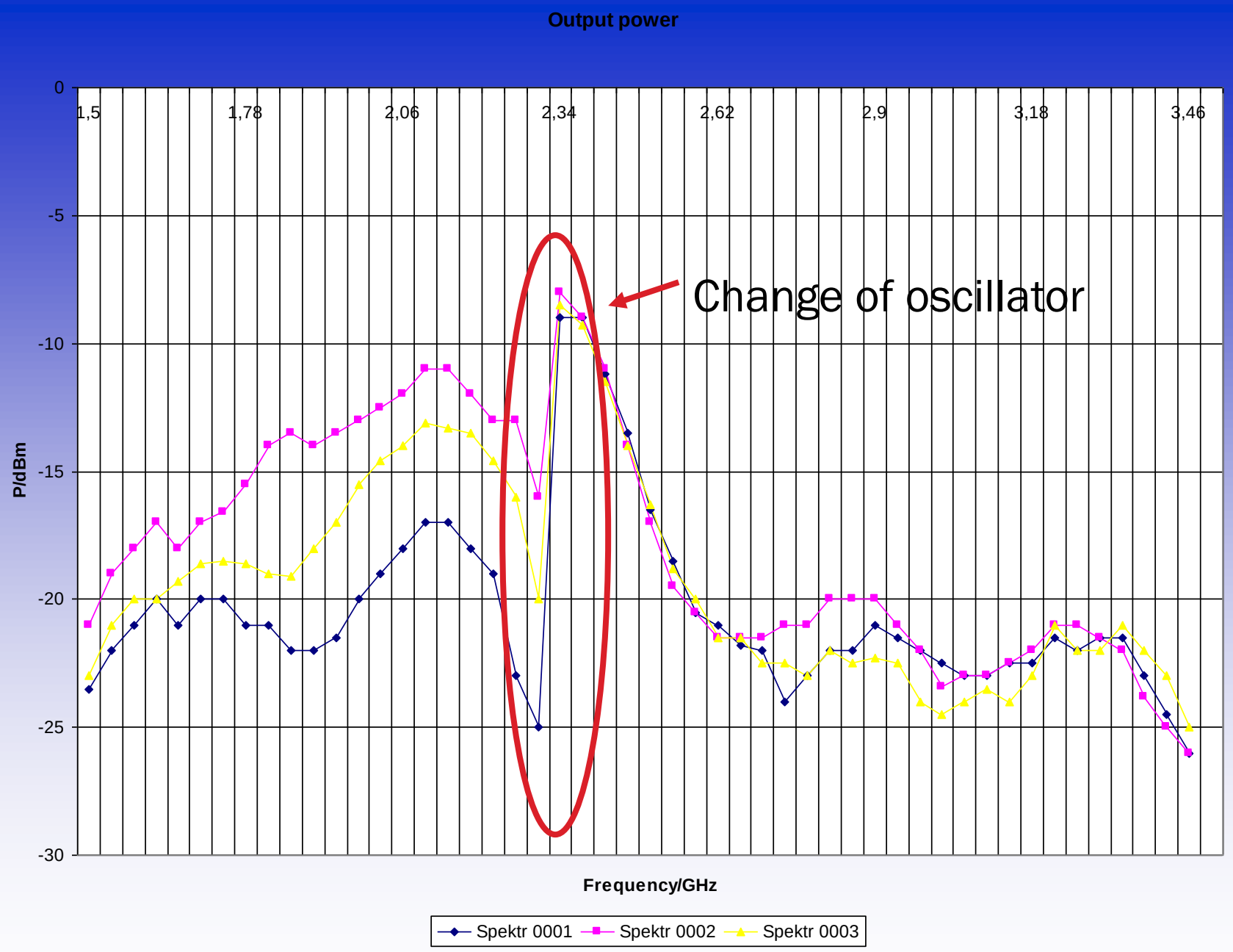
Microwave power: max: -10 dBm

Sensitivity: -80 dBm; 10 measurements/second

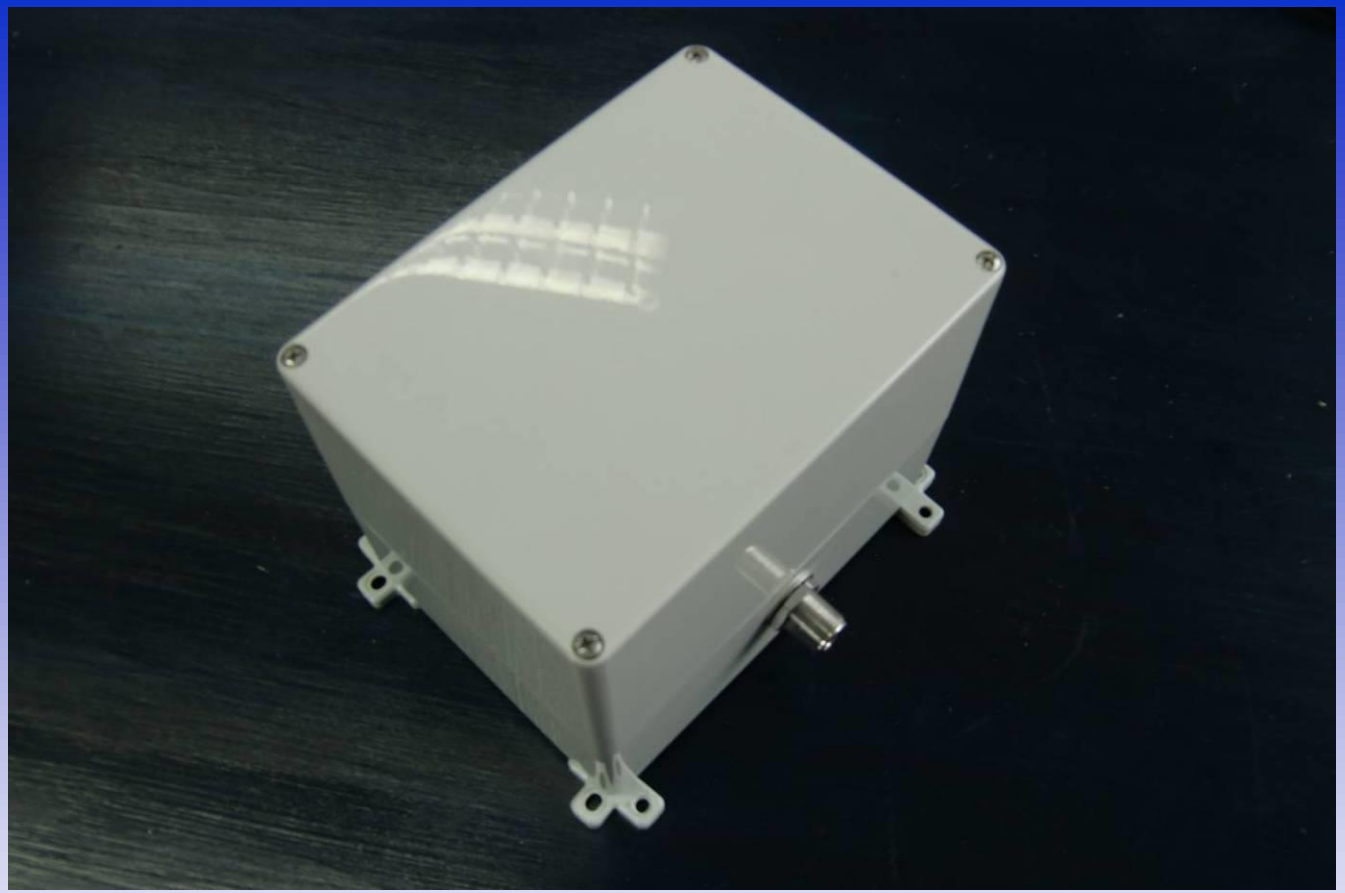

HARRER
KASSEN
Run
Clear
Enter

Connection Diagram HK9





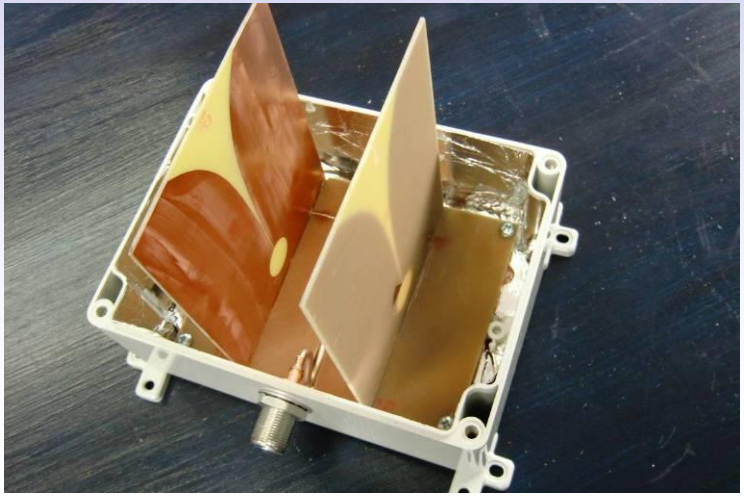
Output power

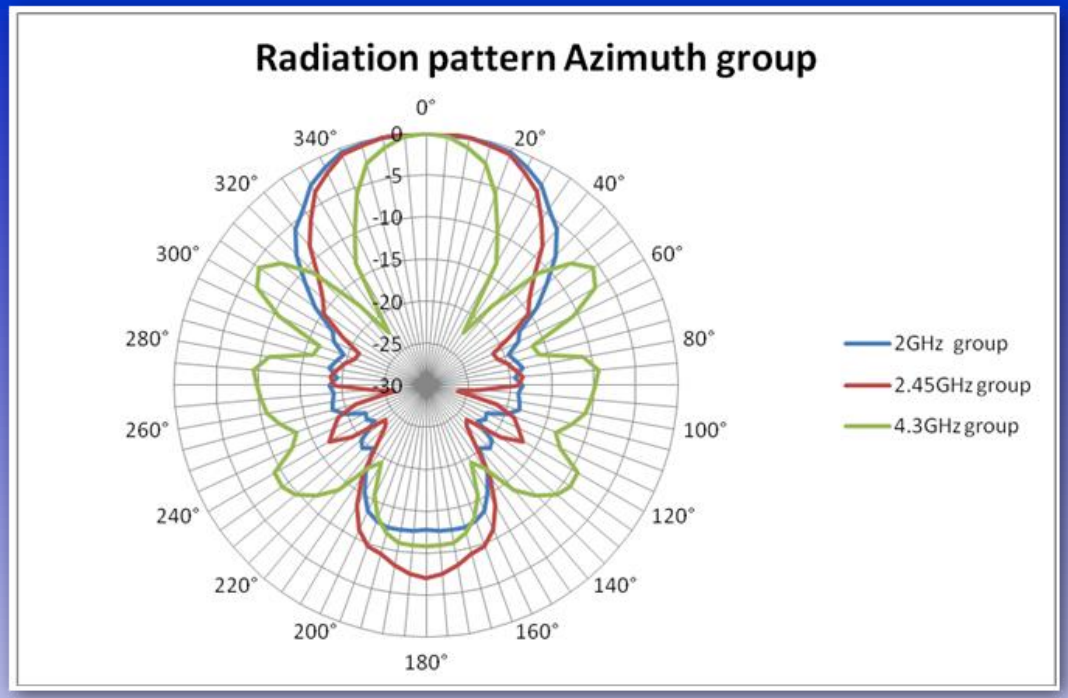


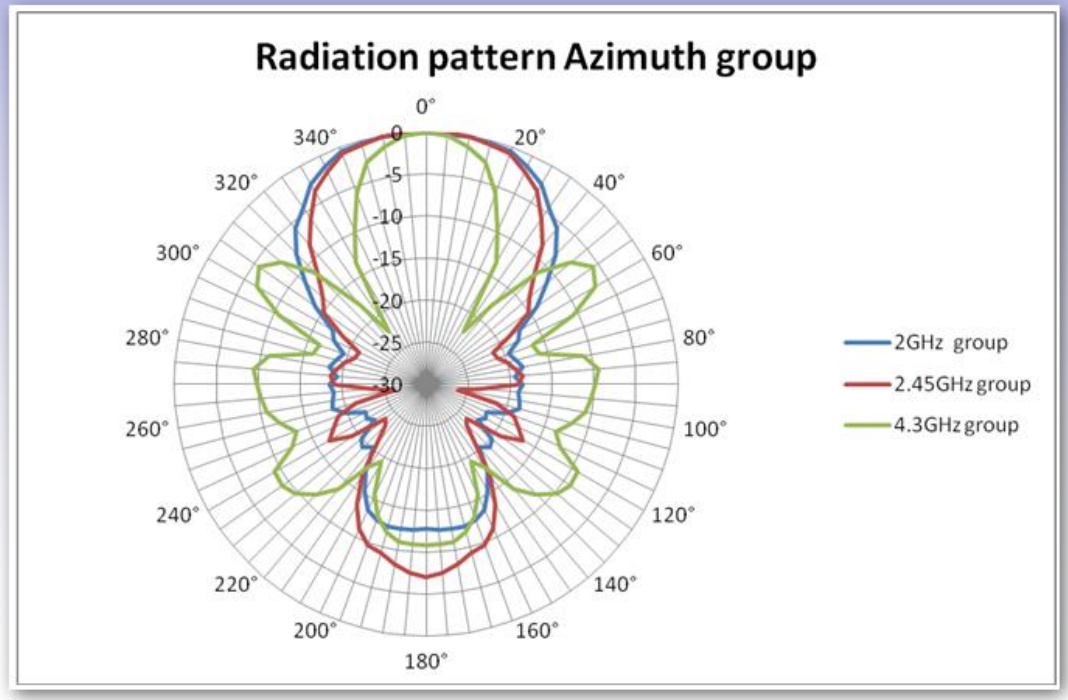
Vivaldi group antenna

Dimension: 160*120*140 mm; L*B*H

Material: ABS; IP 65







Vivaldi antenna

Gain: 10 dB

HPBW: 60° to 70°

Specter 9 software for calibration

- Written by Mr. Gerald Keck
- Based on Spekter 8 Software for NIR calibration
- Uses multilinear Regression for calibrating HK9
- Calculates the coefficients for moisture and density
- PC based software that communicates via RS232 with the HK9 instrument
- Calculates up to 6 coefficients for miosture and up to 7 coefficients for density measurement.

Specter 9 software for calibration

$H_2O = a0 + a1*W1 + a2*W2 + a3*W3 + a4*W4$

with W (1->n) standardised denstiy independ values

$Rho = a0 + a1*T1 + a2*T2 + a3*T3 + a4*T4$

$+a5*T5 + a6*H_2O$

with T (1->n) standardised spectrum

Remark: Number of needed coefficients reduces, if less than 5 wavelength are used.

isotagung - Specter9 Version 1.0.0.

File Communication Undo/Redo Calibration Display Export Data Info

Status

COM-Port: OK. | Calculation: OK.

HARRER KASSEN

Calibration

B0: 5.45 B1: -9.891759 B2: -13.30408 B3: -3.036403 B4: -0.269627 B5: 0.000000

Product: H2O Name: Isopropanol2 Standardisation: dT/Lambda DLG

Send Calib

Calibration quality

STD: Calibration: 0.070 STD: Unknown samples: -NA- R^2: 0.800

Reference

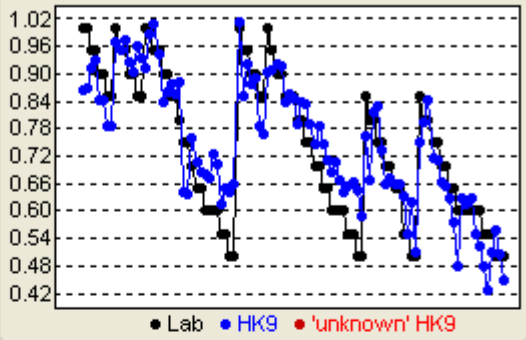
W1	W2	W3	W4	W5
21.000000	17.000000	8.000000	13.000000	9.000000

Send Ref. Edit Ref. Read Ref.HK9

Sample View

x	Comment	W1	W2	W3	W4	W5	H2O	P.H2O	E.H2O
✓	09.04.13 13:54	54.22	48.03	32.38	35.13	36.31	1.00	0.87	-0.13
✓	09.04.13 13:59	54.22	48.03	32.28	35.59	35.77	1.00	0.87	-0.13
✓	09.04.13 14:12	54.47	48.04	32.54	35.42	36.29	0.95	0.91	-0.04
✓	09.04.13 14:15	54.39	48.00	32.51	35.43	36.27	0.95	0.93	-0.02
✓	09.04.13 14:22	54.79	48.25	32.68	35.38	36.39	0.90	0.84	-0.06
✓	09.04.13 14:24	54.74	48.21	32.65	35.33	36.28	0.90	0.84	-0.06
✓	09.04.13 14:27	55.03	48.47	32.74	35.60	36.47	0.85	0.79	-0.06
✓	09.04.13 14:29	54.93	48.36	32.64	35.60	36.46	0.85	0.78	-0.07
✓	09.04.13 13:54	56.64	50.18	34.41	36.45	37.35	1.00	0.97	-0.03
✓	09.04.13 14:12	57.09	50.55	34.58	37.17	37.46	0.95	0.95	0.00
✓	09.04.13 14:15	57.07	50.57	34.57	37.39	37.46	0.95	0.98	0.03
✓	09.04.13 14:22	57.38	50.80	34.84	36.99	37.49	0.90	0.93	0.03
✓	09.04.13 14:24	57.37	50.74	34.76	37.02	37.38	0.90	0.90	0.00
✓	09.04.13 14:27	57.75	51.11	35.14	37.35	37.92	0.85	0.96	0.11
✓	09.04.13 14:29	57.71	51.09	35.09	37.22	37.83	0.85	0.94	0.09

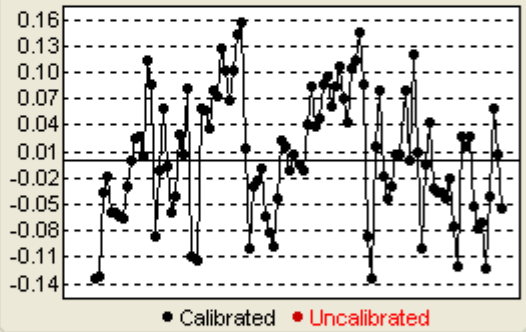
Lab versus HK9



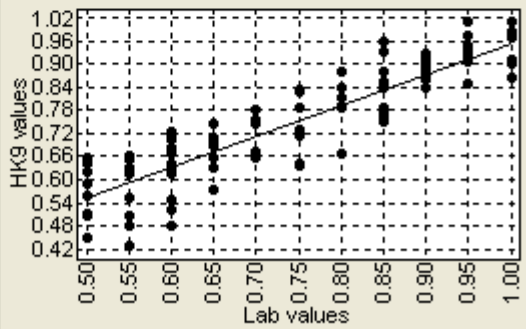
Change view

Calibration quality:

Deviation

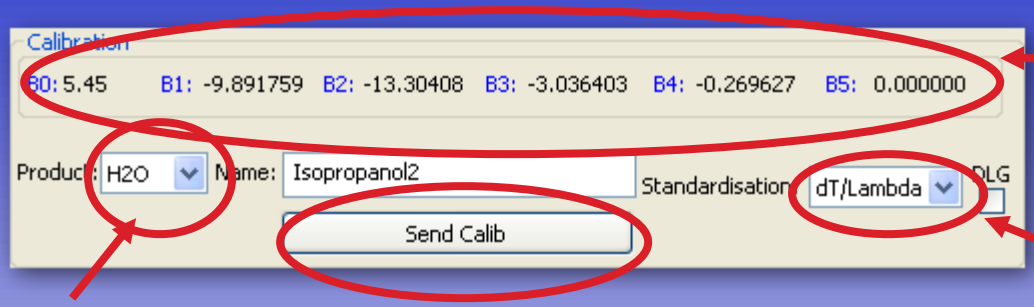


XY View



Delete Sample Edit Sample New Sample manual New Sample HK9 Count: 1 Exit

Specter 9 software for calibration

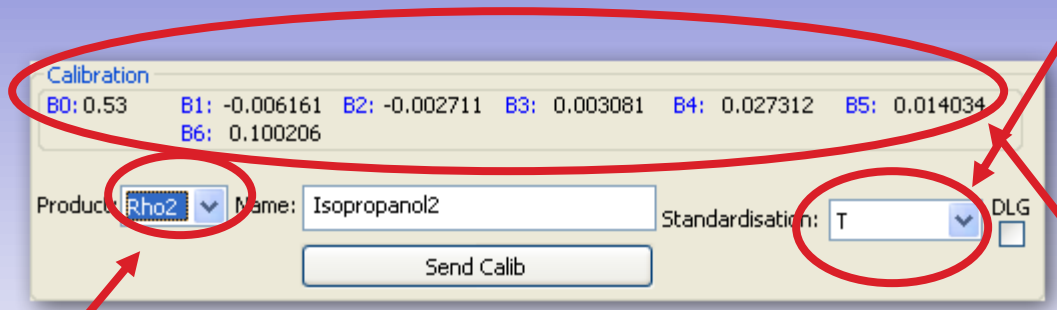


Coeffitions water

Calibration water

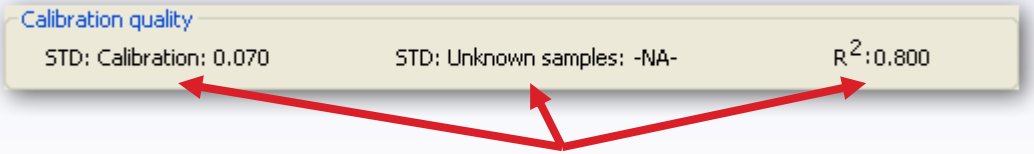
Standardisation

T ; dT/Lambda ;
Special ; Linear



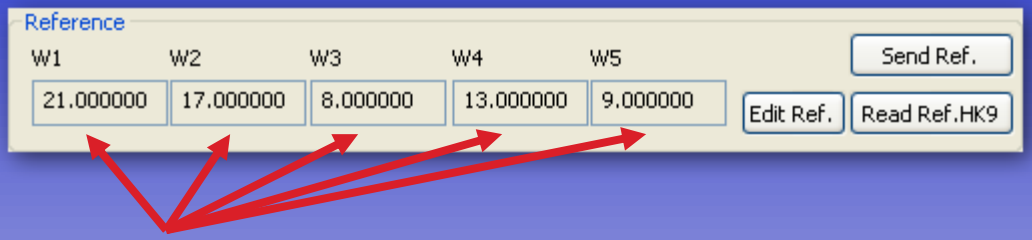
Coeffitions density

Calibration density



Statistical parameters; Quality of calibration

Specter 9 software for calibration

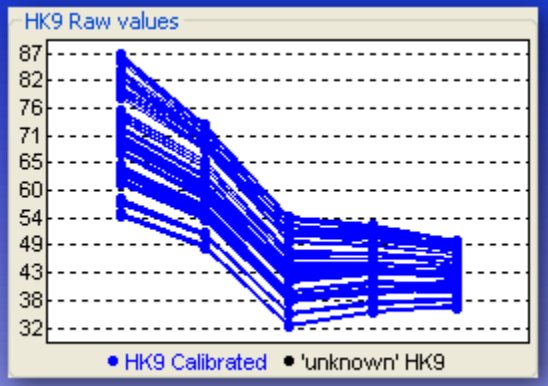


Reference Attenuation for single wavelenth

Spectra with Lab-values; predicted values and deviation

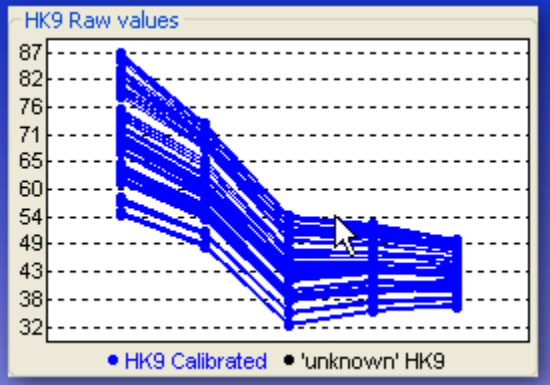
x	Comment	W1	W2	W3	W4	W5	H2O	P.H2O	E.H2O
☑	09.04.13 13:54	54.22	48.03	32.38	35.13	36.31	1.00	0.87	-0.13
☑	09.04.13 13:59	54.22	48.03	32.28	35.59	35.77	1.00	0.87	-0.13
☑	09.04.13 14:12	54.47	48.04	32.54	35.42	36.29	0.95	0.91	-0.04
☑	09.04.13 14:15	54.39	48.00	32.51	35.43	36.27	0.95	0.93	-0.02
☑	09.04.13 14:22	54.79	48.25	32.68	35.38	36.39	0.90	0.84	-0.06
☑	09.04.13 14:24	54.74	48.21	32.65	35.33	36.28	0.90	0.84	-0.06
☑	09.04.13 14:27	55.03	48.47	32.74	35.60	36.47	0.85	0.79	-0.06
☑	09.04.13 14:29	54.93	48.36	32.64	35.60	36.46	0.85	0.78	-0.07
☑	09.04.13 13:54	56.64	50.18	34.41	36.45	37.35	1.00	0.97	-0.03
☑	09.04.13 14:12	57.09	50.55	34.58	37.17	37.46	0.95	0.95	0.00
☑	09.04.13 14:15	57.07	50.57	34.57	37.39	37.46	0.95	0.98	0.03
☑	09.04.13 14:22	57.38	50.80	34.84	36.99	37.49	0.90	0.93	0.03
☑	09.04.13 14:24	57.37	50.74	34.76	37.02	37.38	0.90	0.90	0.00
☑	09.04.13 14:27	57.75	51.11	35.14	37.35	37.92	0.85	0.96	0.11
☑	09.04.13 14:29	57.71	51.09	35.09	37.22	37.83	0.85	0.94	0.09

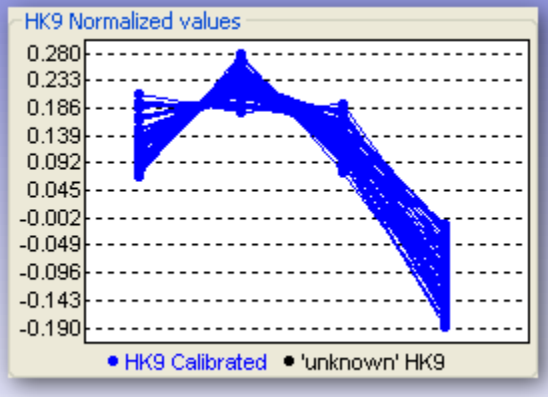
Graphs



Moisture Density

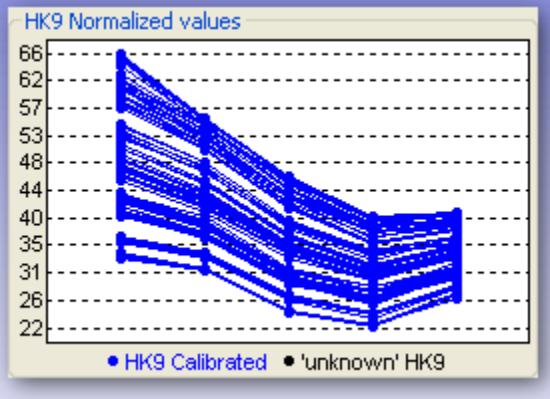
Raw values

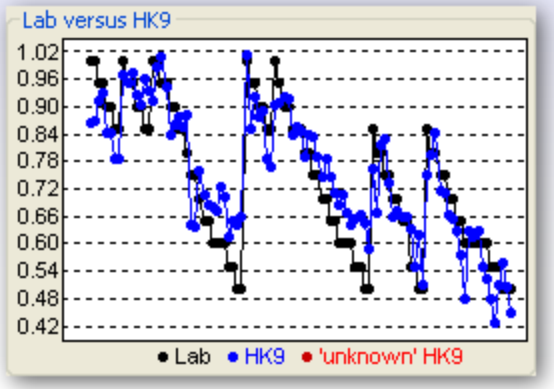




Standardisation

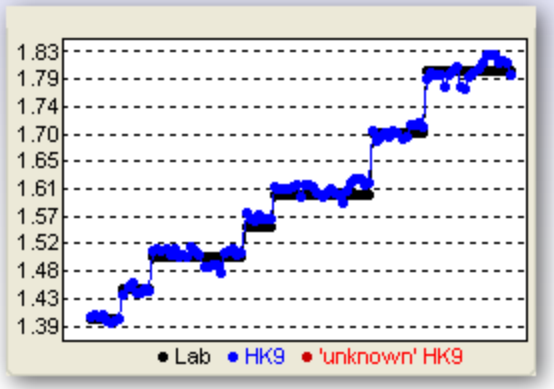
dT/Lambda T



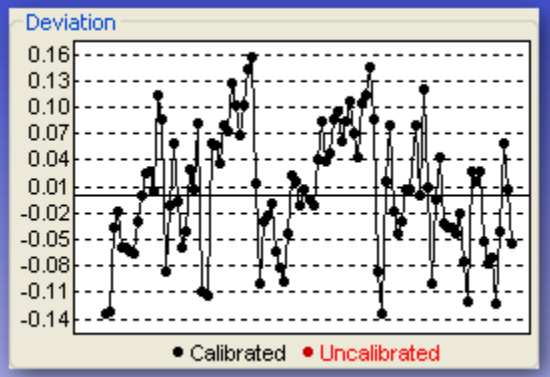


Comparison Lab vs. HK9

Moisture Density

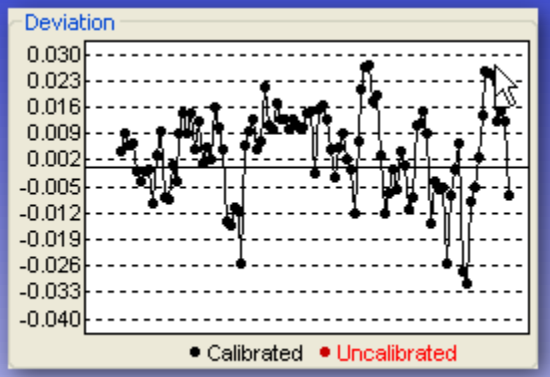


Graphs

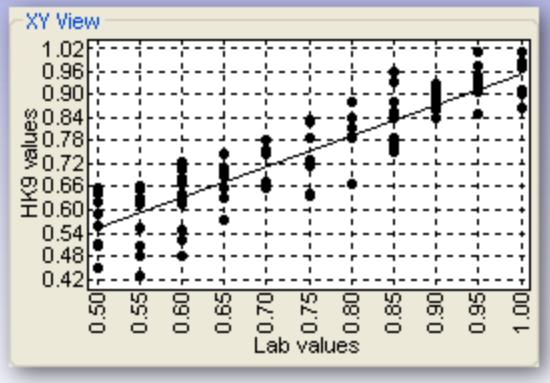


Moisture

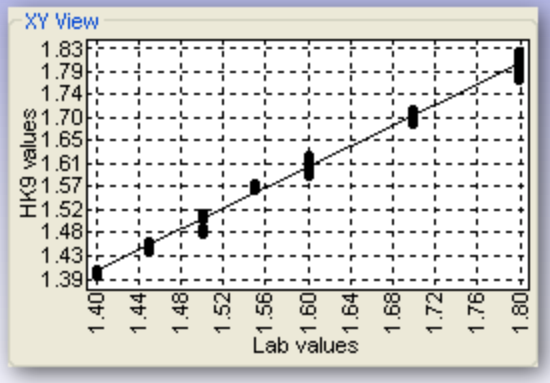
Density



Deviation



Regression



Indoor tests on different products

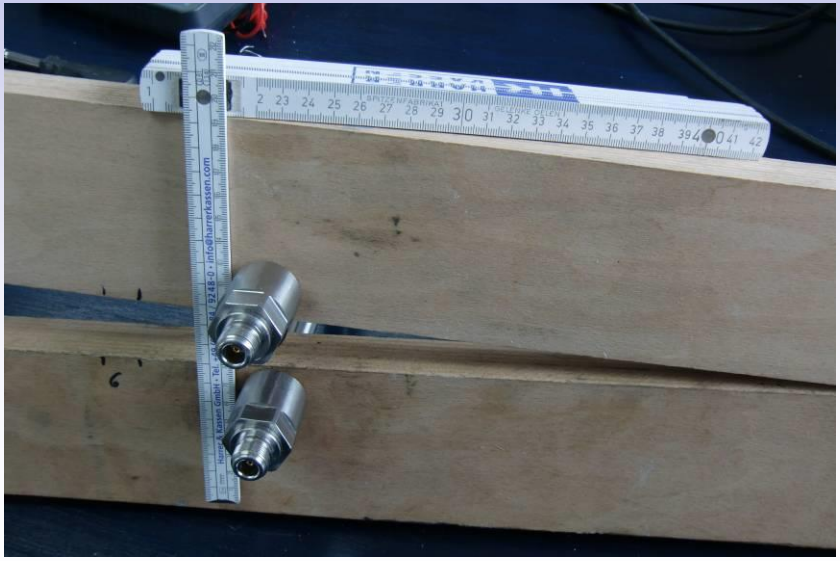
- Isopropanol2
- Sugar
- Sand
- Tobacco

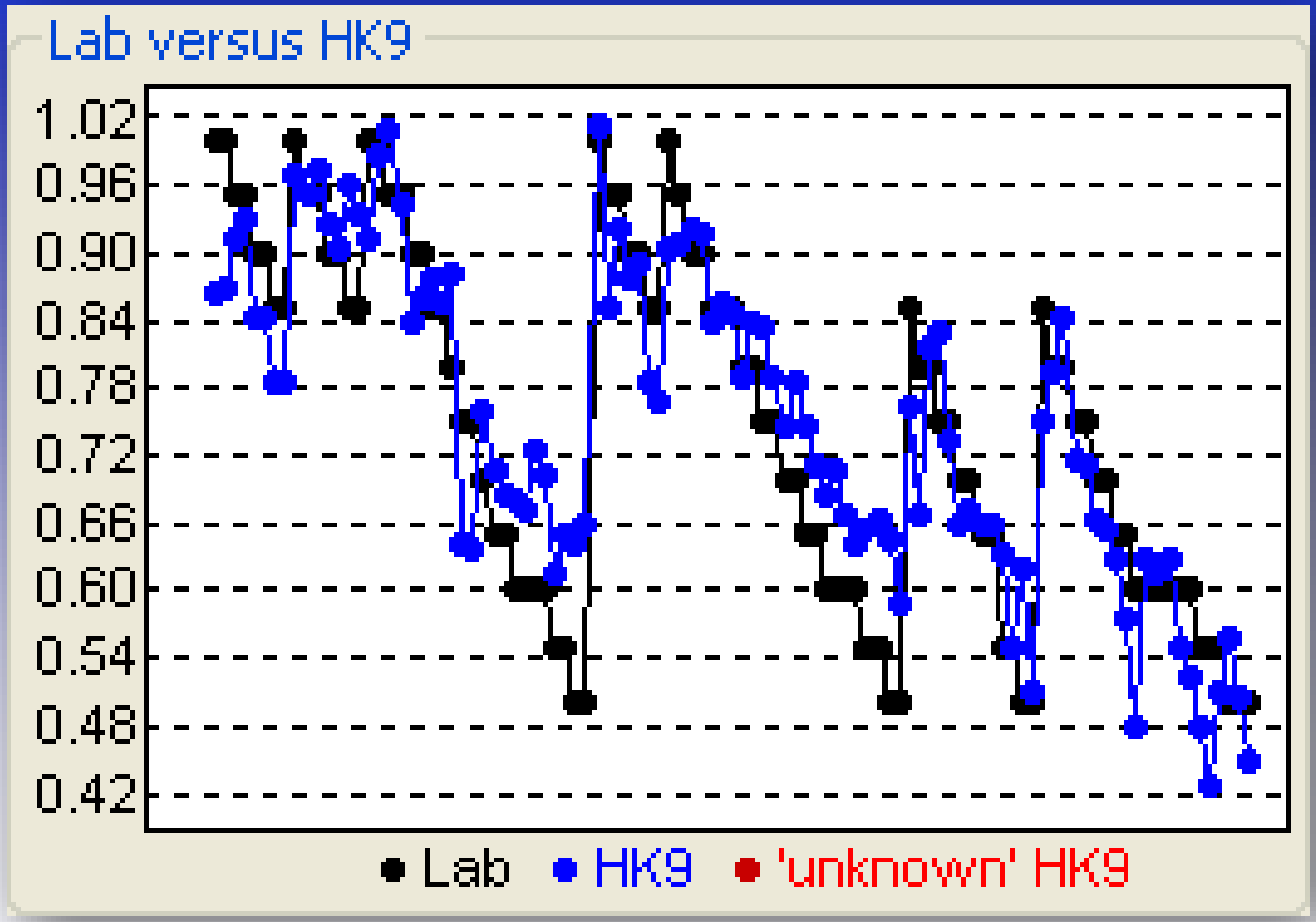
HK9 Isopropanol2 Measurement

2 PIN-antennas tunable in distance, 4cm to 8cm

Bucket with water diluted with Isopropanol2, 100% to 50%

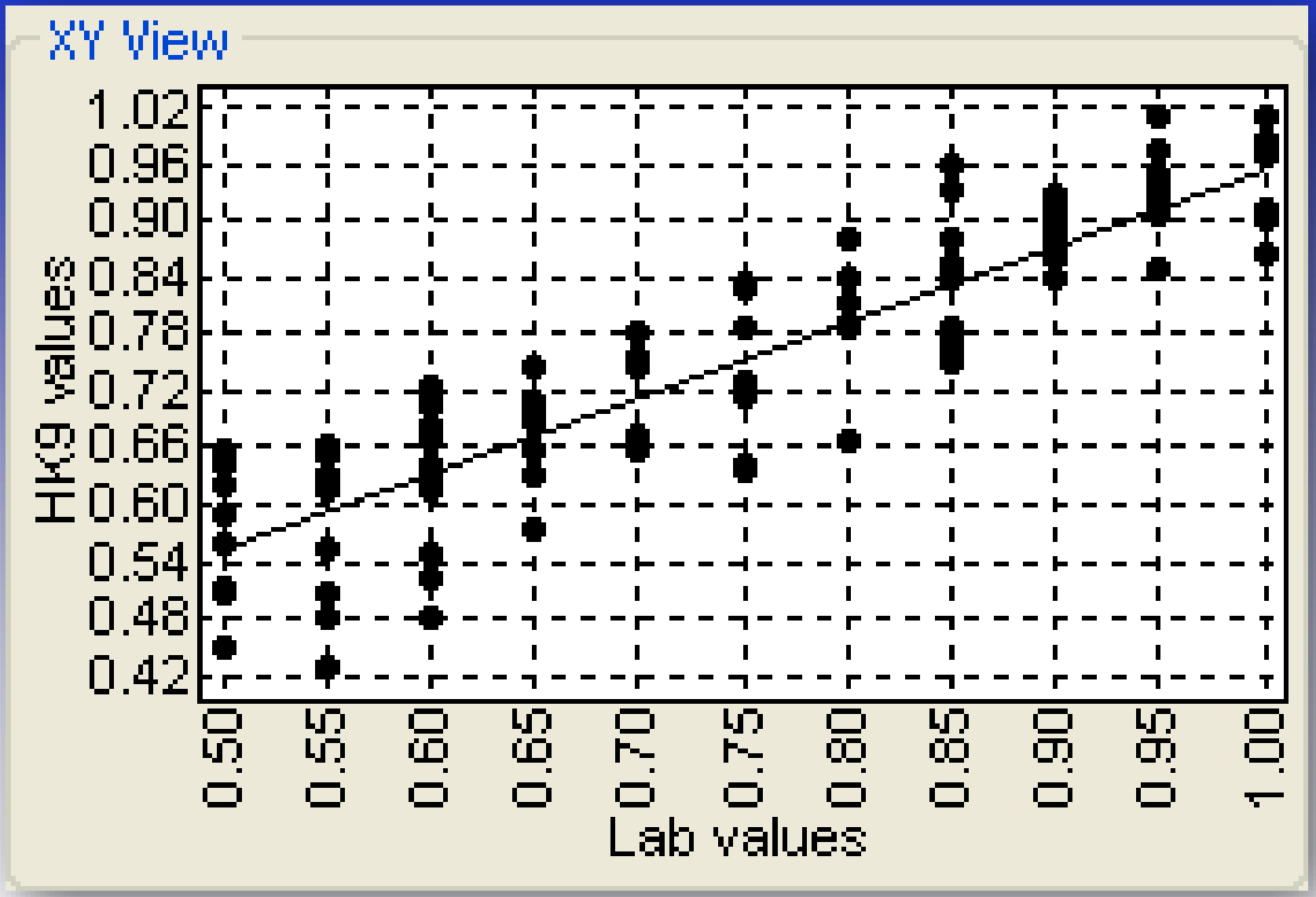
Changing the distance of the antennas corresponds to density variation



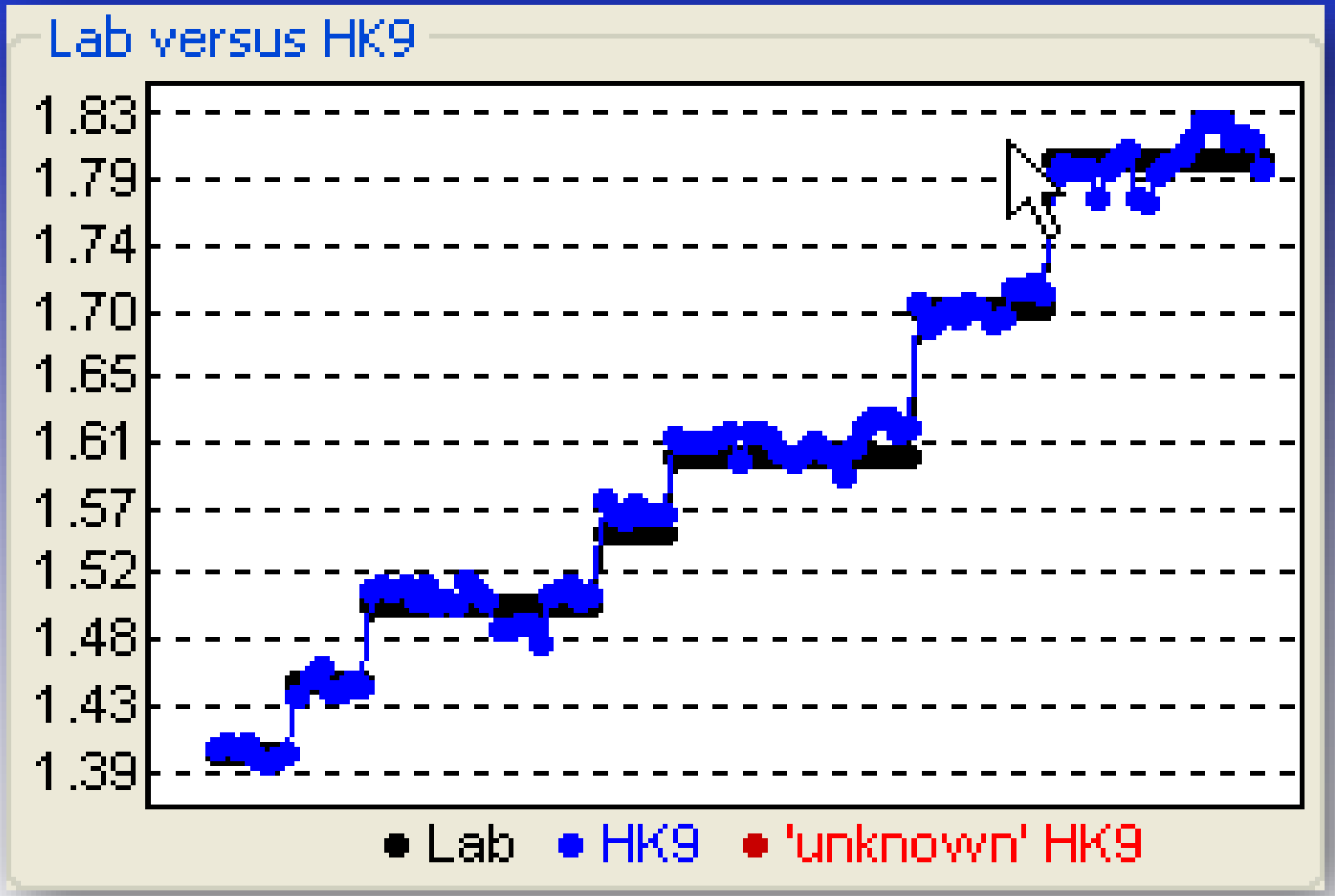


Isopropanol2

dT/Lambda Correlation=80% STDeviation=7%

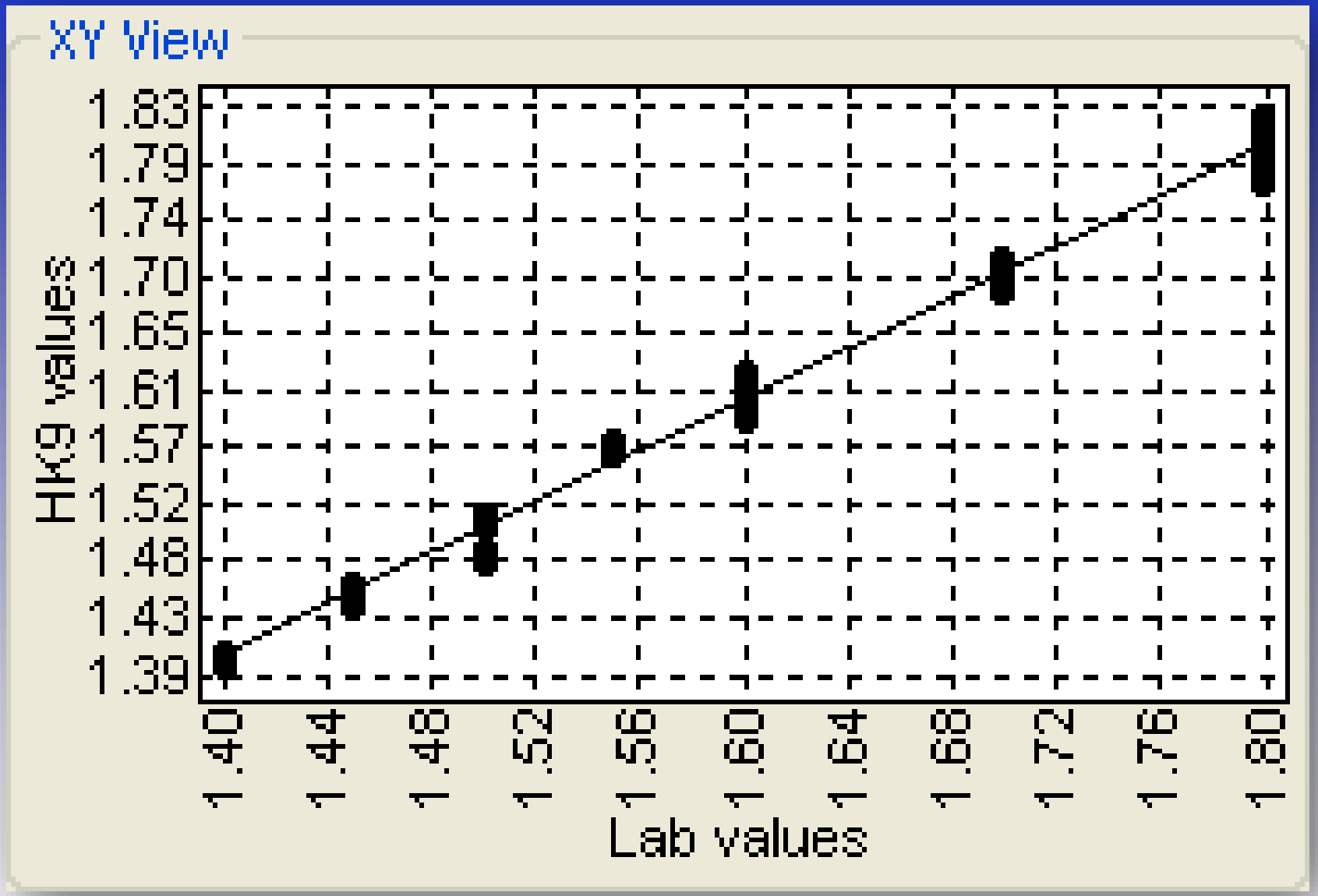


Isopropanol2 density variation 100%



Isopropanol2

T Correlation=99,1% STDeviation=0,012=0,48mm

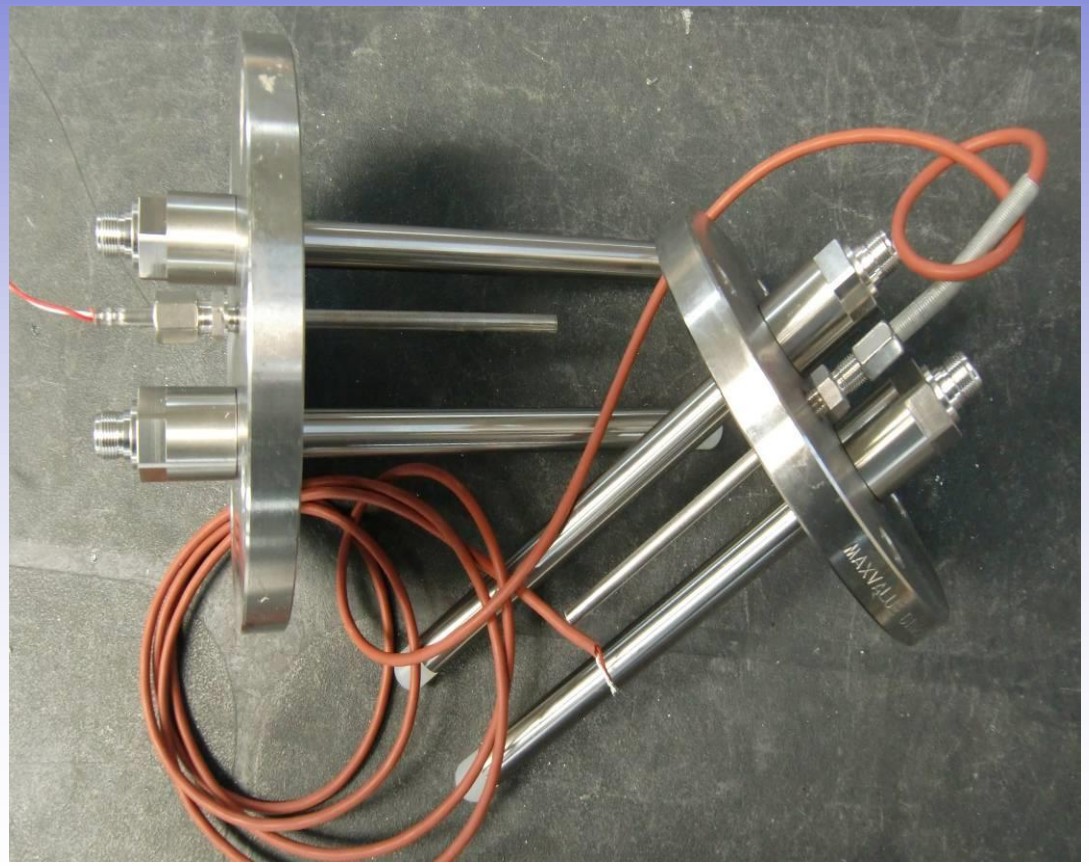


Isopropanol2 moisture variation 50%

HK9 Sugar Measurement

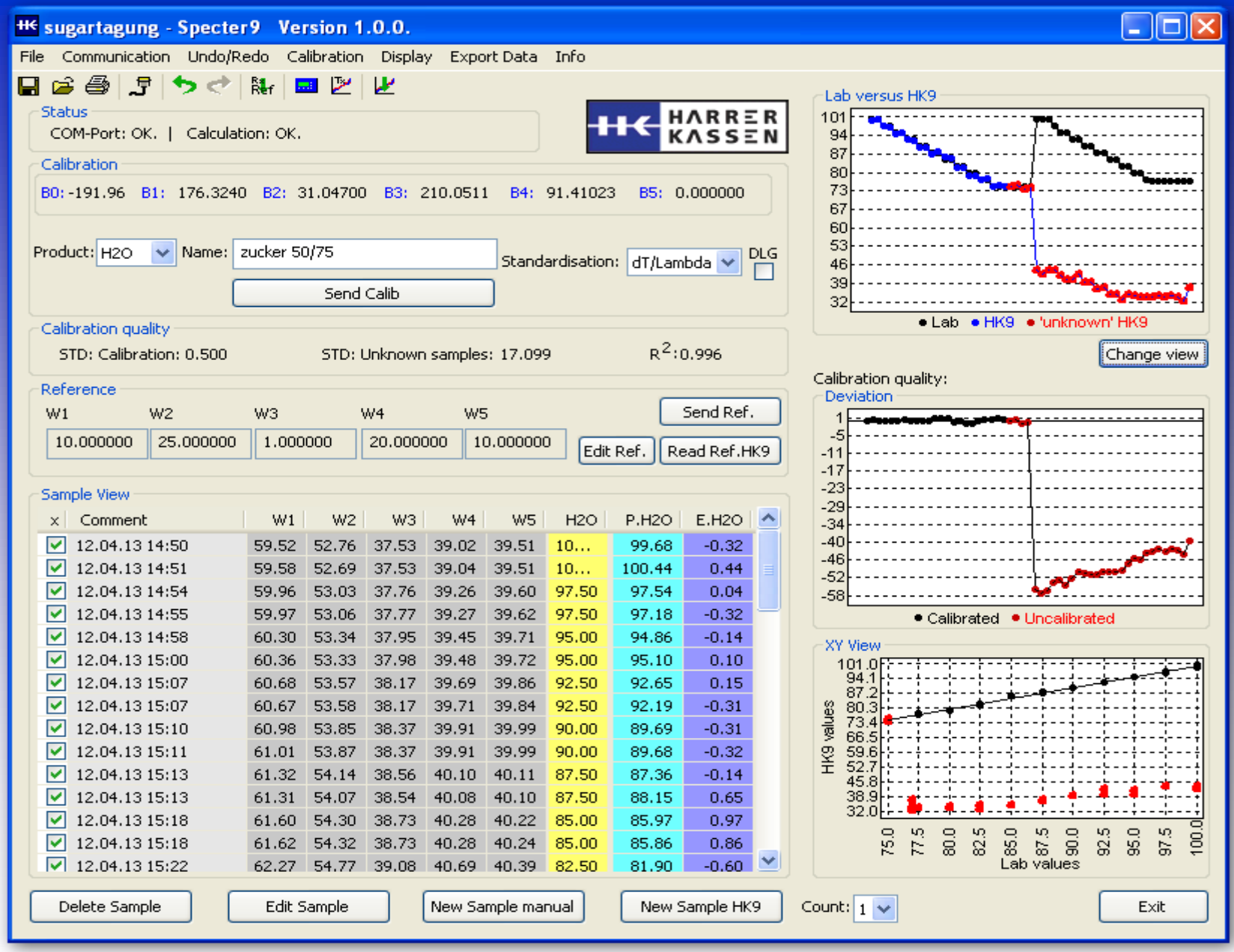
Sugar in a basket measured with two different sensors, spacing of the antennas 50mm and 75mm (picture)

Density independent standardisation provides calibration

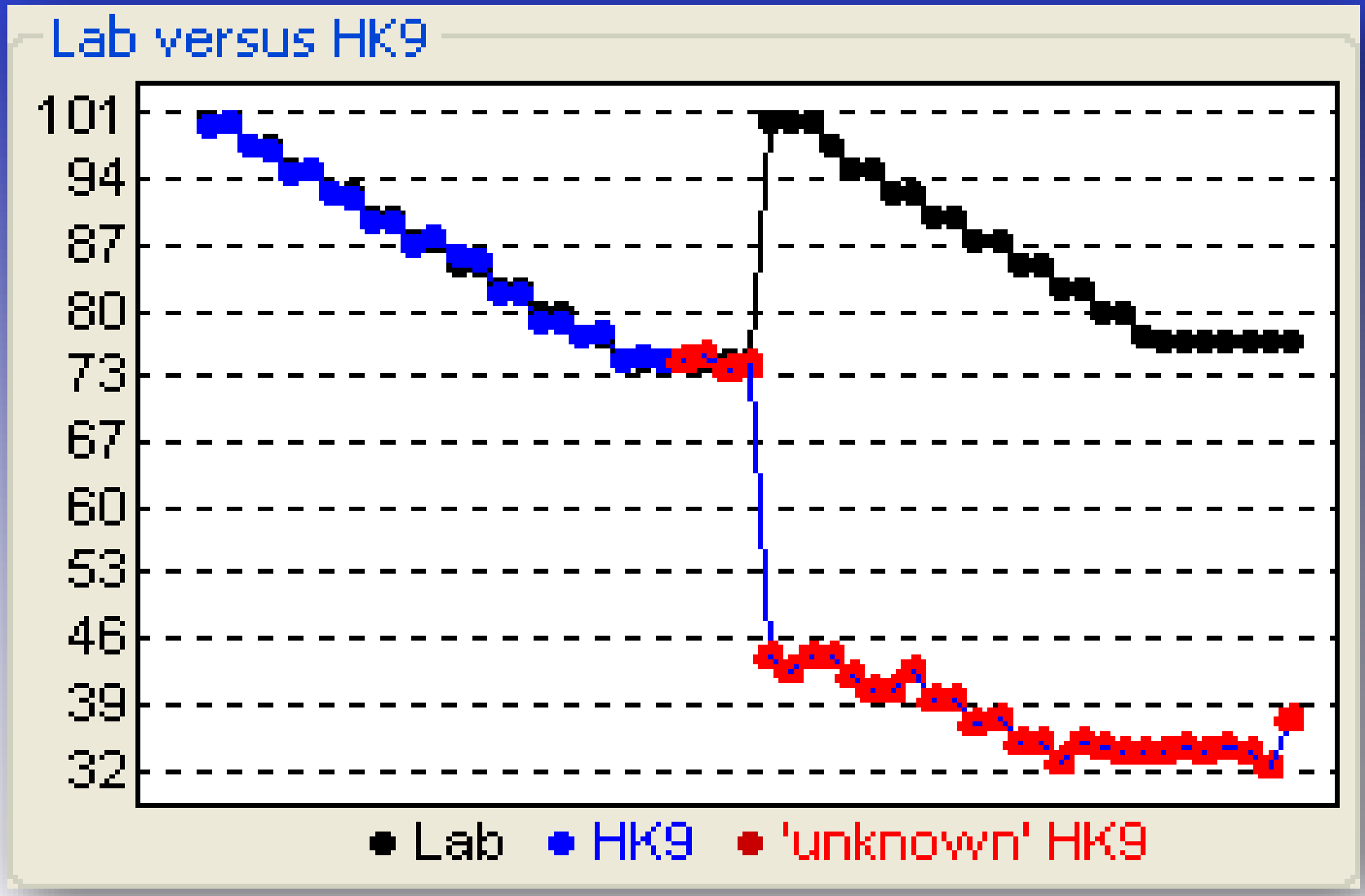


that fits for both sensors.

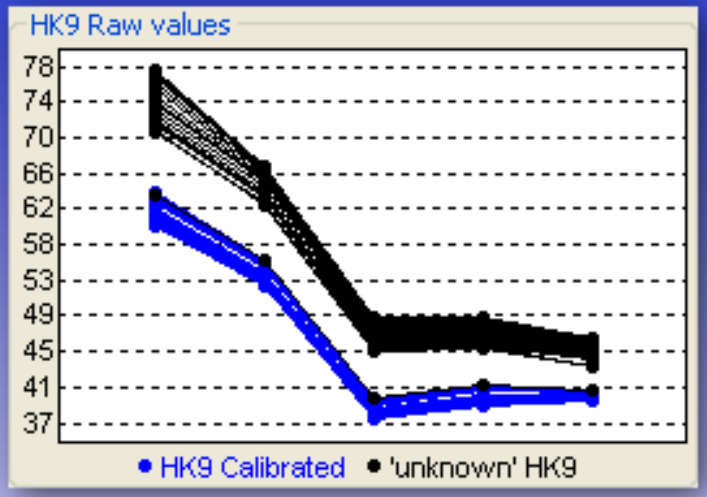
1. Calibration 50mm spacing
2. Calibration all values 50mm and 75mm spacing
3. Calibration extreme values high/low

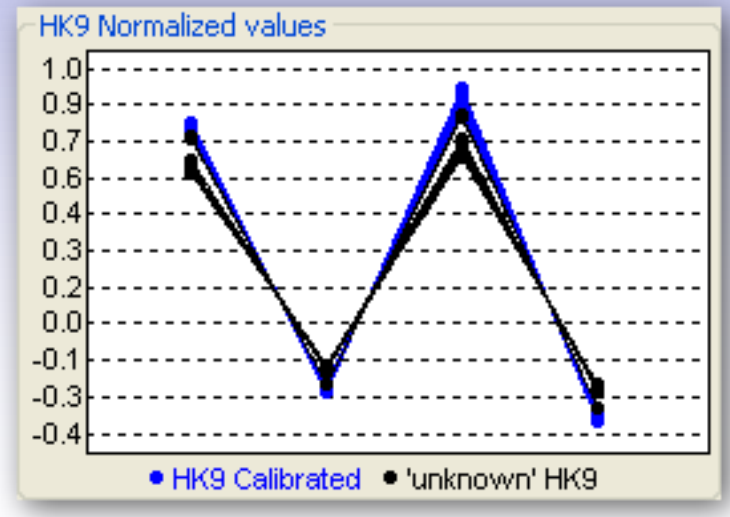


Calibration for 50mm sensor; 0 to 27 Bx



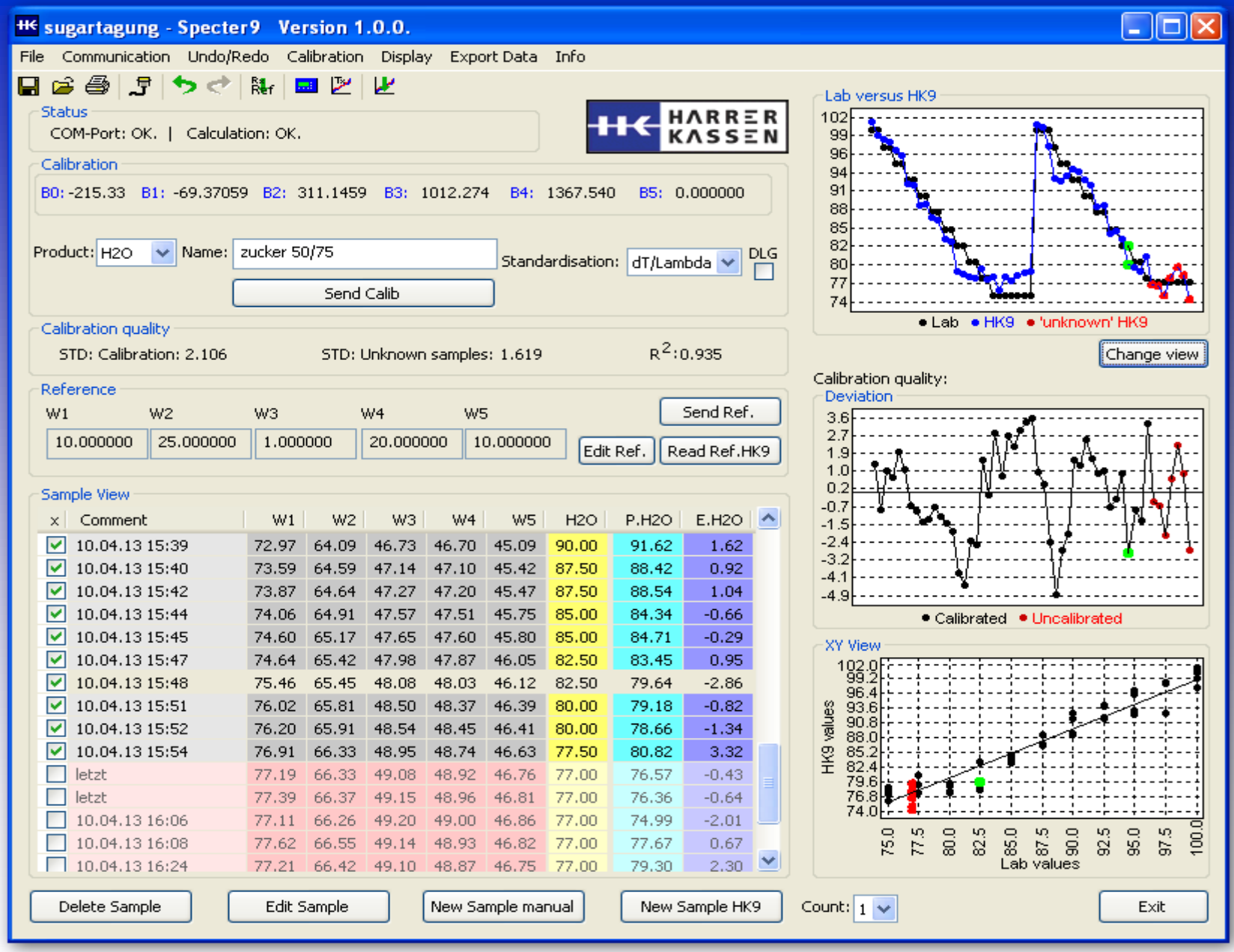
Calibration for 50mm sensor



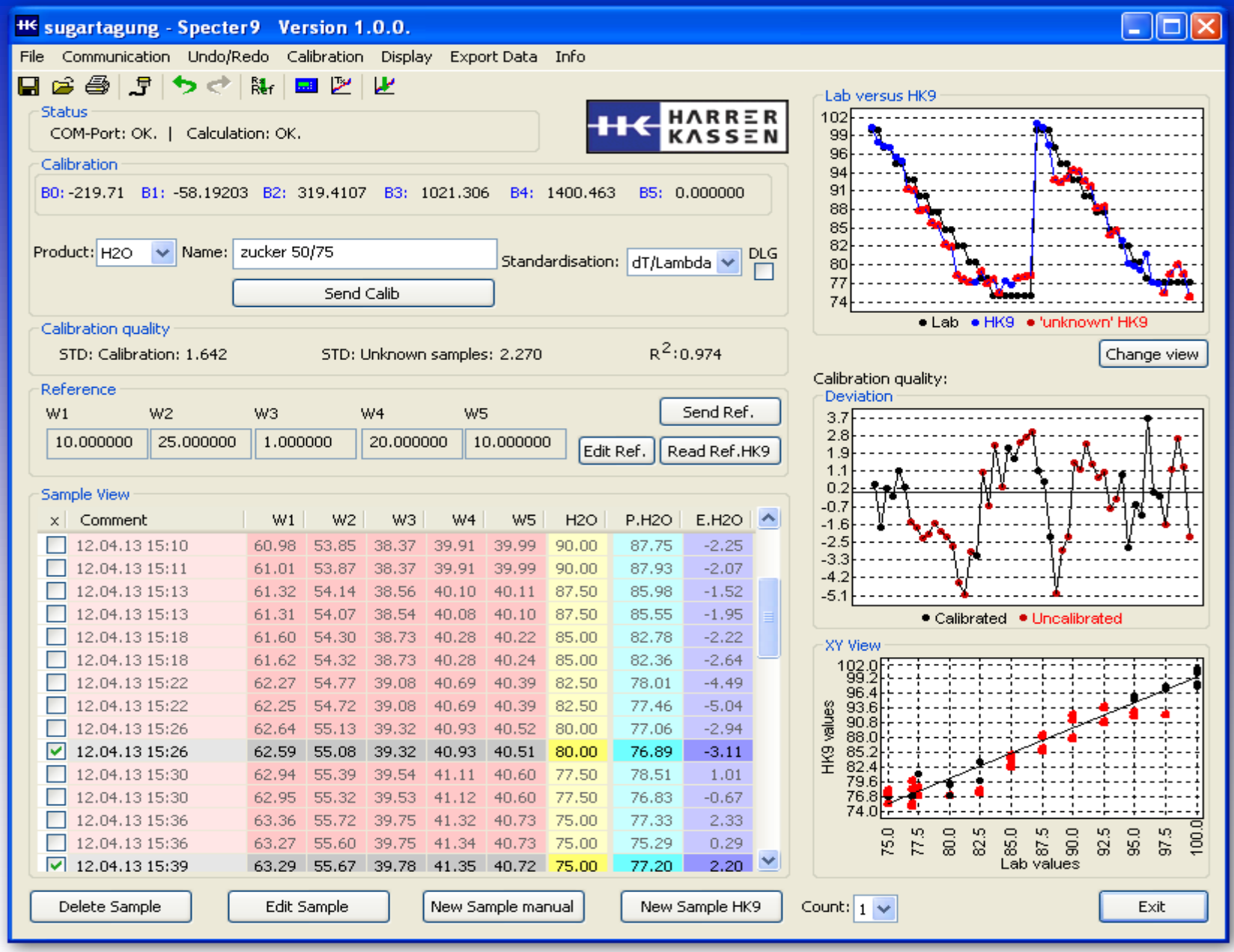


Two groups are visible representing different sensor spacings.

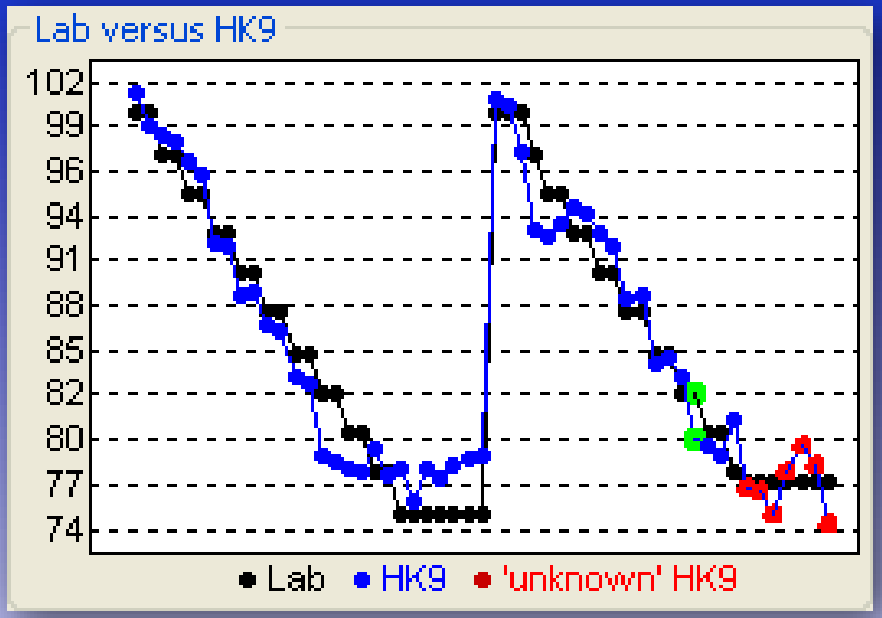
The normalized values show two groups, too. The amplitude of the two groups changes from + to –. As the graps cross each other it is possible to combine them into one calibration.

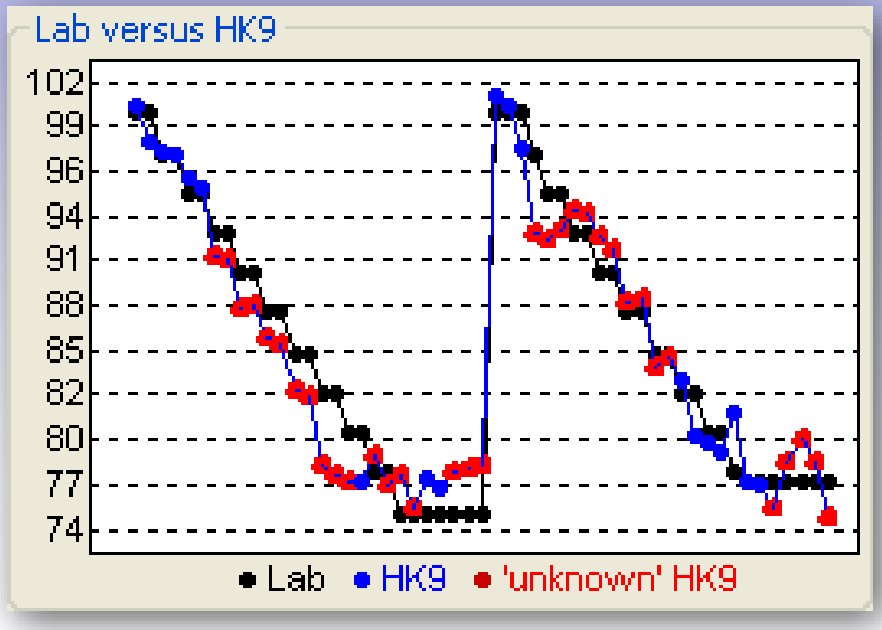


Calibration 50mm and 75mm; all samples



Calibration 50mm and 75mm; extreme values





Calibration 50mm and 75mm

- all values

- extreme values

Remark: The multilinear regression does not predict values that are outside the range used for calibration!

HK9 measurement on sand

HK9 Sand

HK9 measurement on sand

Two Vivaldi antennas, distance 50cm

Plastic pan 56 * 36 *14 cm around 14 l

H_2O range 0 to 9%

Density; the weight of the plastic pan filled up with the sand was taken as density value. The variation in weight was 28 kg to 37,7 kg sand. Only one sample had 20 kg.

The sand was splitted into three parts, water was added and the moisture analyzed. After that two parts were filled into the pan and measured. The third part was added in three portions to give the density variation.

The layer thickness of the sand changed from 10cm to 14 cm.

sandtagungdensity - Specter9 Version 1.0.0.

File Communication Undo/Redo Calibration Display Export Data Info

Status

COM-Port: OK. | Calculation: OK.

HARRER KASSEN

Calibration

B0: 5.15 B1: 5.104699 B2: -1.649854 B3: 13.98629 B4: 18.01647 B5: 0.000000

Product: H2O Name: sand vivaldi Standardisation: dT/Lambda DLG

Send Calib

Calibration quality

STD: Calibration: 0.614 STD: Unknown samples: -NA- R^2:0.936

Reference

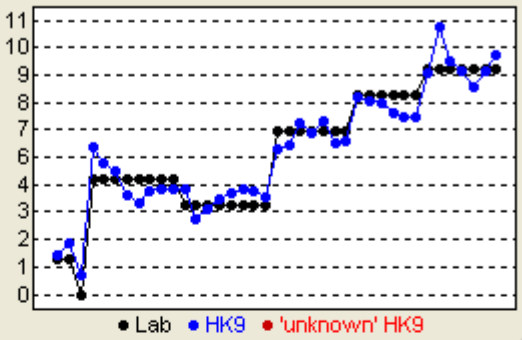
W1	W2	W3	W4	W5
40.000000	10.000000	10.000000	10.000000	10.000000

Send Ref. Edit Ref. Read Ref. HK9

Sample View

x	Comment	W1	W2	W3	W4	W5	H2O	P.H2O	E.H2O
☐	18.04.13 15:58	44.98	42.06	31.52	30.29	30.16		0.99	
☐	18.04.13 15:59	45.55	41.55	30.75	31.69	30.77		0.28	
☐	18.04.13 16:05	45.25	40.69	29.88	32.53	30.84		-0.16	
☐	18.04.13 16:08	45.21	40.60	30.24	31.94	30.09		0.65	
☑	18.04.13 16:12	45.37	40.65	30.96	31.31	29.59	1.38	1.53	0.15
☑	18.04.13 16:17	45.78	41.34	30.73	30.26	28.59	1.38	2.09	0.71
☑	19.04.13 08:43	44.83	41.92	31.21	30.14	30.11	0.00	0.75	0.75
☑	19.04.13 08:57	52.09	46.20	34.40	32.22	28.55	4.62	5.89	1.27
☑	19.04.13 08:58	52.33	45.05	33.15	32.25	28.47	4.62	5.25	0.63
☑	19.04.13 09:03	50.57	43.48	33.04	30.25	28.16	4.62	4.91	0.29
☑	19.04.13 09:05	50.02	43.04	32.90	31.03	29.05	4.62	3.98	-0.64
☑	19.04.13 09:10	49.95	44.04	32.97	30.71	29.24	4.62	3.65	-0.97
☑	19.04.13 09:12	50.38	44.75	33.76	31.13	29.39	4.62	4.16	-0.46
☑	19.04.13 09:16	49.78	43.21	31.79	29.19	27.62	4.62	4.18	-0.44
☑	19.04.13 09:17	49.66	43.21	31.92	29.37	27.74	4.62	4.18	-0.44

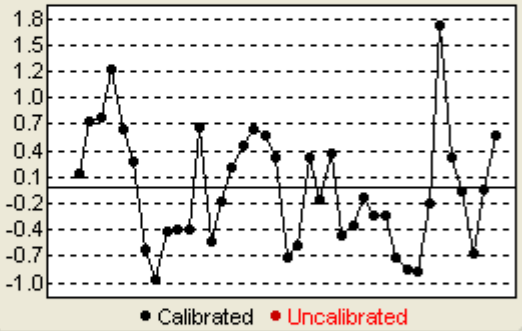
Lab versus HK9



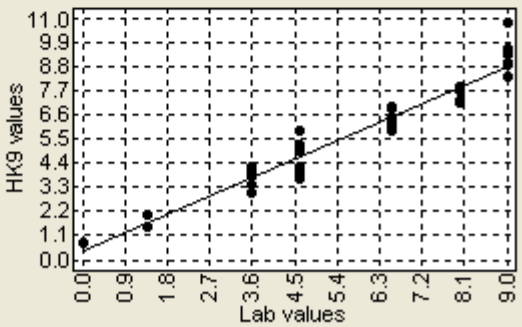
Change view

Calibration quality:

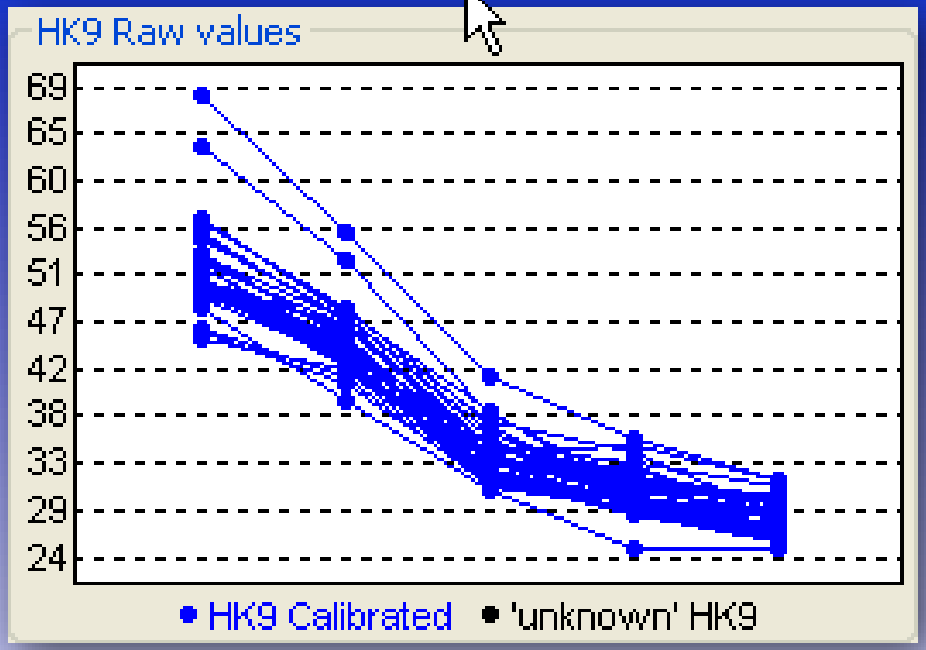
Deviation

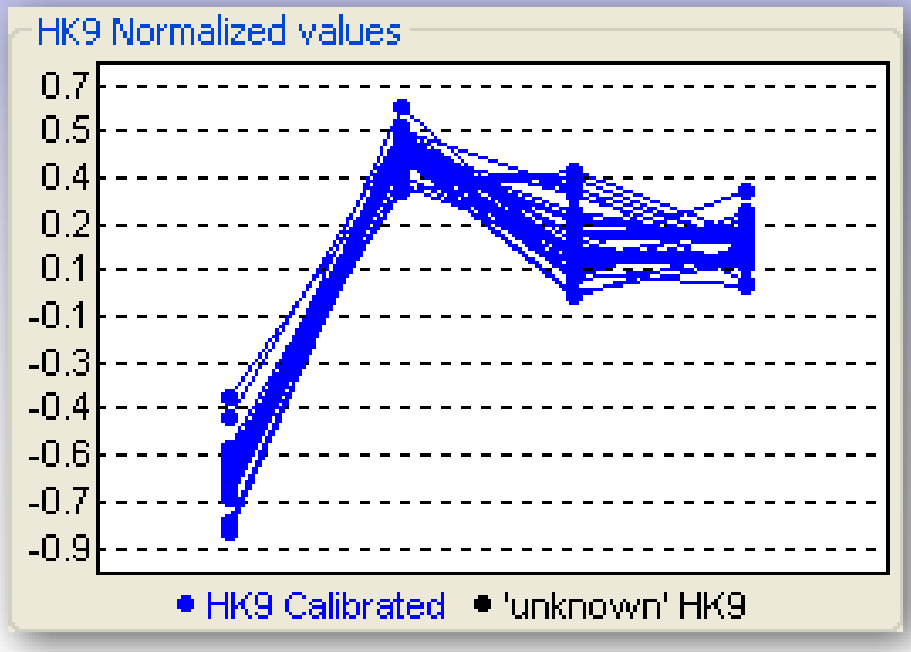


XY View



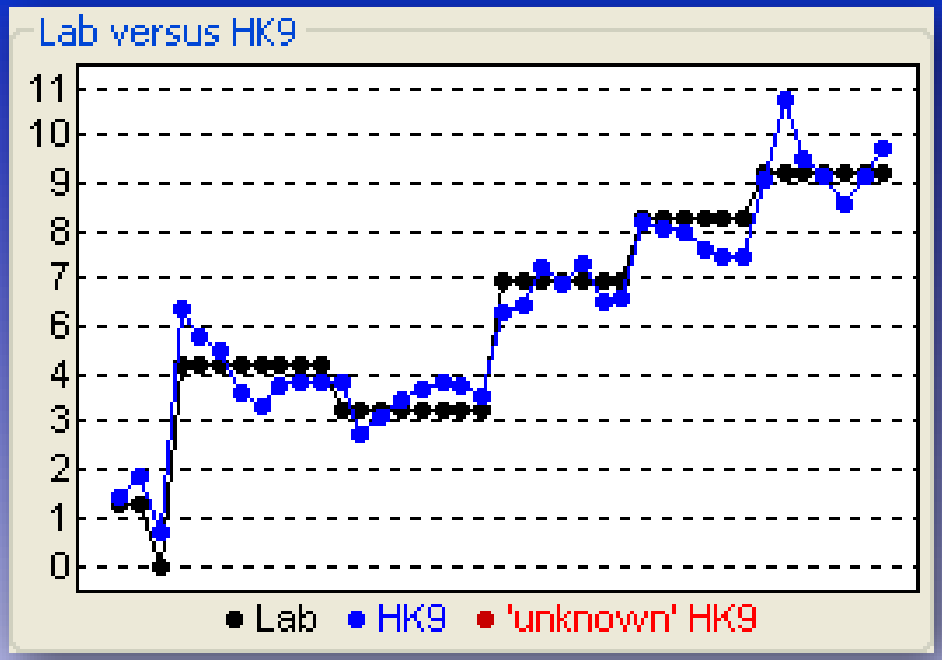
Delete Sample Edit Sample New Sample manual New Sample HK9 Count: 1 Exit





Standardisation: dT/Lambda

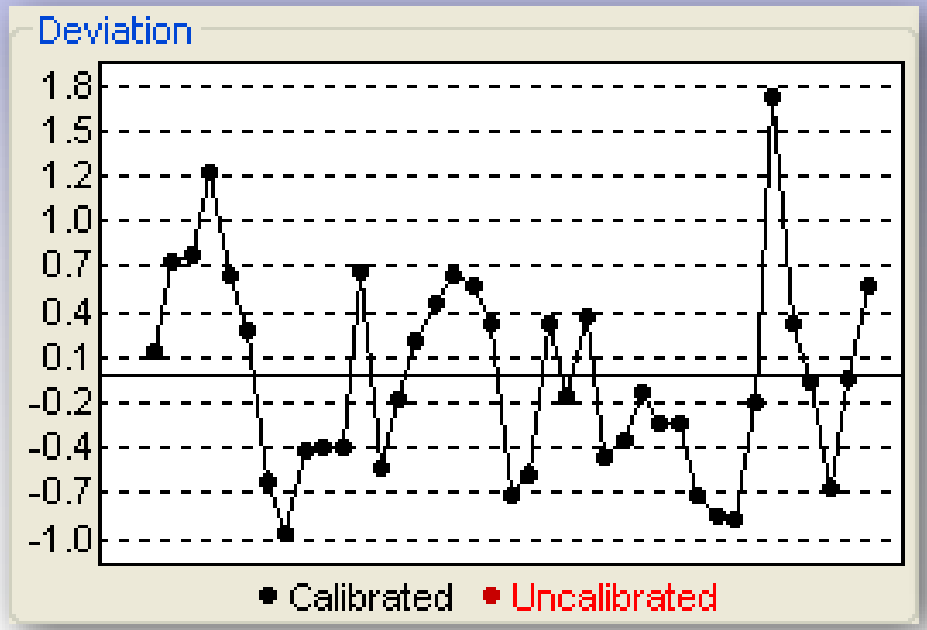
Calibration: H_2O

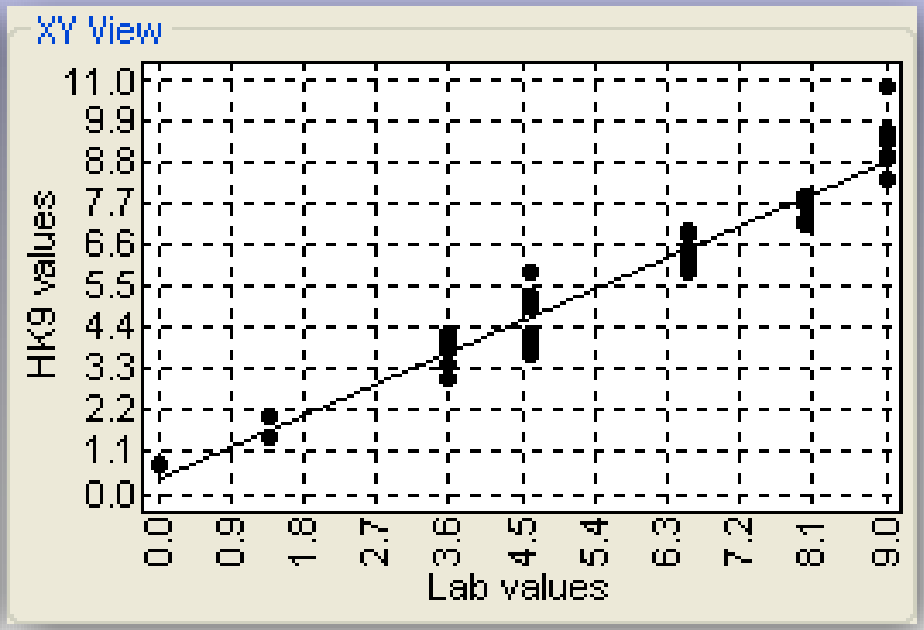


Calibration: H20

Correlation: 93,6%

STDeviation: 0,61%





sandtagungdensity - Specter9 Version 1.0.0.

File Communication Undo/Redo Calibration Display Export Data Info

Status

COM-Port: OK. | Calculation: OK.

HARRER KASSEN

Calibration

B0: 5.00 B1: 0.064408 B2: 0.061495 B3: -0.228291 B4: -0.173749 B5: 0.206677
B6: 0.063844

Product: Rho2 Name: sand vivaldi Standardisation: T DLG

Send Calib

Calibration quality

STD: Calibration: 0.164 STD: Unknown samples: -NA- R^2:0.738

Reference

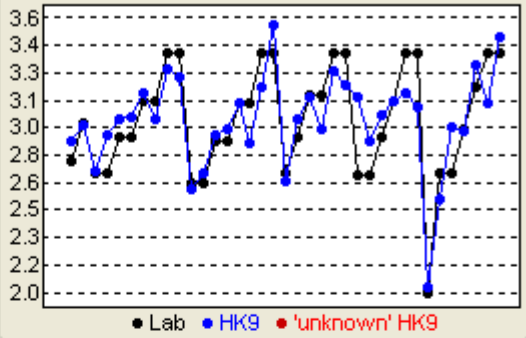
W1	W2	W3	W4	W5
40.000000	10.000000	10.000000	10.000000	10.000000

Send Ref. Edit Ref. Read Ref. HK9

Sample View

x	Comment	W1	W2	W3	W4	W5	Rho	P.H2O	P.Rho	E.Rho
☐	18.04.13 ...	44.98	42.06	31.52	30.29	30.16		0.99	3.08	
☐	18.04.13 ...	45.55	41.55	30.75	31.69	30.77		0.28	3.10	
☐	18.04.13 ...	45.25	40.69	29.88	32.53	30.84		-0.16	3.07	
☐	18.04.13 ...	45.21	40.60	30.24	31.94	30.09		0.65	2.98	
☑	18.04.13 ...	45.37	40.65	30.96	31.31	29.59	2.77	1.53	2.88	0.11
☑	18.04.13 ...	45.78	41.34	30.73	30.26	28.59	2.99	2.09	2.98	-0.01
☐	19.04.13 ...	44.83	41.92	31.21	30.14	30.11		0.75	3.09	
☑	19.04.13 ...	52.09	46.20	34.40	32.22	28.55	2.69	5.89	2.70	0.01
☑	19.04.13 ...	52.33	45.05	33.15	32.25	28.47	2.70	5.25	2.91	0.21
☑	19.04.13 ...	50.57	43.48	33.04	30.25	28.16	2.90	4.91	3.01	0.11
☑	19.04.13 ...	50.02	43.04	32.90	31.03	29.05	2.90	3.98	3.03	0.13
☑	19.04.13 ...	49.95	44.04	32.97	30.71	29.24	3.11	3.65	3.16	0.05
☑	19.04.13 ...	50.38	44.75	33.76	31.13	29.39	3.11	4.16	3.01	-0.10
☑	19.04.13 ...	49.78	43.21	31.79	29.19	27.62	3.40	4.18	3.30	-0.10
☑	19.04.13 ...	49.66	43.21	31.92	29.37	27.74	3.40	4.18	3.26	-0.14

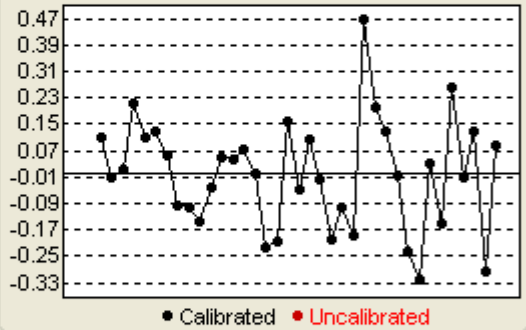
Lab versus HK9



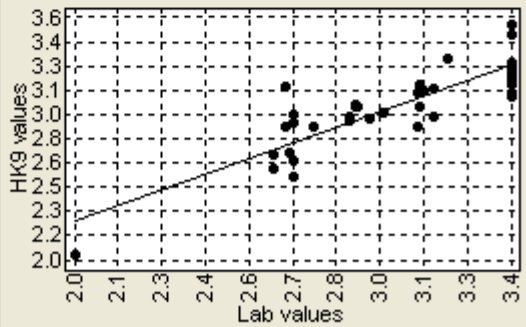
Change view

Calibration quality:

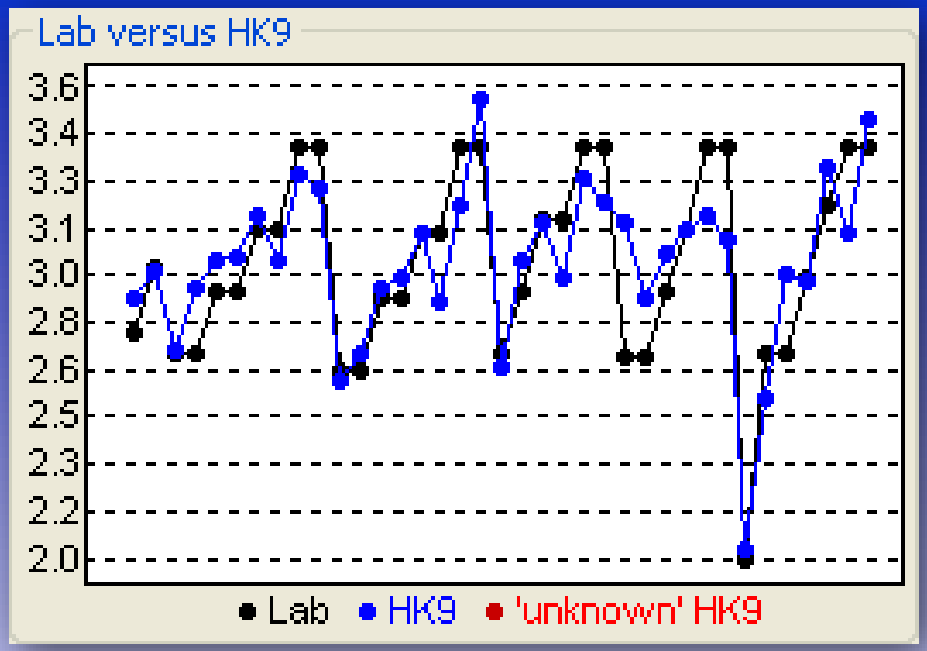
Deviation



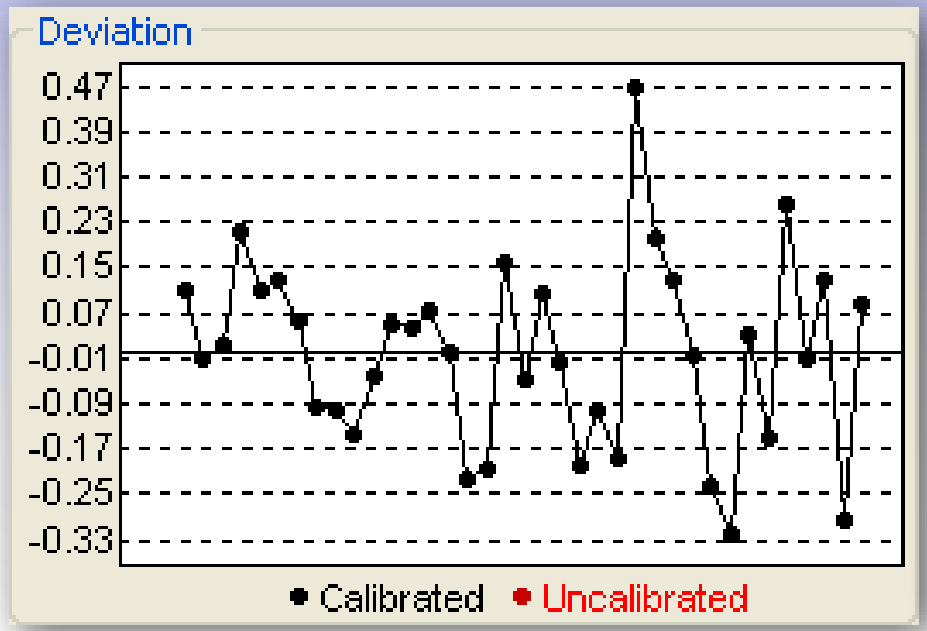
XY View

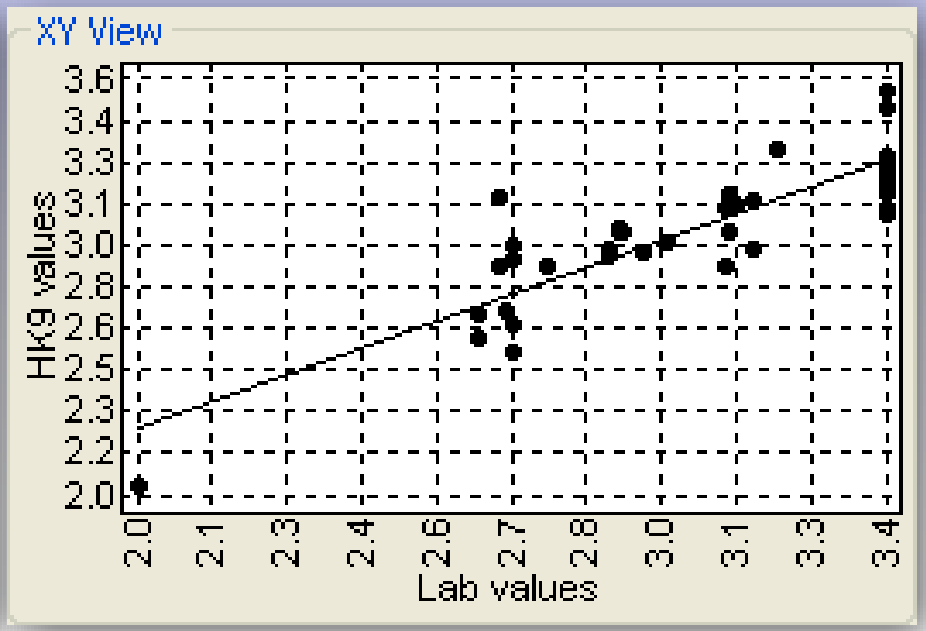


Delete Sample Edit Sample New Sample manual New Sample HK9 Count: 1 Exit



Standardisation: T
Calibration: Rho2
Correlation: 73,8%
STDeviation: 0,16 kg





HK9 measurement on sand

Moisture measurements on sand with variation in density and layer thickness are possible.

The amount of sand between the antennas should be at least 15cm to achieve good resulution and accuracy.

It is possible to measure the amount of material positioned between the antennas. This relates to density and load.

HK9 measurements on tobacco

HK9 tobacco

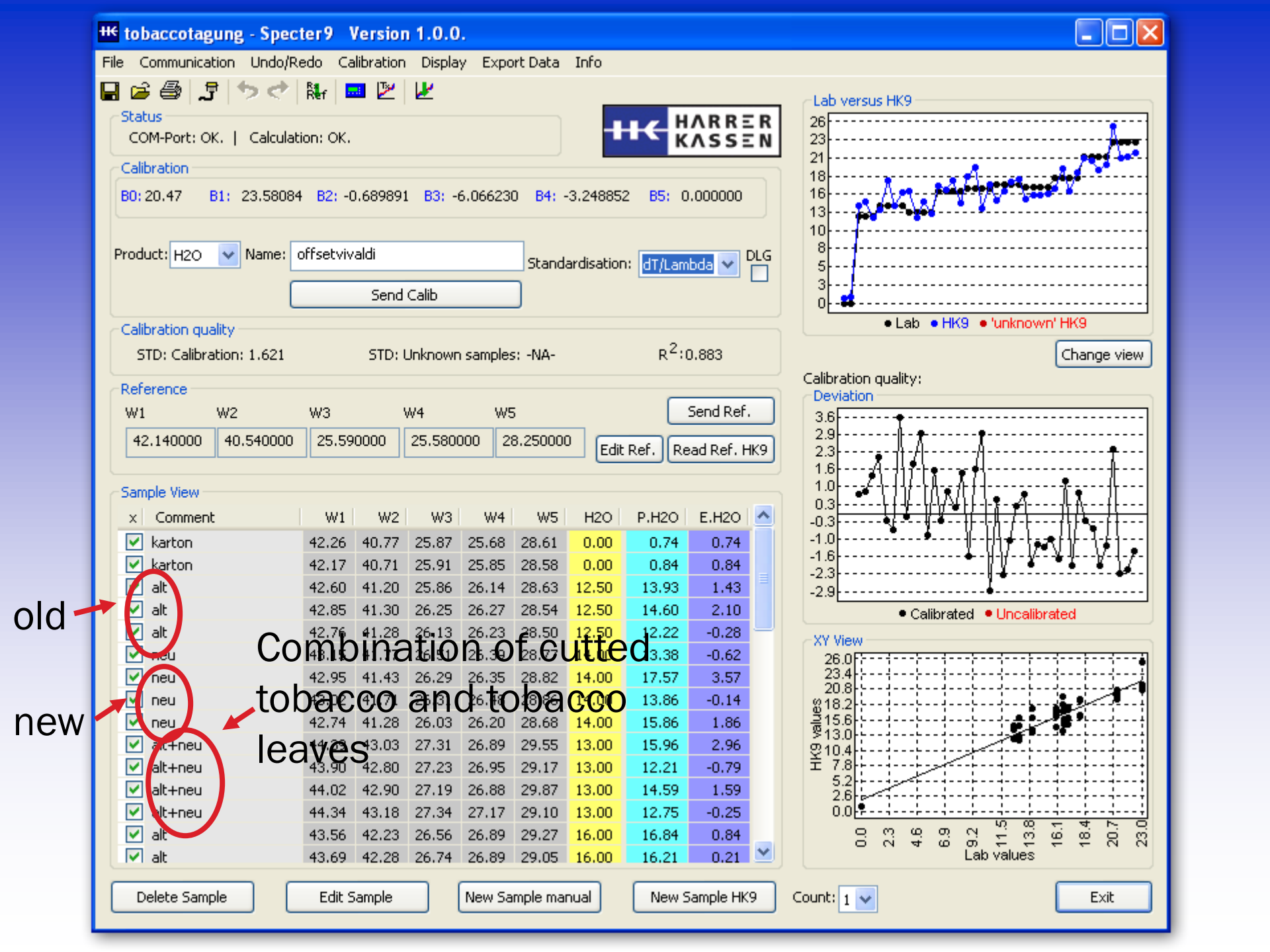
HK9 measurements on tobacco

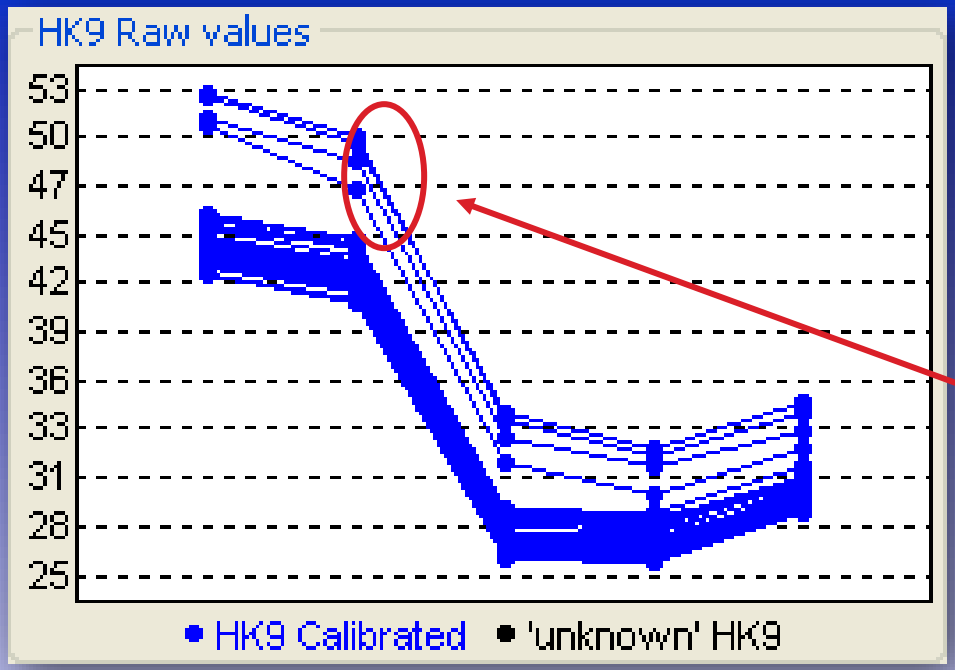
- Two Vivaldi antennas, distance 50cm
- Cardboard box: size 40 * 60 * 30 cm around 72 l (1000g)
- H20 range 10 to 25%
- Two types of tobacco: tobacco leaves and cutted brown tobacco
- Cutted tobacco: weight 2700g; moisture 10%
- Tobacco leaves: weight 2500g; moisture 16,5%
- Density lab value is weight of tobacco with cardboard box

In order to generate different moisture and density values, the tobacco leaves were put into plastic bags that were added to the cutted tobacco. (side by side or laying upon each other)
Time for absorbing water: at least 2 hours

cutted tobacco (old)

tobacco leaves (new)


tobaccotagung - Specter9 Version 1.0.0.
File Communication Undo/Redo Calibration Display Export Data Info
Status
COM-Port: OK. | Calculation: OK.
HARRER KASSEN
Calibration
B0: 20.47 B1: 23.58084 B2: -0.689891 B3: -6.066230 B4: -3.248852 B5: 0.000000
Product: H2O Name: offsetvivaldi Standardisation: dT/Lambda DLG
Send Calib
Calibration quality
STD: Calibration: 1.621 STD: Unknown samples: -NA- R2:0.883
Reference
W1 W2 W3 W4 W5
42.140000 40.540000 25.590000 25.580000 28.250000
Send Ref. Edit Ref. Read Ref. HK9
Sample View
x Comment W1 W2 W3 W4 W5 H2O P.H2O E.H2O
karton 42.26 40.77 25.87 25.68 28.61 0.00 0.74 0.74
karton 42.17 40.71 25.91 25.85 28.58 0.00 0.84 0.84
alt 42.60 41.20 25.86 26.14 28.63 12.50 13.93 1.43
alt 42.85 41.30 26.25 26.27 28.54 12.50 14.60 2.10
alt 42.76 41.28 26.13 26.23 28.50 12.50 12.22 -0.28
neu 42.95 41.43 26.29 26.35 28.82 14.00 17.57 3.57
neu 42.74 41.28 26.03 26.20 28.68 14.00 15.86 1.86
alt+neu 43.90 42.80 27.23 26.95 29.17 13.00 12.21 -0.79
alt+neu 44.02 42.90 27.19 26.88 29.87 13.00 14.59 1.59
alt+neu 44.34 43.18 27.34 27.17 29.10 13.00 12.75 -0.25
alt 43.56 42.23 26.56 26.89 29.27 16.00 16.84 0.84
alt 43.69 42.28 26.74 26.89 29.05 16.00 16.21 0.21
Delete Sample Edit Sample New Sample manual New Sample HK9 Count: 1 Exit
Lab versus HK9
Lab HK9 'unknown' HK9
Change view
Calibration quality:
Deviation
Calibrated Uncalibrated
XY View
HK9 values
Lab values
old
new
Combination of cutted tobacco and tobacco leaves

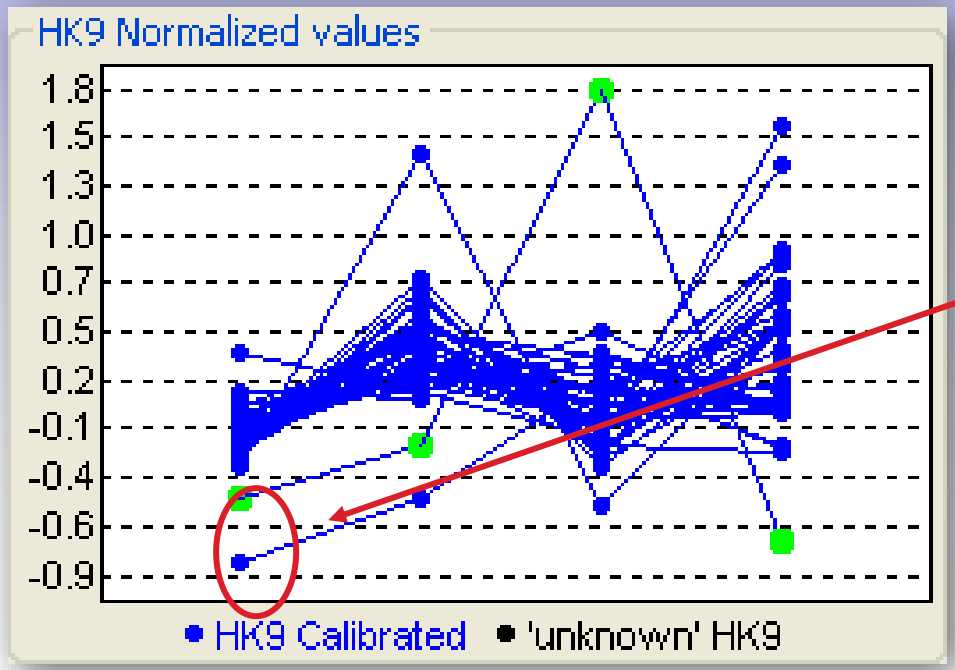


Standardisation: dT/Lambda

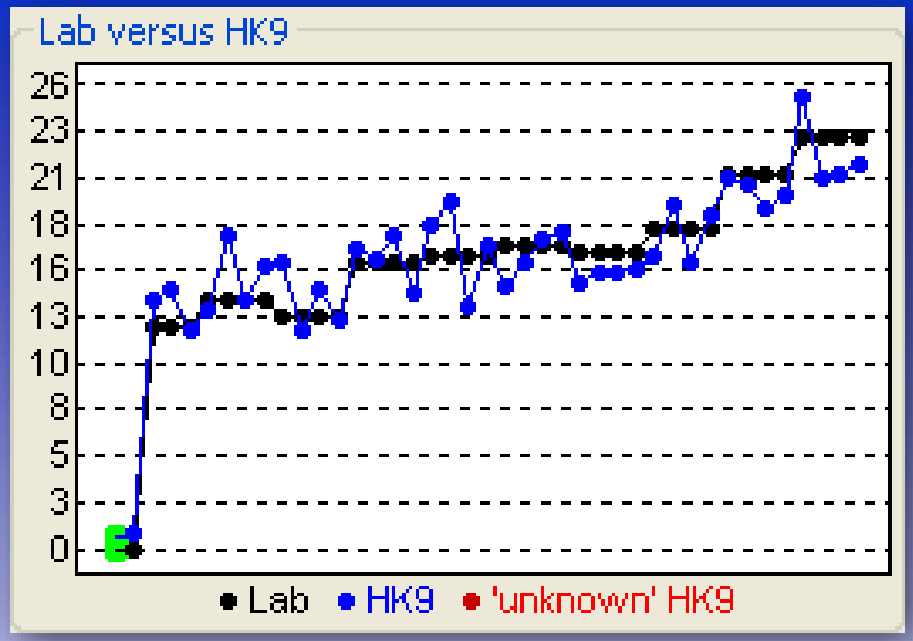
Calibration: H2O

23% H2O; old+new;

high density



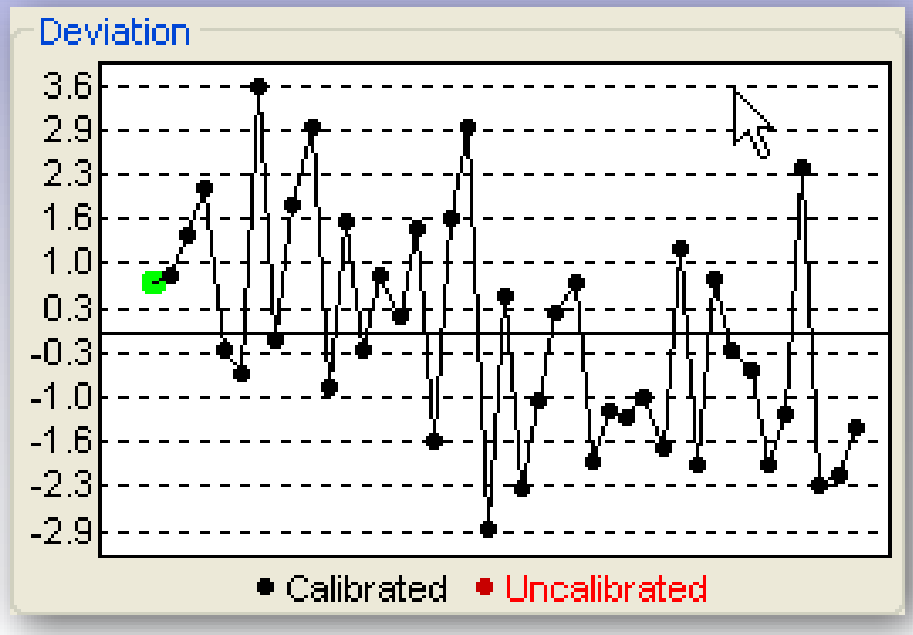
Cardboard box

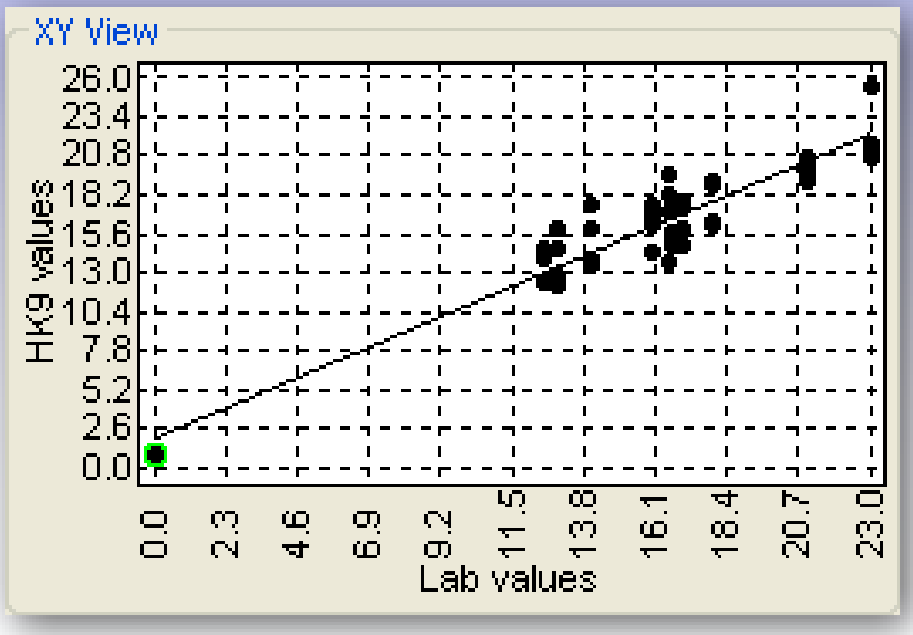


Calibration: H_2O

Correlation: 88,3%

STDeviation: 1,6%





tobaccotagung - Specter9 Version 1.0.0.

File Communication Undo/Redo Calibration Display Export Data Info

Status

COM-Port: OK. | Calculation: OK.

HARRER KASSEN

Calibration

B0: 0.13 B1: -0.204423 B2: 0.323003 B3: 0.319120 B4: -0.420258 B5: -0.096581
B6: 0.018132

Product: Rho2 Name: offsetvivaldi Standardisation: T DLG

Send Calib

Calibration quality

STD: Calibration: 0.059 STD: Unknown samples: -NA- R^2:0.866

Reference

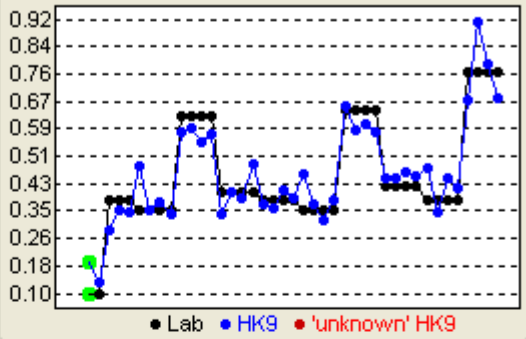
W1	W2	W3	W4	W5
42.140000	40.540000	25.590000	25.580000	28.250000

Send Ref. Edit Ref. Read Ref. HK9

Sample View

x	Comment	W1	W2	W3	W4	W5	Rho	P.H2O	P.Rho	E.Rho
☑	karton	42.26	40.77	25.87	25.68	28.61	0.10	0.74	0.19	0.09
☑	karton	42.17	40.71	25.91	25.85	28.58	0.10	0.84	0.14	0.04
☑	alt	42.60	41.20	25.86	26.14	28.63	0.38	13.93	0.29	-0.09
☑	alt	42.85	41.30	26.25	26.27	28.54	0.38	14.60	0.35	-0.03
☑	alt	42.76	41.28	26.13	26.23	28.50	0.38	12.22	0.34	-0.04
☑	neu	43.15	41.77	26.51	26.39	28.77	0.35	13.38	0.48	0.13
☑	neu	42.95	41.43	26.29	26.35	28.82	0.35	17.57	0.35	0.00
☑	neu	43.02	41.71	26.31	26.48	28.86	0.35	13.86	0.37	0.02
☑	neu	42.74	41.28	26.03	26.20	28.68	0.35	15.86	0.34	-0.01
☑	alt+neu	44.39	43.03	27.31	26.89	29.55	0.63	15.96	0.58	-0.05
☑	alt+neu	43.90	42.80	27.23	26.95	29.17	0.63	12.21	0.59	-0.04
☑	alt+neu	44.02	42.90	27.19	26.88	29.87	0.63	14.59	0.55	-0.08
☑	alt+neu	44.34	43.18	27.34	27.17	29.10	0.63	12.75	0.58	-0.05
☑	alt	43.56	42.23	26.56	26.89	29.27	0.40	16.84	0.34	-0.06
☑	alt	43.69	42.28	26.74	26.89	29.05	0.40	16.21	0.40	0.00

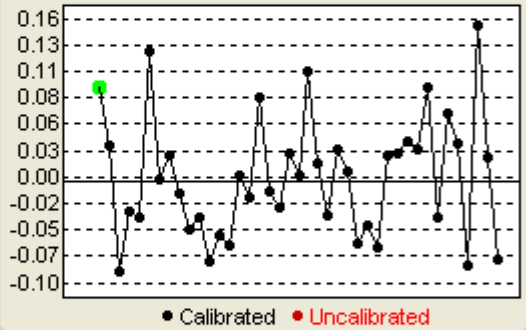
Lab versus HK9



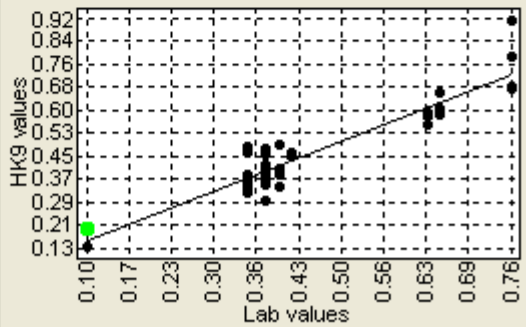
Change view

Calibration quality:

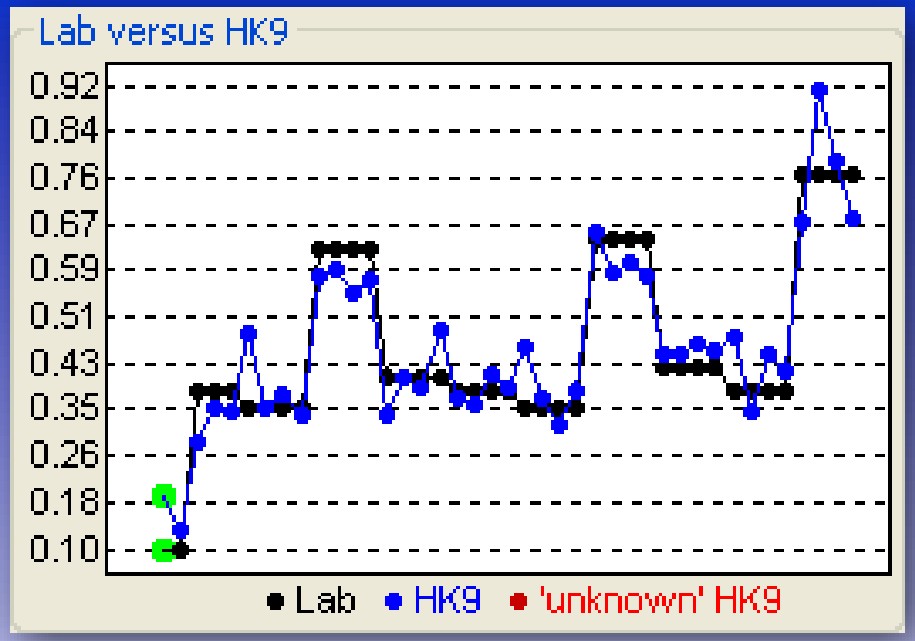
Deviation



XY View



Delete Sample Edit Sample New Sample manual New Sample HK9 Count: 1 Exit

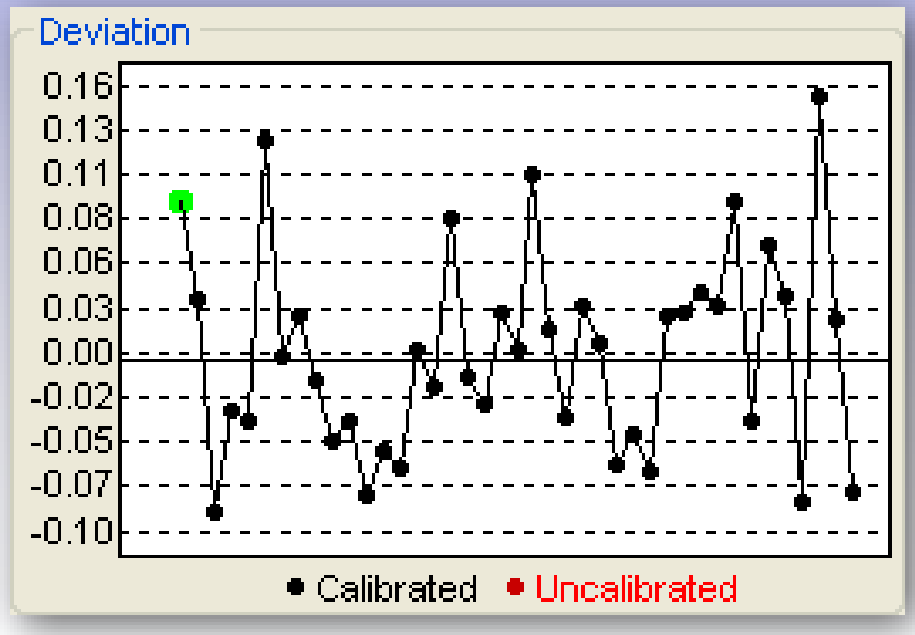


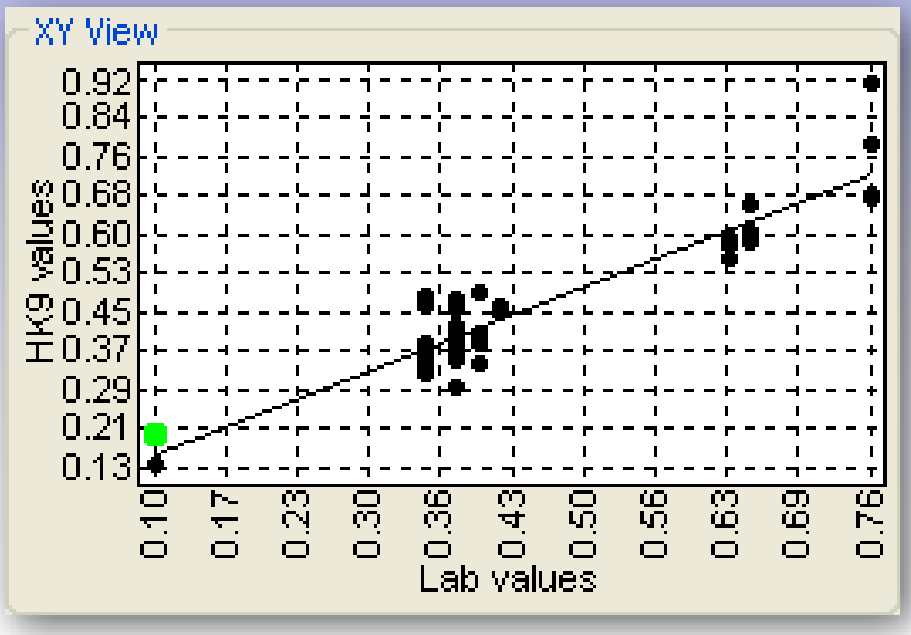
Calibration: Rho2

Standardisation: T

Correlation: 86,6%

STDeviation: 0,059 = 590g





HK9 measurements on tobacco

Measurement of H_2O and density is possible.

5 kg tobacco is too little amount to get better results in moisture and density.

The amount of water between the antennas correlates to a layer thickness of less than 5mm.

Sample taking and manufacturing is difficult. Moisture variations inside the product of more than 2% had been observed.

Positioning the cardboard box between the antennas sometimes gives stupid measuring results, especially when the wall of the box can affect the measurement.

Task list

Field test on tobacco bales in Greece. Bale size should be at least 40 to 50 kg.

Questions: How does the instrument work, when the bale moves?

Which is the most usefull standardisation?

Positioning of the antennas?

Test with waveguides to find out the temperature dependence of the measurement.

Question: Is it necessary and possible to compensate the product temperature?

Test on other products, for instance sand on convayor belt.

Thank you

for your attention!

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