Rockwell Hardness Sensitivity Coefficients HRA

ISO 6508-1 defines the Rockwell A hardness value, *HRA*, as:

$$HRA = 100 - \frac{h}{2}$$

where:

h = permanent depth of indentation under preliminary test force after removal of additional test force (in μm)

A partial derivative allows the sensitivity coefficient for indentation depth to be determined:

$$\frac{\partial HRA}{\partial h} = -0.5$$

For the *HRA* range, practical experiments were carried out to determine the sensitivity coefficients for preliminary test force value, dwell time at preliminary test force, loading time, application rate, total test force value, dwell time at total test force, and dwell time after removal of additional test force.

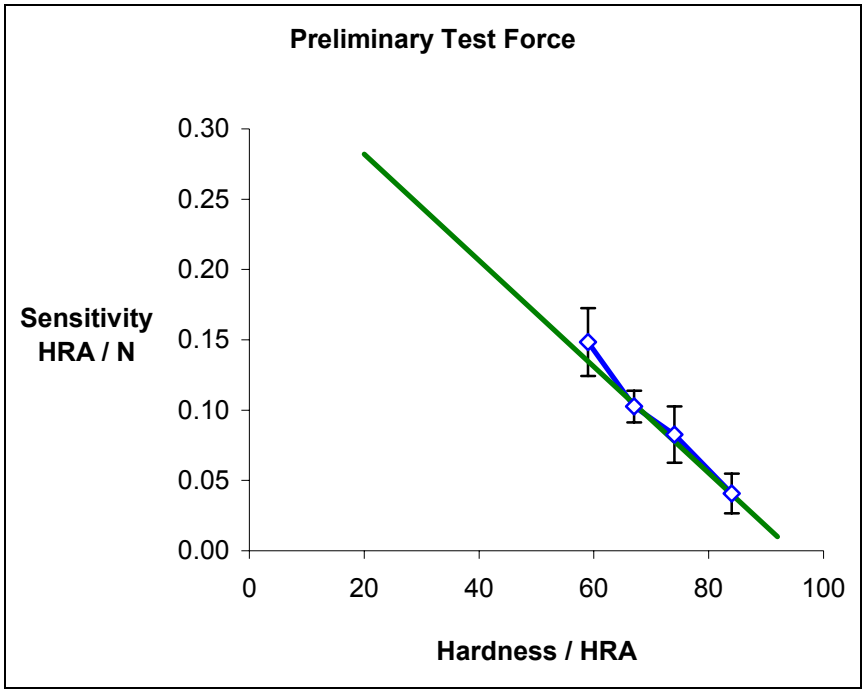
Sensitivity to force values

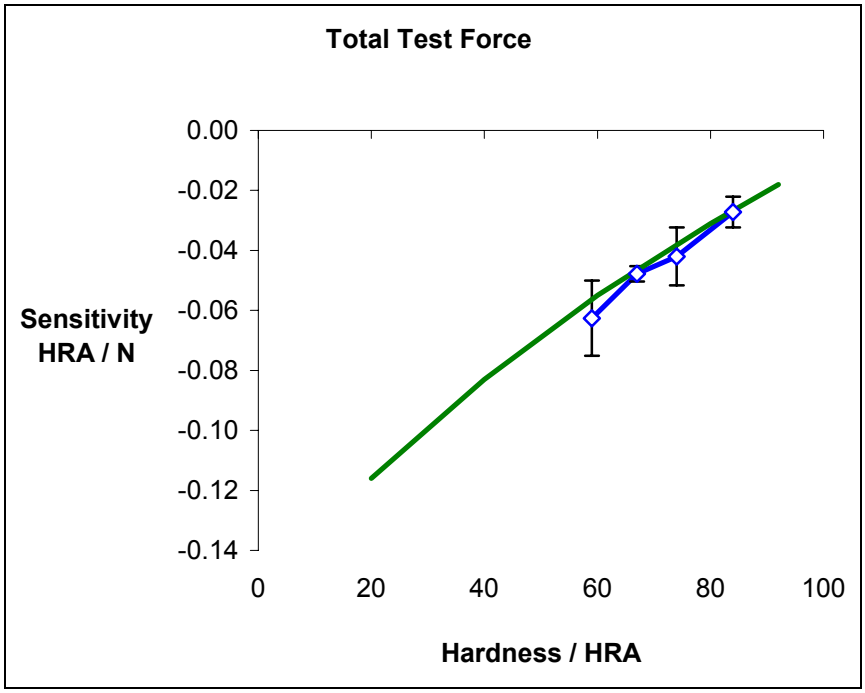
ISO 6508-2 specifies that each of three force verification measurements in the machine (made by an ISO 376 Class 1 proving device) shall agree with the nominal preliminary test force (98.07 N) to within a tolerance of ±2.0 % and with the nominal total test force (588.4 N) to within a tolerance of ±1.0 %.

Five hardness tests were carried out on each of four blocks of different nominal hardnesses, at different values of preliminary and total test force:

Parameter	**Force**				
	Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**
Preliminary test force F_0	98.07 N	96.11 N	100.03 N	98.07 N	98.07 N
Total test force F	588.40 N	588.40 N	588.40 N	582.52 N	594.28 N

For each of the four hardness blocks, the mean measured hardness was plotted against the input parameter (preliminary or total test force) and a linear least squares fit was applied to the data. The gradient of this line (the sensitivity of hardness to the input parameter) was plotted against hardness for the four blocks, and these values are shown in the following two graphs. The error bars relate to the linearity of the fit of hardness against input parameter at each of the hardness values – each error bar is ±2 × the standard error associated with the estimate of the gradient (sensitivity coefficient). The green lines represent results obtained by NIST.





Sensitivity to application time, application rate, and force durations

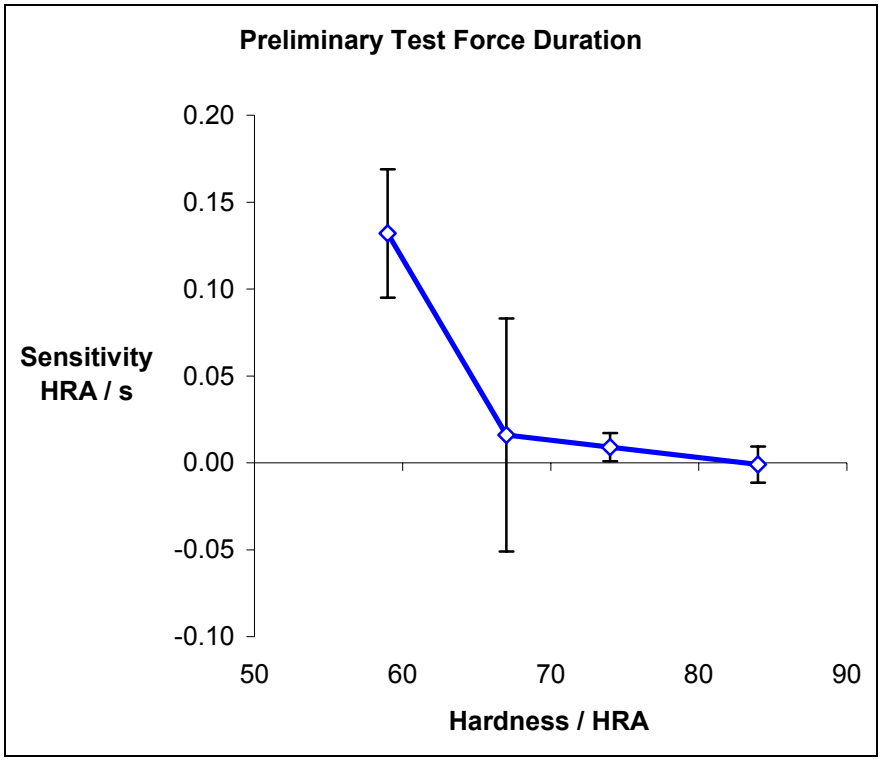
ISO 6508-1 specifies that the "duration of the preliminary test force F_0 shall not exceed 3 s", that the force shall be increased "from F_0 to F in no less than 1 s nor greater than 8 s", that the "total test force F shall be maintained for a duration of 4 s ± 2 s", and that the final reading shall be made at a force of F_0 "after a short time stabilisation".

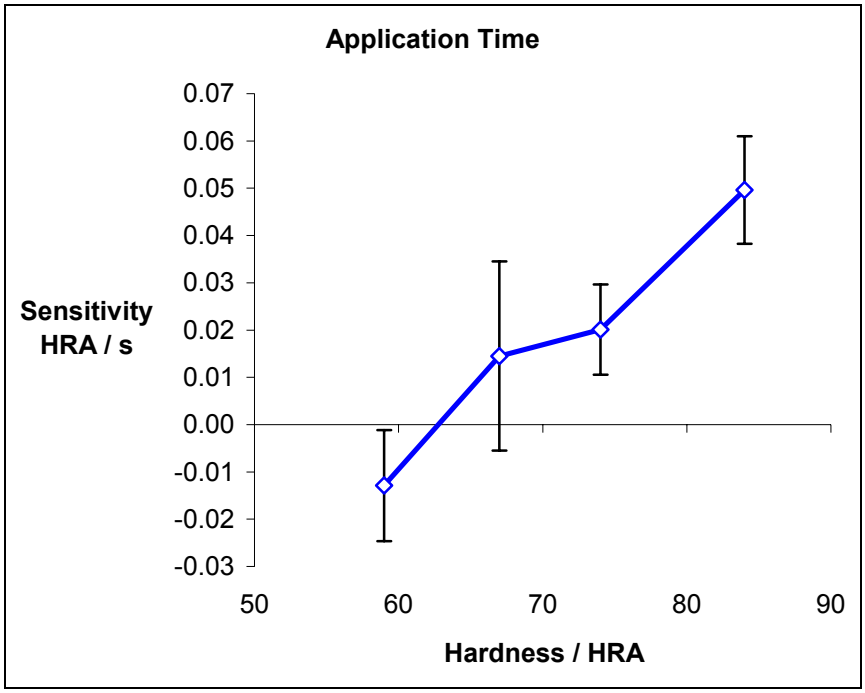
Additionally, ISO 6508-3 specifies that, in the range from 0.6 *F* to 0.8 *F*, the indentation speed should be in the range 20 $\mu m \cdot s^{-1}$ to 40 $\mu m \cdot s^{-1}$.

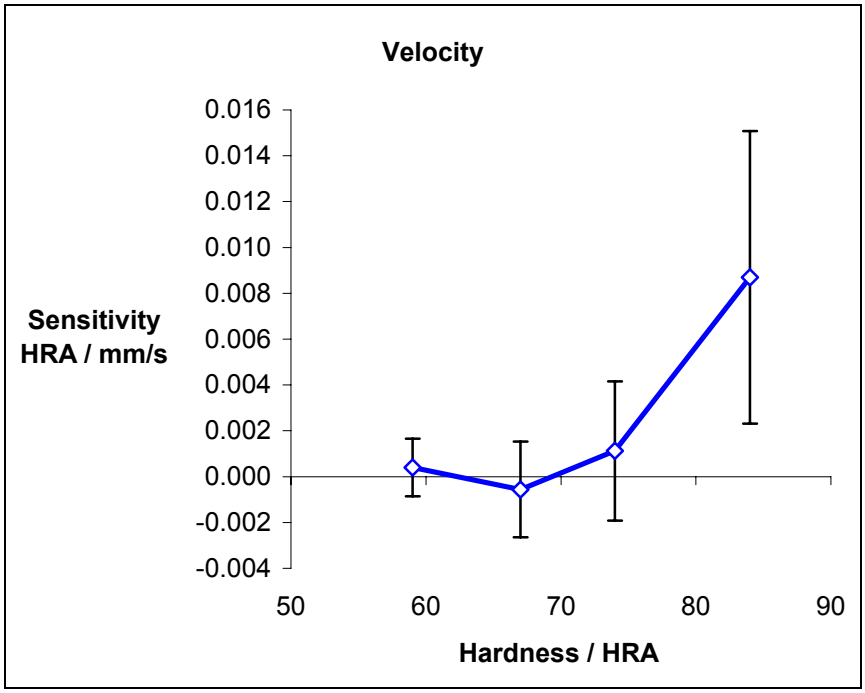
Five hardness tests were carried out on each of four blocks of different nominal hardnesses, at different values of the input parameters, while keeping all other parameter values constant:

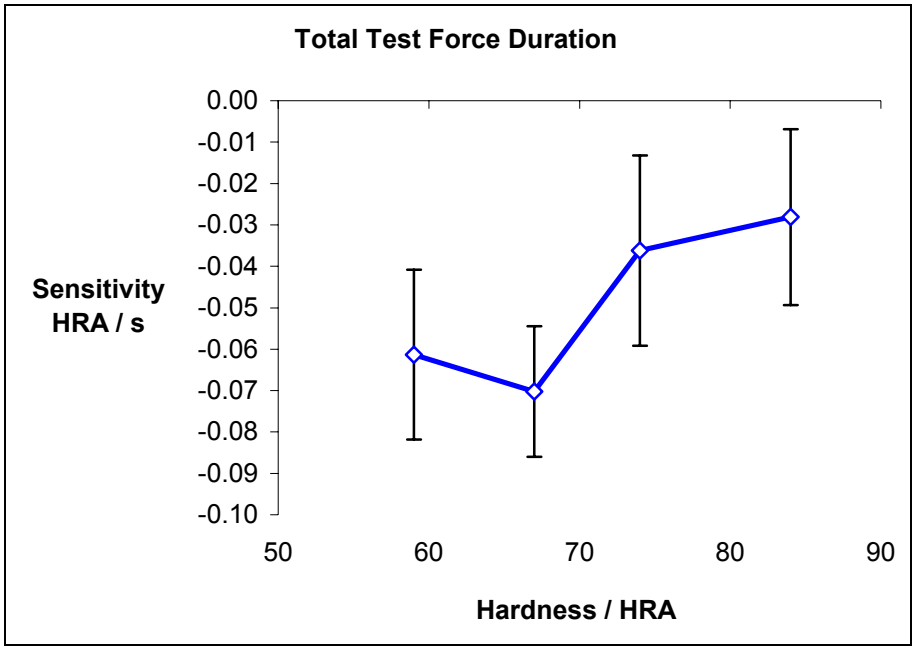
Parameter	Value 1	Value 2	Value 3	Value 4
Preliminary test force duration	1 s	2 s	3 s	N/A
Application time	1.15 s	3 s	5 s	8 s
Application velocity	11.2 $\mu m \cdot s^{-1}$	20.2 $\mu m \cdot s^{-1}$	31.5 $\mu m \cdot s^{-1}$	38.8 $\mu m \cdot s^{-1}$
Total test force duration	2 s	4 s	5.5 s	6 s
Final reading stabilisation time	3 s	4 s	5 s	N/A

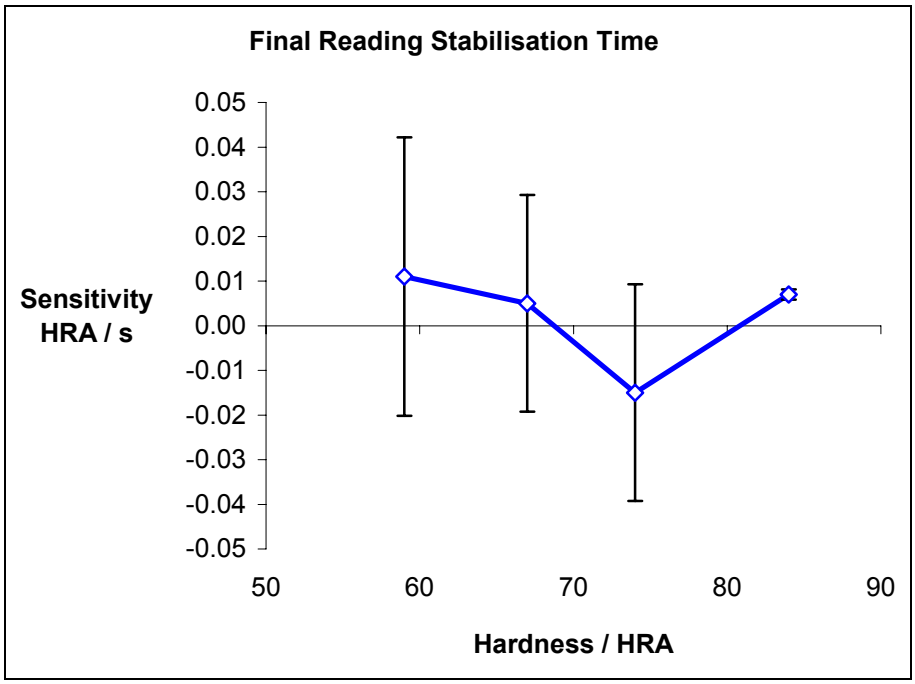
For each of the four hardness blocks, the mean measured hardness was plotted against the input parameter and a linear least squares fit was applied to the data. The gradient of this line (the sensitivity of hardness to the input parameter) was plotted against hardness for the four blocks, and these values are shown in the following graphs. The error bars relate to the linearity of the fit of hardness against input parameter at each of the hardness values – each error bar is ±2 × the standard error associated with the estimate of the gradient (sensitivity coefficient).




Application Time
Sensitivity HRA / s
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
50
60
70
80
90
Hardness / HRA


Velocity
Sensitivity HRA / mm/s
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
50
60
70
80
90
Hardness / HRA


Total Test Force Duration
Sensitivity HRA / s
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
-0.09
-0.10
50
60
70
80
90
Hardness / HRA


Final Reading Stabilisation Time
Sensitivity HRA / s
0.05
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
50
60
70
80
90
Hardness / HRA