R218c – Annex C: Presentation of Hardness on a Scope of Accreditation

Table of Contents

Introduction

This document provides requirements for the presentation of calibration scopes of accreditation for hardness quantities, i.e., direct and indirect verification of hardness testing machines and the standardization of test blocks. This document applies to the hardness tests most often found on calibration scopes of accreditation: Rockwell, Brinell, Vickers, and Knoop.

The requirements are based directly on the applicable ASTM and ISO hardness standard test methods. The example scopes in this document are not meant to imply that every laboratory will be accredited for every measurement provided for in the test standard; however, if a laboratory wishes to be accredited for a particular measurement then the examples show how the scope should be presented. For example, manufacturers of test blocks will typically purchase "blanks" from another manufacturer: the dimensional quantities of the blanks will be verified by the manufacturer of the blank while the hardness value of the blank will be verified by the manufacturer of the test block; the scope of accreditation for the test block manufacturer will generally include only the verification of the hardness value, not the verification of the dimensional characteristics.

Each hardness-testing machine considered in this document has two means of verification: direct verification and indirect verification. The indirect verification is simply a check to ensure that the testing machine yields the correct indication when tested with a reference block of known hardness and it consists of two measures: repeatability and error. Although repeatability and error are distinct measurands with generally different uncertainties, scopes of accreditation will reference only the uncertainty of a single hardness measurement taken in the course of these verifications. Direct verification is calibration of each of the significant features of the testing machine and includes the force and depth indication.~~,~~ The verification of the dimensional features of the indenter is by direct measurement and by performance testing / indirect verification (for Rockwell only).

Apart from verifications of the testing machines, the lab may also be accredited for the standardization of test blocks and the various hardness standards stipulate various dimensional requirements for these blocks as well as tolerances on mean hardness values.

Where the word "uncertainty" is used in this document, it is to be understood to mean "expanded uncertainty", as defined in the GUM, expressed at approximately the 95 % level of confidence using a coverage factor of $k = 2$. The meaning of uncertainty for scopes is equivalent to calibration measurement capability (CMC). Details of how uncertainty is to be estimated for the various measurements can be found in ASTM E18 for example. More uncertainty analysis examples are planned for other ASTM and ISO documents. For that reason, it should be noted that those interested in this document should obtain current ASTM and ISO hardness documents.

It must be remembered that the important feature of a scope is not brevity or pithiness, but *clarity*. An informed reader of a scope of accreditation should have no difficulty in learning what a lab is accredited to do and how they do it. The numbers and measurement methods used in the example scopes are for illustrative purposes only: different labs will generally have different CMCs and may utilize other measurement methods than the ones indicated here.

Rockwell Hardness, Rockwell Superficial Hardness, and Portable Rockwell Hardness

Indirect verification: The scope of accreditation for the indirect verification of Rockwell hardness testers shall include the following information: the scales the lab is able to verify, the ranges for each scale for which the lab has reference blocks, the best uncertainty for a single hardness measurement, and reference to the indirect verification of Rockwell hardness testers by the method of ASTM E18. E18 requires that a tester shall be tested in the low, middle, and high hardness ranges for each scale used. Therefore, for each scale, there will be three ranges indicated and three generally different best uncertainties. When indirectly verifying a portable tester, the ASTM document E110 is used. Care must be taken to ensure the portable is not a comparative tester that electronically or uses charts to convert test values to hardness numbers. In any case, a tester can only meet E110 if it has the same test parameters as those specified in E10 and E18. A sample scope for the indirect verification of Rockwell hardness testers can be found in Table 1.

Table 1. Sample scope of accreditation for the indirect verification of Rockwell hardness testers.

Parameter/Equipment	Range	CMC (±)	Comments
Indirect Verification of Rockwell Hardness Testers	HRC: (20 to 30) HRC (35 to 55) HRC (59 to 65) HRC	 0.31 HRC 0.32 HRC 0.37 HRC	Indirect verification per ASTM E18.

Notes:

1) There is no need to list the actual hardness values of the reference blocks (generic reference to the range is sufficient) since this creates an unnecessary need to update the scope of accreditation if new blocks are obtained. Only if the lab wishes to update the CMCs should it be necessary to revise the scope when new blocks are obtained.

Direct verification: As noted in the Introduction, direct verification of hardness testers involves several distinct calibrations. For Rockwell hardness, these are:

1) Verification of the test force.

   The range of forces the lab can verify and the associated best uncertainties shall be indicated. The actual uncertainty of force verification will generally be different than the best uncertainty but this is not relevant due to the decision rules in E18. The comments section shall reference E4, the standard practice for force verification of testing machines. At this point in time, the error component of force can not be converted to hardness values. All hardness uncertainties are calculated using indirect verification from uncertainty annex shown in ASTM E18.

2) Verification (direct) of the indenter.

   a) If the laboratory desires accreditation of diamond indenters. E18 specifies complex dimensional characteristics for the diamond spheroconical indenter and its relation to the seating surface. The scope of any lab seeking accreditation for these measurements shall include the feature(s) measured and associated best uncertainty. Specification of ranges for these measurements is unnecessary. Apart from these dimensional characteristics, E18 also specifies a performance test for the indenter, and it is this performance test that most labs are accredited to perform. Ranges and best uncertainties for the performance test are irrelevant and need not be listed. The scope will simply note, "Indenters are verified only through the performance test."

b) Carbide balls

Hardness of the ball (using, ASTM E384 or ISO 6507 Vickers)
Geometry of the ball
Density of the ball

Note: All or some of the above may be determined by other laboratories if they are accredited.

3) Verification of the depth-measuring device.

There is a need to indicate the range of verification of the depth-measuring device, and the Calibration Measurement Capability shall be listed and the Comments section shall indicate the method of verification.

In many cases, depth verification can not be performed in the field because of tester incompatibilities. It may be necessary to list those types of testers which can be verified directly in the field.

Laboratories that cannot perform each of these verifications shall not normally be accredited for the direct verification of Rockwell hardness testers. If a laboratory is accredited for a partial direct verification, this fact shall be noted on the scope so that potential customers will know that an accredited, full direct verification is not available.

A sample scope of accreditation for the direct verification of a Rockwell hardness tester is shown in Table 2.

Table 2. Sample scope of accreditation for the direct verification of a Rockwell Hardness Tester.

Parameter/Equipment	Range	CMC(±)	Comments
Direct Verification of Rockwell Hardness Testers – Verification of the test force	 150 kgf	 1 kgf	Direct verification method per ASTM E18. Verification of the test force is by load cell per the method of ASTM E4.

Parameter/Equipment	Range	CMC(±)	Comments
Direct Verification of Rockwell Hardness Testers (cont) –			
Diamond indenter	See E18, ISO 6507 Tip Radius Angle Straightness of the generatric line of the cone	1 µm 0.1 degrees 1 µm	The dimensional characteristics of the diamond indenter.
Carbide ball indenter:	Hardness Radius Density	12 HV 1 µm 0.1 gcm^{-3}	
Verification of the depth-measuring device	(0 to 4) mm	0.3 µm	

Notes:

1) Ranges need to be specified for the parameters of a direct verification. The nominal value of every feature is specified in E18.
2) CMCs are required for the verification of the force indication and verification of the depth-measuring device. If the dimensional characteristics of the diamond indenter are verified, then uncertainties need to be specified as well as measurement method, but no ranges.

Standardization of test blocks: Several features of standardized test blocks are specified in E18. The following features are considered to be trivially easy to verify and therefore do not warrant accreditation: block thickness, block surface area[1], demagnetization.

A sample scope of accreditation for the standardization of a Rockwell test block is found in Table 3.

[1] However, certificates for blocks that exceed the 4 in^2 surface area limitation of E18 shall not bear the A2LA logo.

Table 3. Sample scope of accreditation for the calibration of standardized Rockwell and Rockwell Superficial test blocks.

Parameter/Equipment	Range	CMC(±)	Comments
Calibration of Standardized Rockwell Hardness and Rockwell Superficial Hardness Test Blocks:			
Mean hardness value (HRC scale)	(20 to 30) HRC (35 to 55) HRC (59 to 65) HRC	0.37 HRC 0.32 HRC 0.30 HRC	ASTM E18

Notes:

1) Verification of the dimensional characteristics of test blocks is not generally found on scopes of accreditation. In those cases, the scope should note that flatness, parallelism, and surface roughness are not verified and that the calibration is a limited calibration.
2) If the block calibration laboratory is not in full compliance with the block geometry specifications of E18, that calibration will not be listed on the scope.

Vickers Hardness

Indirect verification: The scope of accreditation for the indirect verification of Vickers hardness testers shall include the following information: levels of hardness for which the lab has standardized test blocks and reference to the indirect verification of Vickers hardness testers by the method of ASTM E384. The decision rules for the indirect verification of Vickers hardness testers are given in terms of length or of a fraction of a length: therefore, best uncertainties are given as a length or fraction of a length.

A sample scope for the indirect verification of Vickers hardness testers can be found in Table 4.

Table 4. Sample scope of accreditation for the indirect verification of Vickers hardness testers.

Parameter/Equipment	Range	CMC(±)	Comments
Indirect Verification of Vickers Hardness Testers	(100 to 240) HV (>240 to 600) HV >600 HV	***5 HV*** ***8 HV*** ***12 HV***	Indirect verification per ASTM ***E384.***

Direct verification: As noted in the Introduction, direct verification of hardness testers involves several distinct calibrations. For Vickers hardness, these are:

1) Verification of the test force.

   The range of forces the lab can verify and associated best uncertainties shall be indicated. The actual uncertainty of force verification will generally be different than the best uncertainty. The comments section shall reference E4, the standard practice for force verification of testing machines.

2) Verification of the indenter.

   Unlike Rockwell diamond indenters, E92 does not specify a performance test for Vickers indenters. Therefore, each of the dimensions specified in E92 must be checked either by direct measurement or by projection. These features are:

   a) angle between opposite faces of the pyramid;
   b) inclination of the four faces to the axis of the pyramid;
   c) junction of indenter faces for indenters used in routine testing;
   d) junction of indenter faces for indenters used for calibrating standardized test blocks;
   e) angles of the quadrilateral formed by the intersection of the four faces of the indenter with a plane perpendicular to the axis of the indenter.

   All laboratories wishing to be accredited for the direct verification of Vickers hardness testers shall be accredited for items a – c and e. Laboratories wishing to be accredited for the direct verification of Vickers hardness testers used for the calibration of standardized test blocks shall be accredited for at least items a, b, d, e or obtain from an accredited source a directly verified indenter.

3) Verification of the measuring microscope.

   There is a need to indicate the range of verification of the measuring microscope, but best uncertainties shall be listed and the Comments section shall indicate the method of verification.

Laboratories that cannot perform each of these verifications shall not normally be accredited for the direct verification of Vickers hardness testers. If a laboratory is accredited for a partial direct verification, this fact shall be noted on the scope so that potential customers will know that an accredited, full direct verification is not available.

A sample scope of accreditation for the direct verification of a Vickers hardness tester is shown in Table 5.

Table 5. Sample scope of accreditation for the direct verification of a Vickers hardness tester.

Parameter/Equipment	Range	CMC(±)	Comments
Direct Verification of Vickers Hardness Testers –			Direct verification method per ASTM E92.
Verification of the test force	5 kgf	1 kgf	Verification of the test force is by load cell per the method of ASTM E4.
Verification of the dimensional characteristics of the indenter:			
Angle between opposite faces of the pyramid		7’	Verification of these dimensional features is by optical projection.
Inclination of the faces to the axis of the pyramid		7’	
Junction of indenter faces for indenters used in routine testing		250 µm	
Junction of indenter faces for indenters used for calibrating standardized test blocks		120 µm	
Angles of the quadrilateral formed by the intersection of the four faces of the indenter with a plane perpendicular to the axis of the indenter		3’	
Verification of the device for measuring indentation diagonals	(0 to 200) µm	0.28 µm	

Notes:

1) Ranges need to be specified for the parameters of a direct verification except for force (since not every lab will necessarily be capable of verifying the entire force range). The nominal value of every other feature is specified in E92.

Standardization of test blocks: Several dimensional features of standardized test blocks are specified in E92 but the only non-trivial block geometry such as surface roughness, flatness and thickness shall be demonstrated.

A sample scope of accreditation for the standardization of a Vickers test block is found in Table 6.

Table 6. Sample scope of accreditation for the calibration of standardized Vickers test blocks.

Parameter/Equipment	Range	CMC(±)	Comments
Calibration of Standardized Vickers Test Blocks	(100 to 240) HV (>240 to 600) HV >600 HV	4 HV 6 HV 10 HV	ASTM E384

Brinell Hardness

Indirect verification: The scope of accreditation for the indirect verification of Brinell hardness testers shall include the following information: specification of each of the conditions the laboratory is accredited to verify and reference to the indirect verification of Brinell hardness testers by the method of ASTM E10.

A sample scope for the indirect verification of Brinell hardness testers can be found in Table 7.

Table 7. Sample scope of accreditation for the indirect verification of Brinell hardness testers.

Parameter/Equipment	Range	CMC(±)	Comments
Indirect Verification of Brinell Hardness Testers at Test Condition(s) –			
HBW 10/3000/15	(200 to 399) HBW (400 to 600) HBW	4 HBW 8 HBW	Indirect verification method per ASTM E10.

Notes:

1) The notation HBW 10/3000/15 gives the conditions of the verification: in this example, "10" is the diameter of the indenter in millimeters, "3000" is the test force in kilogram-force and "15" is the duration of force application in seconds.

Direct verification: As noted in the Introduction, direct verification of hardness testers involves several distinct calibrations. For Brinell hardness, these are:

1) Verification of the test force.

   The test forces the lab can verify and associated best uncertainties shall be indicated. Standard test forces for Brinell hardness testing are 3000, 1500, and 500 kgf. The actual uncertainty of force verification will generally be different than the best uncertainty but this is not relevant due to the decision rules in E10. The comments section shall reference E4, the standard practice for force verification of testing machines.

2) Verification of the indenter.

   a) Unlike Rockwell diamond indenters, E10 does not specify a performance test for Brinell indenters. Therefore, the mean diameter of a Brinell ball indenter must be determined per E10 section 15.1.2 and the ball must be selected at random from a lot meeting the hardness requirements specified in section 5.2 of E10. If the laboratory manufactures indenter balls and they wish to be accredited for indenter lot hardness certifications, then this will be a separate line item on the scope.

3) Verification of the measuring device.

   There is a need to indicate the range of verification of the measuring device, and the best uncertainties shall be listed and the Comments section shall indicate the method of verification.

Laboratories that cannot perform each of these verifications shall not normally be accredited for the direct verification of Brinell hardness testers. If a laboratory is accredited for a partial direct verification, this fact shall be noted on the scope so that potential customers will know that an accredited, full direct verification is not available.

A sample scope of accreditation for the direct verification of a Brinell hardness tester is shown in Table 8.

Table 8. Sample scope of accreditation for the direct verification of a Brinell hardness tester.

Parameter/Equipment	Range	CMC(±)	Comments
Direct Verification of Brinell Hardness Testers – Verification of the device for measuring indentation diameters	(0 to7) mm	0.028 mm	Direct verification per ASTM E10.

Standardization of test blocks: Several features of standardized test blocks are specified in E10

A sample scope of accreditation for the standardization of a Brinell test block is found in Table 9.

Table 9. Sample scope of accreditation for the calibration of standardized Brinell test blocks.

Parameter/Equipment	Range	CMC(±)	Comments
Calibration of Standardized Brinell Hardness Test Blocks: Mean hardness value	≤ 225 HBW > 225 HBW	5 HBW 10 HBW	ASTM E10

Notes:

1) Verification of the dimensional characteristics of test blocks is not generally found on scopes of accreditation.

Microindentation Hardness (Knoop and Vickers)

Indirect verification: The scope of accreditation for the indirect verification of microindentation hardness testers (Knoop and Vickers) shall include the following information: levels of hardness for which the lab has standardized test blocks , and reference to the indirect verification of microindentation hardness testers by the method of ASTM E384. The decision rules for the indirect verification of microindentation hardness testers are given in terms of length or of a fraction of a length: therefore, best uncertainties are given as a length or fraction of a length.

A sample scope for the indirect verification of microindentation hardness testers can be found in Table 10.

Table 10. Sample scope of accreditation for the indirect verification of microindentation hardness testers.

Parameter/Equipment	Range	CMC(±)	Comments
Indirect Verification of Microindentation Hardness Testers (Knoop and Vickers)	(100 to 250) HK (250 to 650) HK >650 HK (100 to 240) HV	3 HK 8 HK 12 HK 7 HV	Indirect verification method per ASTM E384

Direct verification: As noted in the Introduction, direct verification of hardness testers involves several distinct calibrations. For microindentation hardness, these are:

1) Verification of the indenter

   The features to be verified on the Vickers and Knoop indenters are:

   a) Vickers: face angles, offset, inclination of the faces to the axis of the indenter.

   b) Knoop: indenter constant, included longitudinal edge angle, included transverse edge angle, offset, inclination of the faces to the axis of the indenter.

2) Force verification

   The range of forces the lab can verify and associated best uncertainties shall be indicated. The comments section shall reference E4, the standard practice for force verification of testing machines, and the method of force measurement.

3) Measuring microscope verification

   There is no need to indicate the range of verification of the measuring microscope, but best uncertainties shall be listed and the Comments section shall indicate the method of verification.

Laboratories that cannot perform each of these verifications shall not normally be accredited for the direct verification of microindentation hardness testers. If a laboratory is accredited for a partial direct verification, this fact shall be noted on the scope so that potential customers will know that an accredited, full direct verification is not available.

A sample scope of accreditation for the direct verification of microindentation hardness testers is shown in Table 11.

Table 11. Sample scope of accreditation for the direct verification of a Vickers hardness tester.

Parameter/Equipment	Range	CMC(±)	Comments
Direct Verification of Vickers and Knoop Hardness Testers –			Direct verification method per ASTM E384
Verification of the test force	1000 gf	3 gf	Verification of the test force is by load cell per the method of ASTM E4
Verification of the dimensional characteristics of the indenter:	----		Verification of these dimensional features is by optical projection
Vickers		7′	
Face angles		0.125 µm	
Offset		7′	
Inclination of the faces to the axis of the indenter		7′	

Table 11. Sample scope of accreditation for the direct verification of a Vickers hardness tester.

Parameter/Equipment	Range	CMC(±)	Comments
Direct Verification of Vickers and Knoop Hardness Testers –	-----		
Verification of the dimensional characteristics of the indenter:			
Knoop			Verification of these dimensional features is by optical projection.
Included longitudinal edge angle, ∠A		0.1°	
Included transverse edge angle, ∠B		0.1°	
Indenter constant, cp		0.00018	
Offset		0.25 µm	
Inclination of the faces to the axis of the indenter		7′	
Verification of the device for measuring indentation diagonals		0.12 % of reading	

Notes:

1) No ranges need to be specified for the parameters of a direct verification except for force (since not every lab will necessarily be capable of verifying the entire force range). The nominal value of every other feature is specified in E384.

Standardization of test blocks:

Several features of standardized test blocks are specified in E384. The following block parameters, scales and ranges, and associated best uncertainties shall be included on the scope: uniformity of hardness and mean of the hardness values found during the standardization. The following features are considered to be trivially easy to verify and therefore do not warrant accreditation: block thickness and demagnetization.

A sample scope of accreditation for the standardization of microindentation test blocks is found in Table 12.

Table 12. Sample scope of accreditation for the calibration of standardized hardness test blocks for microindentation hardness test.

Parameter/Equipment	Range	CMC(±)	Comments
Calibration of Standardized Microindentation Hardness Test Blocks	(100 to 250) HK (250 to 650) HK >650 HK	*4 HK* *9 HK* *12 HK*	ASTM E384

References

A2LA, *R218 - Applications for Calibration Scopes of Accreditation.*

ISO/IEC Guide 98-3:2008(E) *Uncertainty of Measurement – Part 3: Guide to the Expression of Uncertainty in Measurement (GUM:1995).*

ASTM D1415, *Standard Test Method for Rubber Property – International Hardness*.

ASTM D2240, *Standard Test Method for Rubber Property – Durometer Hardness*.

ASTM E10, *Standard Test Method for Brinell Hardness of Metallic Materials*.

ASTM E18, *Standard Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*.

ASTM E4, *Standard Practices for Force Verification of Testing Machines*.

ASTM E92, *Standard Test Method for Vickers Hardness of Metallic Materials*.

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*.

Document Revision History

DATE	DETAILS
5/5/11	Initial Publication of Document