Hardness scale maintenance in Italy

5th Italy-USA Bilateral Seminar

5° Seminario bilaterale Italia-USA

COOPERATION IN METROLOGY EQUIVALENCE OF THE NATIONAL STANDARDS DISSEMINATION OF SI UNITS

GAITHERSBURG, 26 - 29 FEBRUARY 1996

COOPERAZIONE IN METROLOGIA EQUIVALENZA DEI CAMPIONI NAZIONALI DISSEMINAZIONE DELLE UNITÀ SI

GAITHERSBURG, 26 - 29 FEBBRAIO 1996

NIST National Institute for Standards and Technology

Consiglio Nazionale delle Ricerche

Istituto di Metrologia "G. Colonnetti" C.N.R.

Istituto Elettronico Nazionale "G. Ferraris"

ENEA Ente per le Nuove Tecnologie l'Energia e l'Ambiente

Editors: Gianfranco Molinar - Flavio Galliana - Paolo Soardo

NIST GAITHERSBURG	5th U.S. - Italy BILATERAL SEMINAR "COOPERATION IN METROLOGY, EQUIVALENCE OF THE NATIONAL STANDARDS, DISSEMINATION OF SI UNITS	26 - 29 February 1996

Hardness Scale maintenance in Italy

A. Germak, S. Desogus

Istituto di Metrologia "G. Colonnetti" (IMGC) - CNR - Torino (Italy)

1. Introduction

The work carried out by the IMGC for hardness-scale realization, maintenance, improvement and dissemination is aimed, essentially, at establishing an appropriate system of hardness measurement traceability available to the national and foreign industry. Industrial requirements have been getting increasinlingly stringent, so that it is necessary, on the one hand, to continue improving standards and, on the other, to modify the norms defining hardness scales, to make them adequate to requirements.

Standardization becomes critical when hardness scales must be correctly defined from a metrological standpoint and, at the same time, be suitable from the viewpoint of industrial needs. The different Quality Systems of industrial concerns involve, to an increasing extent, the determination of materials hardness, to serve as a production testing tool. It is required that the hardness test duration be as short as possible, but this contrasts with metrological exigencies, since in hardness tests, which have a very important dynamic effect, measurements must be carried out under the most stable conditions, which consequently need relatively long times.

Much work is expected for norms preparation; for this reason IMGC takes part in all international and European meetings and promotes the establishment of *ad hoc* working groups.

Obviously, for the maintenance and the improvement of its hardness scales IMGC has established a programme of comparisons with the scales maintained by the national standards laboratories of several countries in Europe and elsewhere /1/. In this way, scales can be regularly checked and, which is also very important, it is possible to observe the effects of modifications in the relevant norms on overall measurement uncertainty.

One important action IMGC undertook some years ago, was cooperative work for the development of hardness scales in countries where work had been until then exclusively entrusted to industrial concerns. In our opinion, the correct realization of hardness scales based on the standards of force, time and length is as important for measurement quality as a correct traceability system is for scale dissemination to the industry.

The most important cooperation has been that of IMGC and NIST, which equipped its laboratory with a hardness standard machine designed by IMGC. This cooperation allows both laboratories to improve their hardness standards. Other cooperation programmes are being carried out in other extra-European countries, to provide consultancy for the establishment of an efficient

traceability system; in future, cooperation is likely to include the construction of other standard machines.

2. Work carried out at IMGC

IMGC designed and constructed all the apparatus it needed for the realization of the main hardness scales. The IMGC hardness laboratory possesses a hardness standard machine /2/ realizing all the Rockwell, Vickers and Brinell scales to 187.5 kgf and a micro-hardness standard for Vickers and Brinell scales from 200 gf to 3 kgf. Instrumentation for indenter checking and for automatic measurement of Vickers and micro-Vickers indentations /3/ has been designed and constructed. Much work is devoted to the improvement of the existing instrumentation and to the development of new apparatus.

Investigations are being carried out also into hardness measurements on non-metallic materials (ceramics, elastomers and rubber) and into universal hardness, that is, the determination of the characteristics of the materials during testing.

Since 1978, the year when the standard hardness machine was constructed, IMGC has participated in several intercomparisons between European countries /4 to 7/, and with the U.S.A., Japan, the People's Republic of China /8/ and Australia /9/. The hardness scales maintained at the IMGC have thus been compared with those maintained by numerous countries all over the world; in majority of cases, results have shown full measurement agreement as regards the uncertainty stated by the different laboratories.

Of the IMGC activities in the hardness field, an important one is scales dissemination to the laboratories accredited by the Calibration Service in Italy (SIT) and to the laboratories accredited by UKAS (NAMAS) in Great Britain, which certify blocks and hardness testing machines. By their activities of hardness testing machine calibration for industrial concerns, these accredited Laboratories allow hardness scales to be disseminated in a capillary way.

3. Results of IMGC cooperation with NIST

In 1992 the Officine Galileo (Italy) constructed a new standard hardness machine according to IMGC design. The machine had been commissioned by NIST as an integrating part a cooperation agreement for the construction of the U.S.A. hardness standard. It was based on the hardness standard machine already existing at IMGC, which had been designed in 1976.

Its essential characteristics are:

- an isostatic, high-rigidity, three-columns structure
- loading by dead-weights
- air-bearing frictionless frame guides
- a laser-interferometer measuring system
- test verification by a load cell.

Initially, its completely automatic test control was made by means of a pneumo-hydraulic system. Sequence management, data acquisition and processing were computer controlled. Thanks to the IMGC-NIST cooperation, the control and operation system of the machine could be considerably improved.

IMGC produced a new electro-mechanical control and NIST a new operation software /10/. This modifications on both machines made it possible to improve the dynamics of testing and machine versatility. With the new control, the apparatus response is, from the dynamic standpoint, more efficient and more easily modifiable; thanks to the new software, it is possible to vary test parameters (duration and velocity), an important feature, which makes the hardness machine a flexible investigation tool for determining result behavior and materials hardness when test parameters are changed. This feature will also make it possible to conform, without difficulty, to future variations in the relevant norms.

The expected results have been achieved, and subsequent comparisons have also yielded satisfactory results (0.1 to 0.4 HRC difference).

4. Activities aimed at norms improvement

In 1994 a European intercomparison was made between the three laboratories which maintain hardness scales in France, in Germany and in Italy. The comparison was confined to the Rockwell C scale and the purpose was to verify the results following changes of certain parameters in the test definition contained in the norms. The changes in question resulted in considerable worsening of the agreement between the scales maintained by the Laboratories. An analysis of the problems connected with hardness measurements /11 to 14/ indicate that the reason for the large discrepancies is to be found in the test definition, which in the new norms /15/ is less metrologically correct than in the preceding definition /16/ and which materializes inadequately in standard hardness machines and, as a consequence, subsequently in industrial hardness testing machines /17/. As fig. 1 shows clearly, results, besides being considerably scattered, exhibit also a systematic effect due to the changes in the norms. Laboratory B (IMGC) has produced two different scales, depending on whether test parameters had been established in accordance with the previous norms (B/2) (as were those of laboratories A and F), or whether the parameters were those contained in the new norms (B/1). The systematic scale shift results constant and appreciable around -0.4 HRC.

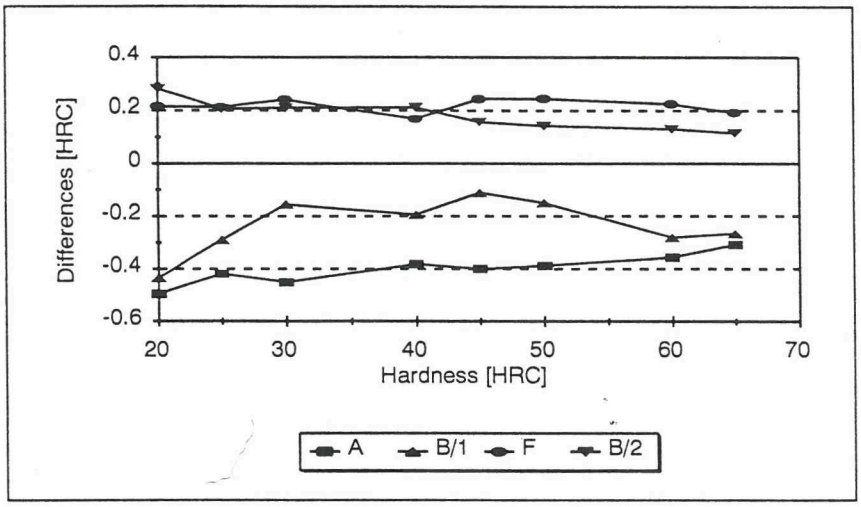

Fig. 1 *Differences between the standard machines (and procedures) determined in the 1994 comparison with a common indenter. The procedure required by EN 10109-3 produces results B/1, whereas the harmonized procedure produces results B/2.*

This fact points out that the work carried out by standardization organizations and the work of the laboratories maintaining hardness scales must be coordinated, since changes in the definition of testing procedures have immediate effects on hardness scales.

On the occasion of the more recent meetings at the European and international levels to discuss modifications in the existing norms, IMGC has promoted the establishment of working groups

to study a correct definition from the metrological standpoint and meeting at the same time industrial requirements. It is advocated that all the standards Laboratories that maintain hardness scales take part in this work, in order to produce norms by which the intrinsic definition uncertainty may be reduced and an adequate quality level in hardness measurements may be attained by the industry.

5. Dissemination in Italy

As already mentioned, IMGC carries out considerable activities for the calibration of reference blocks for secondary SIT-accredited laboratories, such blocks being themselves used for the calibration of hardness blocks and industrial hardness testing machines /18/.

In fig. 2 is schematized the traceability organization in Italy. It is essentially pyramidal, with IMGC at the top maintaining the standard, at the second level, the laboratories accredited for block calibration and at the third, the laboratories accredited for industrial hardness testing machines.

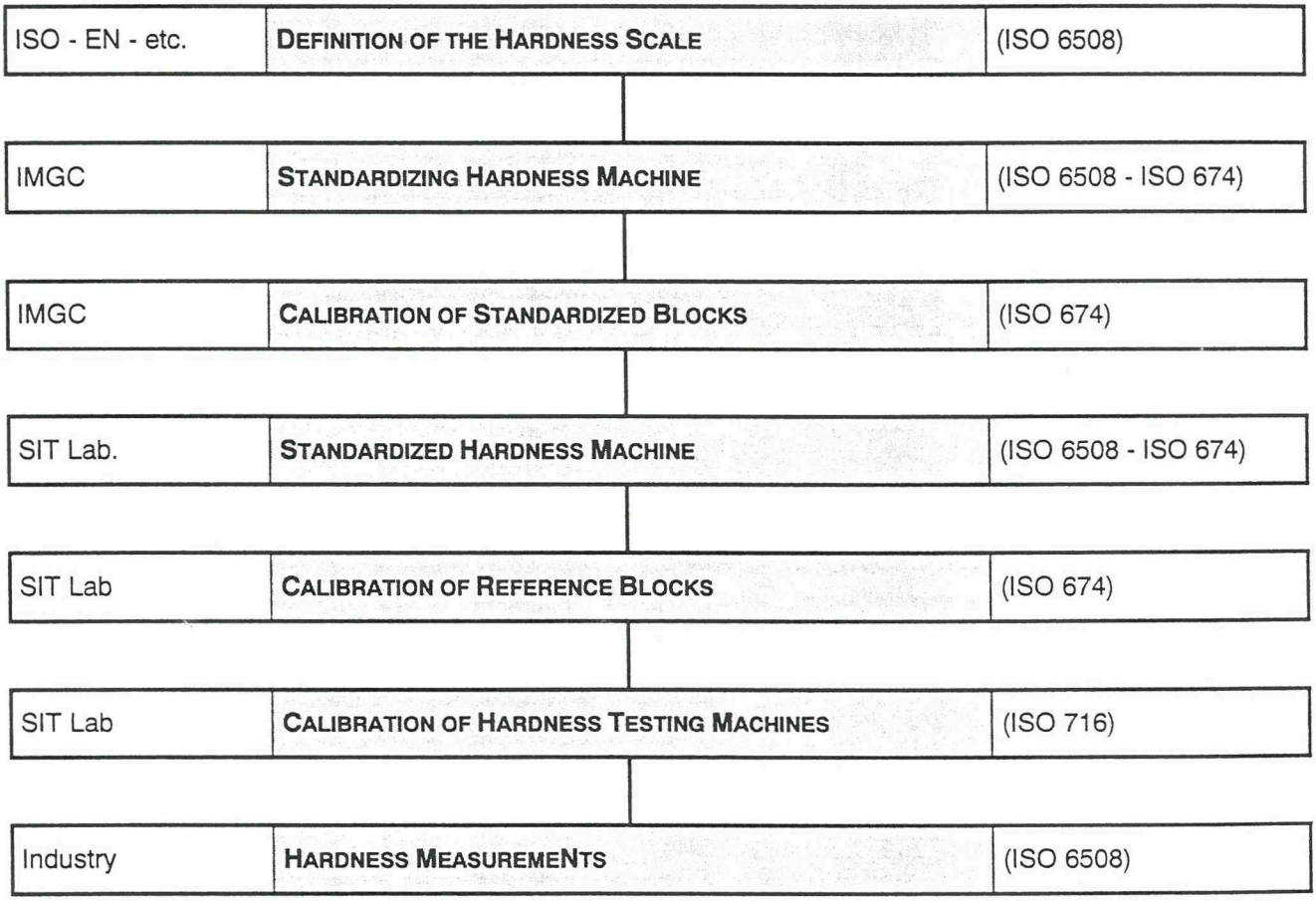

Fig. 2 Scheme of hardness scale dissemination in Italy. The diagram shows the responsible laboratory and the norms for each of the levels (HRC example).

Dissemination is carried out essentially by means of blocks and the calibration of hardness testing machines. During the phases of new laboratory accreditation and of accreditation renewal,

IMGC has the role of laboratory evaluator and of the technico-scientific responsible organization. This involves examination and checking of staff, laboratory structure and procedures; calibration of the measuring instrumentation and the supply of standards. In the specific case of hardness, once the basic conditions (staff, laboratory structure and procedures) have been proved satisfactory, the secondary hardness machine to be used for block calibrations is calibrated /19/ and, finally, measurement values are checked on the basis of blocks calibrated by the IMGC. This ensures perfect traceability to standard, as is required also by the present international norms for Quality Assurance. Analogous procedures are applied for the accreditation of the secondary laboratories that calibrate industrial hardness testing machine. In this case, too, traceability to standard is ensured.

Since the present traceability system in Italy is similar to that of the United Kingdom and since in 1988 NPL decided to cease maintaining hardness standards, an agreement was stipulated in the EUROMET framework between IMGC and NPL, according to which IMGC maintains and disseminates hardness scales also on the behalf of the U.K. Within the framework of this agreement, several block calibrations are made yearly for the UKAS (NAMAS) accredited laboratories, such blocks being used for the calibration of blocks and industrial testing machines. It must be pointed out that IMGC has no role whatever in laboratory accreditation (and accreditation renewal) and that, consequently, UKAS is totally responsible for the verification of the conditions necessary for accreditation granting.

In accordance with the mutual recognition of several European Accreditation Systems, the Italian SIT Centers which calibrate industrial hardness testing machines are free to choose, for use in calibrations by the indirect method, blocks calibrated by SIT accredited laboratories or accredited by UKAS or other recognized accredited bodies.

In the light of the work jointly carried out by IMGC and NIST as regards hardness measurements, mutual recognition in this field would be recommendable. Obviously and besides continuation of comparisons (possibly extended to other scales) between the two primary partners, it would be necessary to examine carefully the two different traceability systems in force in Italy and in the U.S.A. Such mutual recognition would deservedly crown the cooperation which has now been developed during several years and would be of advantage especially to the industrial concerns, of both countries, having commercial relationships with the foreign partner.

6. References

[1] Helmrath Ch., Gould D., *The development of a unified European HRC hardness scale*, VDI Berichte 804, (1990) 316-324.

[2] Barbato G., Desogus S., Levi R., *Design and performance of a dead-weight standard Rockwell hardness testing machine. Journal of Testing and Evaluation*, p. 276[27. 1978.

[3] Barbato G., Desogus S., Grattoni P., *Automatic Vickers Indentation Measurement.* Testing of Metals for Structures, Edited by F.M. Mazzolani, 1992.

[4] Stute H., *Final report: Investigation and performance tests on HRC*, MPA NRW report on contract 1231[1[4[031[82[9BCR-D, (1983).

[5] Wood J. G., *Report: Intercomparison of Hardness Measurements for the Community Bureau of References (BCR)*, Contract N. 1601[1[4[031[83[9, 1986 and
Peggs G. N., *Syntesis Report on the intercomparison of hardness standards,* NPL report ISSN 0309-3069, (1988).

[6] Barbato G., Desogus S., Germak A., *Report on the Microhardness Test Carried out for the BCR Comparison*, Feb.1988, Rapp. Tec. Int. Nr. 261.

[7] Barbato G., Desogus S., Germak A., *Comments on the results obtained in the comparison of the HRC scales maintained at ETCA, IMGC and MPA NRW,* VDI VDE Berichte, Dusseldorf 1995.

[8] Desogus S., Germak A, Li Qing Zhong., *Comparison results of hardness between NIM and IMGC*, Apr. 1995, Rapp. Tec. Int. Nr. 401.

[9] Germak A., *Attività svolta presso lo CSIRO-NML*, Jan1996, Rapp. Tec. Int. Nr. 421.
[10] Barbato G., Desogus S., Germak A., *The IMGC Hardness Standard Machine. Description of the actual software and of proposed modifications*, Gen. 1992, Rapp. Tec. Int. Nr. 345.
[11] Weiler W., *Ein Beitrag zur Abhangigkeit der Rockwell Harte von der Zeit der Lastaufbringung*. VDI Berichte n. 100 (1967).
[12] Marriner, R.S., Wood J. G., *Comparisons of international Rockwell C and Vickers HV30 Hardness Scales during 1970 and 1971*, NPL report MC8, (1972).
[13] Barbato G., Desogus S., Levi R., VDI Berichte, (1978) 97-103.
[14] Barbato G., Desogus S., Levi R., *Journal of Testing and Evaluation*, (1978) 276- 27.
[15] Barbato G., Desogus S., Germak A., *Hardness Measurement from Empiricism to Metrology - An application to Rockwell C scale, in "Basic Metrology and applications",* Levrotto &Bella, Torino, 1994.
[16] Barbato G., Petik F., *Metrological involvement in the definition and dissemination of hardness scales*, XIII IMEKO World Congress, Torino, (1994) 761-766.
[17] Petik F., *The Effect of a Change of Loading Cycle Parameters in Hardness Testing*, OIML Bull. N. 113, (1988) 35-40.
[18] Bertozzi R., Germak A., *La misura di durezza sui materiali metallici*. Apr. 1995, Conv. annuale SIT, 1995.
[19] Barbato G., Desogus S., Gori G., Liguori A., *Realization of the Officine Galileo hardness standard machine and comparison with the national hardness standard of the IMGC*, VDI Berichte 583. p. 323[345. 1986.