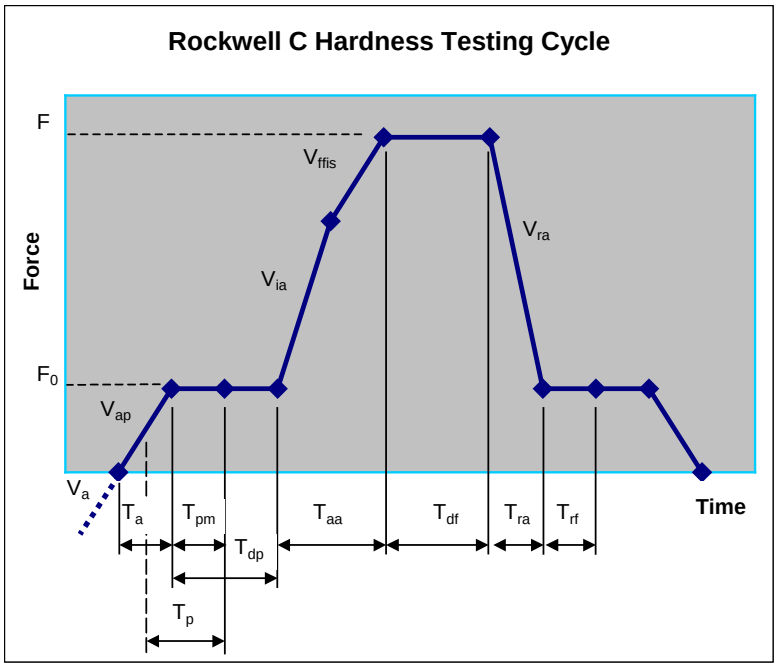
HRC Definition

Reference values for HRC					
Symbol	*Test parameters*		*Reference value*	*Start measurement*	*Stop measurement*
F_0	Preliminary force		98,0665 N	-	-
F	Total test force		1470,998 N	-	-
α_m	Angle of the indenter		120°	±30°	±400 µm
R_a	Spherical tip radius of the indenter		200 µm	-30° (from the axis)	+30° (from the axis)
V_{fis}	Final indentation speed of additional load application		30 µm·s^{-1}	~80% F	~99% F
T_p	Total time of preliminary test force	$T_p = \frac{T_a}{2} + T_{pm}$	3 s	-	-
T_a	Application time of preliminary test force		-	~1% F_0	~99% F_0
T_{pm}	Duration time of preliminary test force			~99% F_0	Reading
T_{df}	Duration of the total force		5 s	~99% F	~99% F
T_{rf}	Final reading time		4 s	~101% F_0	Reading
T	Temperature of test		23°C	Beginning of the test	End of the test

Figure 1. Identification of parts of the HRC testing cycle.



Test parameters

F0 – Preliminary Force

F – Total Test Force

Ta – Application time of preliminary test force

Tpm – Duration time of preliminary test force

Tdp – Preload Dwell Time

Tp – Total time of preliminary test force

Taa – Additional load Application Time

Tdf – Duration of the total force

Tra – Additional load Removal Time

Trf – Final reading time

Va – Approach Velocity

Vap – Preload Application Velocity

Viaa – Initial Velocity of Additional load Application

Vfis – Final indentation speed of additional load application

Vra – Additional load Removal Velocity

Annex A – Uncertainty calculation and sensitivity coefficients

The European Association of National Metrology Institutes (EURAMET) has published *Guidelines on the Estimation of Uncertainty in Hardness Measurements* [1], which details the values of the sensitivity coefficients for HRC measurements (obtained by experiment at three different hardness levels). It is summarized, as an example, in the following table:

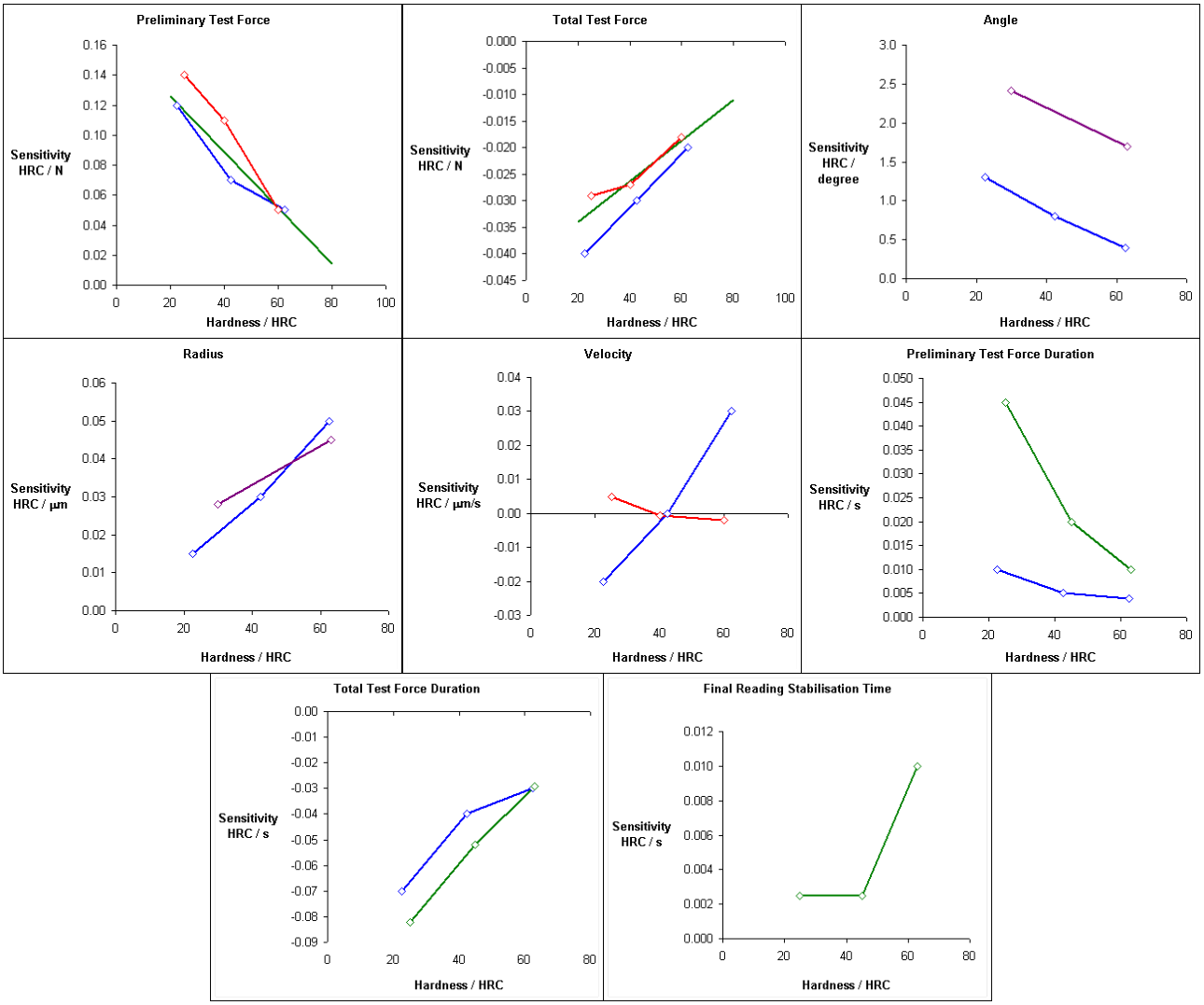
Example of evaluation of the uncertainty based on the state of the art of primary hardness standard machines for the 20 HRC to 25 HRC hardness level.

parameter/unit	*calibration data*			*sensitivity coefficient* $c_i = \frac{\Delta H}{\Delta x_i}$	*variation in hardness* ΔH_i */HRC*	*contribution to the uncertainty,* $u_i^2(H)$/ *HRC*^{2}
	difference from the nominal value, Δx_i	*expanded uncertainty,* U_i (2σ)	*degrees of freedom,* ν_I			
F_0/N	0,01	0,01	20	$1{,}2\cdot10^{-1}$	$1{,}2\cdot10^{-3}$	$3{,}6\cdot10^{-7}$
F/N	0,15	0,05	20	$-4{,}0\cdot10^{-2}$	$-6{,}0\cdot10^{-3}$	$1{,}0\cdot10^{-6}$
α_m/°	0,05	0,02	20	$1{,}3\cdot10^{0}$	$6{,}5\cdot10^{-2}$	$1{,}7\cdot10^{-4}$
R_a/mm	0,003	0,001	20	$1{,}5\cdot10^{+1}$	$4{,}5\cdot10^{-2}$	$5{,}6\cdot10^{-5}$
l/(µm)	0,1	0,05	20	$-5{,}0\cdot10^{-1}$	$-5{,}0\cdot10^{-2}$	$1{,}6\cdot10^{-4}$
V_{fis}/(µm/s)	5	2	10	$-2{,}0\cdot10^{-2}$	$-1{,}0\cdot10^{-1}$	$4{,}0\cdot10^{-4}$
T_p/s	0,5	0,2	10	$1{,}0\cdot10^{-2}$	$5{,}0\cdot10^{-3}$	$1{,}0\cdot10^{-6}$
T_{df}/s	0,5	0,2	10	$-7{,}0\cdot10^{-2}$	$-3{,}5\cdot10^{-2}$	$4{,}9\cdot10^{-5}$
Total					-0,07	0,001
Standard uncertainty u_m/HRC						0,03
Degrees of freedom						36
Coverage factor k for confidence level p = 95%						2,03
Expanded uncertainty U/HRC $= ku$/HRC						0,06

Some NMIs have carried out experiments to verify these sensitivity coefficients and to investigate others., The data are summarized in the following table and plotted in blue in the subsequent graphs (the green lines represent results obtained at NIST [2], the red lines results from INRIM (formerly IMGC) [3, 4], and the purple lines results from NPL [5]).

Sensitivity coefficients of the HRC influence parameters

Symbol	*Parameter*	*Unit*	*Sensitivity coefficient symbol*	*Sensitivity coefficient*		
				20 to 25 HRC	*40 to 45 HRC*	*60 to 65 HRC*
F_0	Preliminary Test Force	N	$\partial HRC/\partial F_0$	0,12	0,07	0,05
F	Total Test Force	N	$\partial HRC/\partial F$	-0,04	-0,03	-0,02
α_m	Angle of the indenter	°	$\partial HRC/\partial \alpha_m$	1,3	0,8	0,4
R_a	Spherical tip radius of the indenter	µm	$\partial HRC/\partial R_a$	0,015	0,03	0,05
L	indentation depth	µm	$\partial HRC/\partial l$	-0,5	-0,5	-0,5
V_{fis}	Final indentation speed of additional load application	$\mu m \cdot s^{-1}$	$\partial HRC/\partial V_{fis}$	-0,02	0,00	0,03
T_p	Total time of preliminary test force	s	$\partial HRC/\partial T_p$	0,010	0,005	0,004
T_{df}	Duration of the total force	s	$\partial HRC/\partial T_{df}$	-0,07	-0,04	-0,03
T_{rf}	Final Reading Time	s	$\partial HRC/\partial T_{rf}$	0,002	0,002	0,01



[1] EURAMET/cg-16/v.01, “EA Guidelines on the Estimation of Uncertainty in Hardness Measurements”, Previously EA-10/16, July 2007 (http://www.euramet.org/index.php?id=calibration-guides)

[2] Samuel R. Low, “Rockwell Hardness - Measurement of Metallic Materials”, NIST Recommended Practice Guide, National Institute of Standards and Technology, Spec. Publ. 960-5, 116 pages (January 2001) CODEN: NSPUE2 (http://www.nist.gov/manuscript-publication-search.cfm?pub_id=853006)

[3] G. Barbato, S. Desogus, A. Germak, "Hardness measurement from empiricism to metrology an application to Rockwell C scale". -In: "Basic metrology and applications", Ed. Levrotto & Bella, 1994, pp. 112-117.

[4] G. Barbato, S. Desogus, A. Germak, "Experimental analysis on the influence quantities in the Rockwell C hardness Test". -Proc. HARDMEKO '98, Beijing, China, Sept. 21-23, 1998, pp. 67-73

[5] L. Brice, F. Davis, A. Crawshaw, “Uncertainty in hardness measurement”, NPL Report CMAM 87, April 2003 (http://www.npl.co.uk/engineering-measurements/mass-force-pressure/hardness/rockwell-hardness-sensitivity-coefficients)