Ultrasonic Contact Impedance (UCI) accuracy, measurement deviation and repeatability explained

Many producers talk about the UCI accuracy and how accurate the probes are, but this creates even greater confusion among the users when it comes to the technique itself.

So why is the probe accuracy an inaccurate statement? The probe accuracy refers to "how accurate the technology and its components" are but does not define what multi-point accuracy the probe can deliver. Even more important is that the UCI method is strongly influenced by other parameters, such as operator's experience or handling. For the UCI method the two other parameters are of much greater significance for the user, when it comes to device performance: **measurement deviation** and **repeatability**.

So how these two parameters are described and what do they really mean?
According to DIN 50159, ASTM A1038, and GB/T34205-2017 the **measurement deviation** is defined as follows:

$$E = \frac{\overline{H} - H}{H} \cdot 100\ \%$$

(E – measurement deviation, $\overline{H}$ – Average value of n measurements, H – reference value i.e. test block)

In other words: it describes how the average value deviates from the reference value.

The repeatability of UCI also denoted as coefficient of variation is defined in **DIN 50159 (also ASTM & GB/T)** and describes the relative difference between the highest and the lowest hardness value with respect to the average:

$$r = \frac{H_{max} - H_{min}}{\overline{H}} \cdot 100\ \%$$

(r-repeatability, H_{min} and H_{max} – the lowest and the highest hardness values respectively, $\overline{H}$- average value)
In other words: it describes how far the measurement values are scattered from each other.

So what are the numbers I should pay attention to?

Let the following Table 1 be a quick guideline.

Scale	Max. measurement deviation (E) in % DIN 50157, ASTM A1038, and GB/T 34205-2017								Repeatability %	
	<250 HV		250 -500 HV		500 – 800 HV		>800 HV		≤ 250 HV	> 250 HV
	DIN & GB/T	*ASTM*	DIN & GB/T	*ASTM*	DIN & GB/T	*ASTM*	DIN & GB/T	*ASTM*	DIN & GB/T	DIN & GB/T
HV 0.1	**5**	*6*	**6**	*7*	**7**	*8*	**8**	*9*	**8**	**6**
HV 0.3	**5**	*6*	**6**	*7*	**7**	*8*	**8**	*9*	**8**	**6**
HV 0.8	**4**	*6*	**4**	*7*	**5**	*8*	**6**	*9*	**8**	**6**
HV 1	**4**	*5*	**4**	*5*	**5**	*7*	**4**	*7*	**8**	**8**
HV 5	**4**	*5*	**4**	*5*	**4**	*7*	**4**	*7*	**5**	**5**
HV 10	**4**	*5*	**4**	*5*	**4**	*7*	**4**	*7*	**5**	**5**

Table 1. The summary of maximum tolerable errors for measurement deviation and repeatability from DIN 50157, ASTM A1038 and GB/T 34205-2017.

Why there are different values for different scales and hardness ranges ?

The UCI method uses a vibrating rod (with Vickers diamond at the tip) to measure the indentation depth. The indenter vibrates with a specific frequency (f_0), which changes upon the indentation (f_i) or better to say as the response to the contact area between the diamond and the material. The greater the indentation the higher the frequency change. Typically, the indentation depth varies between 5 µm and 35 µm.

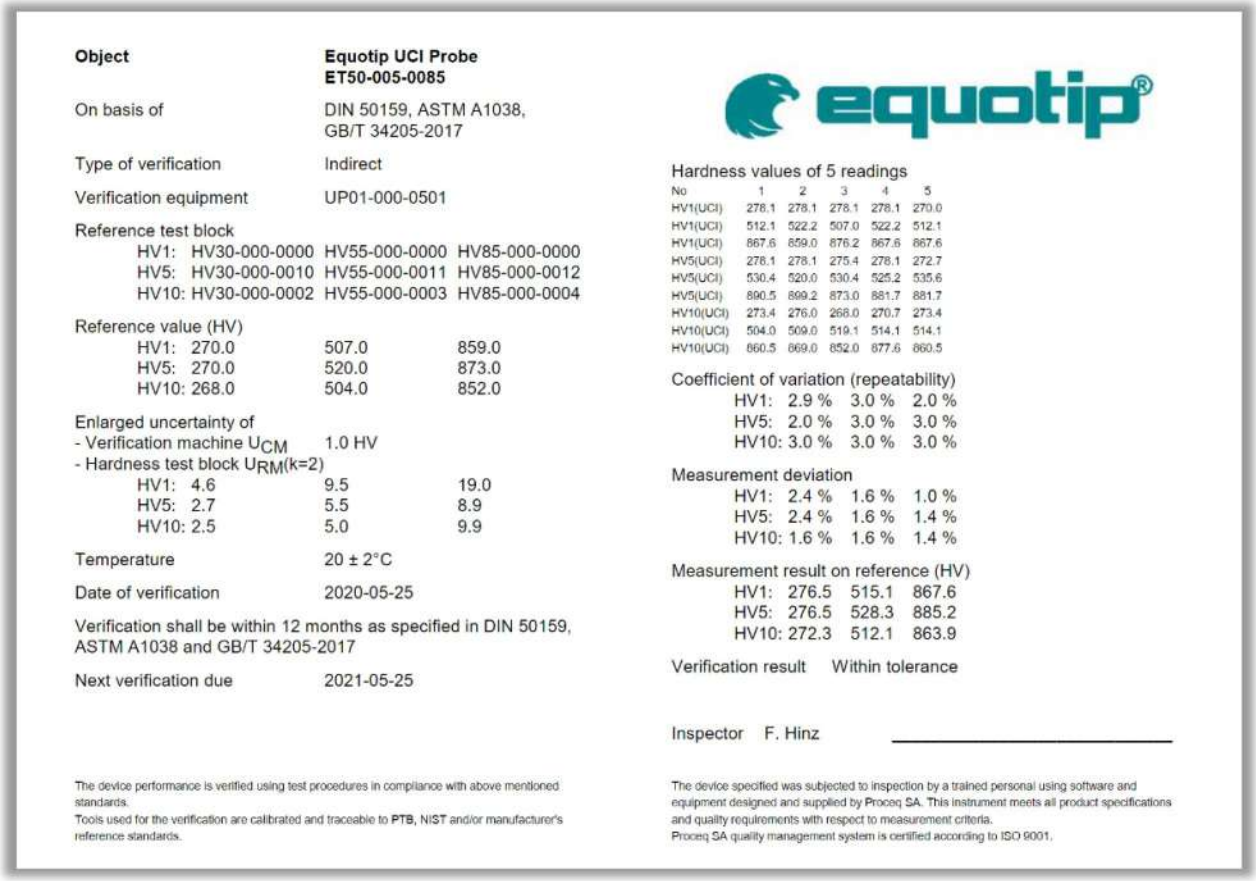
It is correct to say that the greater frequency changes can be measured more accurately, what indicates that: the higher the contact with the diamond (i.e. higher indentation depth) the lower the uncertainty of the measurement.

Higher tolerance values for lower HV scales and harder material ranges are based on the fact that for the low HV scales such as HV 0.1- HV 0.8 the low force is applied, leading to lower material penetration by the intender.

This combined with other measurement uncertainties such as different than 90° angle of the probe or wobbly hand of the operator can contribute additionally to a greater measurement deviation. This effect is even more pronounced for harder materials, whereby the penetration depth is even lower. In other words: the highest accuracy is expected for soft materials measured with HV 10 scale whereas hard materials measured with the low force are more prone to errors.

Does the calibration certificate include all necessary values ?

Yes, UCI probes from Proceq comply to DIN 50159, ASTM A1038 as well as GB/T 34205-2017. Measurement deviation and repeatability are specified on each certificate delivered with each UCI probe.



Object	**Equotip UCI Probe ET50-005-0085**		
On basis of	DIN 50159, ASTM A1038, GB/T 34205-2017		
Type of verification	Indirect		
Verification equipment	UP01-000-0501		
Reference test block			
HV1:	HV30-000-0000	HV55-000-0000	HV85-000-0000
HV5:	HV30-000-0010	HV55-000-0011	HV85-000-0012
HV10:	HV30-000-0002	HV55-000-0003	HV85-000-0004
Reference value (HV)			
HV1:	270.0	507.0	859.0
HV5:	270.0	520.0	873.0
HV10:	268.0	504.0	852.0
Enlarged uncertainty of			
- Verification machine U_{CM}	1.0 HV		
- Hardness test block $U_{RM}(k=2)$			
HV1:	4.6	9.5	19.0
HV5:	2.7	5.5	8.9
HV10:	2.5	5.0	9.9
Temperature	20 ± 2°C		
Date of verification	2020-05-25		
Verification shall be within 12 months as specified in DIN 50159, ASTM A1038 and GB/T 34205-2017			
Next verification due	2021-05-25		

The device performance is verified using test procedures in compliance with above mentioned standards.
Tools used for the verification are calibrated and traceable to PTB, NIST and/or manufacturer's reference standards.

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Hardness values of 5 readings

No	1	2	3	4	5
HV1(UCI)	278.1	278.1	278.1	278.1	270.0
HV1(UCI)	512.1	522.2	507.0	522.2	512.1
HV1(UCI)	867.6	859.0	876.2	867.6	867.6
HV5(UCI)	276.1	278.1	275.4	278.1	272.7
HV5(UCI)	530.4	520.0	530.4	525.2	535.6
HV5(UCI)	890.5	899.2	873.0	881.7	881.7
HV10(UCI)	273.4	276.0	268.0	270.7	273.4
HV10(UCI)	504.0	509.0	519.1	514.1	514.1
HV10(UCI)	860.5	869.0	852.0	877.6	860.5

Coefficient of variation (repeatability)

HV1:	2.9 %	3.0 %	2.0 %
HV5:	2.0 %	3.0 %	3.0 %
HV10:	3.0 %	3.0 %	3.0 %

Measurement deviation

HV1:	2.4 %	1.6 %	1.0 %
HV5:	2.4 %	1.6 %	1.4 %
HV10:	1.6 %	1.6 %	1.4 %

Measurement result on reference (HV)

HV1:	276.5	515.1	867.6
HV5:	276.5	528.3	885.2
HV10:	272.3	512.1	863.9

Verification result Within tolerance

Inspector F. Hinz

The device specified was subjected to inspection by a trained personal using software and equipment designed and supplied by Proceq SA. This instrument meets all product specifications and quality requirements with respect to measurement criteria.
Proceq SA quality management system is certified according to ISO 9001.

Disclaimer:
This document shows only a fraction of the information described in DIN 50159, ASTM A1038, and GB/T 34205-2017. Proceq AG has done everything in its power to translate accurately the sections of the DIN 50159 and GB/T 34205-2017 Standard. For an authorized translations or more information the interested readers are encouraged to read the full version of standards DIN 50159, ASTM A1038, and GB/T 34205-2017 available at www.beuth.de, www.astm.org or www.spc.org.cn