

The CIPM Working Group on Metrology of Materials

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ABSTRACT

Following international discussion of the traceability issues arising in the measurement of materials properties, the CIPM meeting in October 2005 accepted the proposal to set up an *ad hoc* Working Group on Metrology of Materials. The Working Group is assessing a wide range of materials properties, looking particularly at the need for improved traceability routes, data comparability and the availability of appropriate reference materials. The Group will report to CIPM in October 2007, with the intention of raising the profile of materials metrology internationally and engaging the leading NMIs (National Measurement Institutes) in recognising and addressing known difficulties in demonstrating traceability of many material properties to the SI. Terms of Reference have been agreed, and the first meeting took place at the UK's National Physical Laboratory in May. This paper describes the range of properties being investigated and highlights the studies being undertaken by the Working Group members.

1. BACKGROUND

The need for wider international collaboration in the measurement of materials properties, and in particular the issues of standards and traceability have been under discussion for a number of years at meetings of the Versailles Project on Advanced Materials and Standards (VAMAS). VAMAS operates under a Memorandum of Understanding signed by senior representatives of government in countries of the Economic Summit (G7) and of the European Community. It supports international trade through projects aimed at providing the technical basis for drafting codes of practice and specifications for advanced materials. The scope of this international collaboration embraces all aspects of enabling science and technology required as a precursor to the drafting of standards. Through its activity, VAMAS fosters the development and harmonisation of international standards for advanced materials by the various existing standards agencies. Since its inauguration in 1982, VAMAS has had a considerable impact on the development of internationally accepted standards for engineering materials. The specification of materials in terms of their characterisation and their performance is based mainly on measurement methods and procedures, with a lack of emphasis on the need for reliable traceability.

In 2004, the VAMAS Steering Committee approved actions aimed at bringing about closer collaboration between VAMAS and CIPM. Seeing the need to widen participation in their activities, Dr Graham Sims (VAMAS Chairman) wrote to Professor Andrew Wallard at BIPM, drawing his attention to the need to include materials in the formal international structure for metrology by engaging the attention of NMIs and the CIPM. They saw this as the way to bring international authority and metrological experience to the hugely important and growing area of materials metrology.

Following discussion at the meeting of NMI Directors in September 2004, BIPM hosted a workshop in February 2005 to explore the issues, identify specific traceability issues in materials science and propose further international initiatives in the field. The conclusions of this workshop informed a discussion at the 2005 meeting of the CIPM (Comité Consultatif des Poids et Mesures). The CIPM decided to set up an *ad hoc* Working Group with the following Terms of Reference:

- to identify those material properties for which globally comparable, traceable measurement results are important for science, engineering and manufacturing technology;
- to identify those material properties for which the needs for traceable measurements are not covered by the activities of the Consultative Committees;
- to establish the user needs for activity in materials metrology;
- to investigate the existing capabilities of participating NMIs by initiating some pilot studies, including a small number of interlaboratory comparisons;
- to develop tools and methodologies for establishing traceability in materials testing; to define the objectives, aims and initial activities for an ongoing programme in metrology for materials, including recommendations for underpinning activities, such as the organisation of Key Comparisons and the development of Reference Materials and Reference Methods; to liaise closely with other interested organisations; and to report its conclusions to the CIPM by October 2007.

2. THE ISSUE: MEASUREMENTS, TRACEABILITY AND STANDARDS

In most areas of metrology, the concept of traceability to established national or international standards is well understood. The SI (Système International) provides a coherent set of well-defined units which provide a common language for expressing and understanding the results of measurements. The NMIs maintain standards according to their national needs and the equivalence of these standards has been established through the mechanisms of the CIPM Mutual Recognition Arrangement: key intercomparisons, mutual review of claimed capabilities and regional assessment of NMI quality systems.

The result of this methodology is that NMIs can generally demonstrate excellent agreement in intercomparison exercises in these classical fields and they pass this metrological confidence on to accredited laboratories which are in turn required to demonstrate the traceability of their results. Figure 1 shows the results of measurements of the length of a 175-millimetre gauge block by eleven NMIs. All the results agree within 1 part in 10^6 and with one exception the agreement is better than 3 parts in 10^7 . This impressive result reflects a very thorough and careful approach to the relatively straightforward measurement of a length standard.

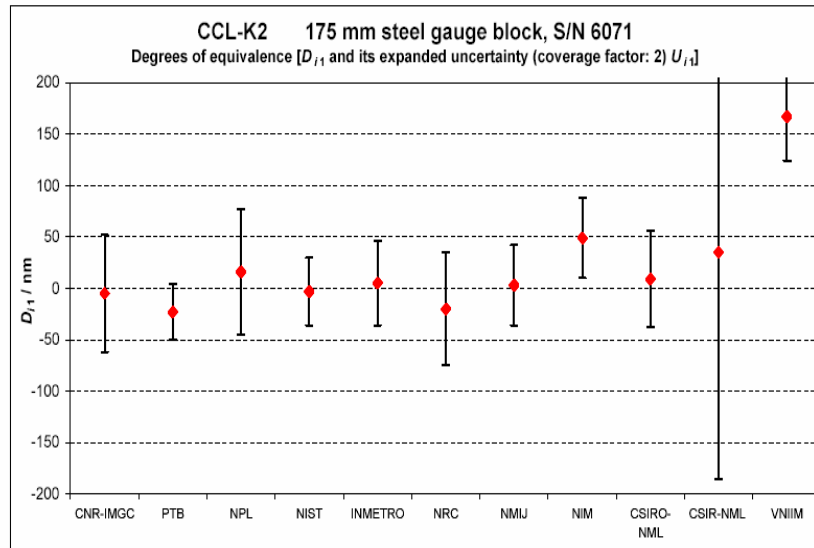


Figure 1. Results of international comparison of 175-mm gauge block

Similar exercises to evaluate the ability of laboratories to measure materials properties are often less impressive. Figure 2 illustrates the results of a national intercomparison exercise in the UK to determine Young's modulus. The spread of the results from 25 laboratories for a simple modulus measurement show a spread of nearly 25%. There are many possible reasons for this enormous discrepancy between laboratories, but the contrast with the level of agreement obtained by NMIs comparing results for the calibration of a length standard could hardly be more marked.

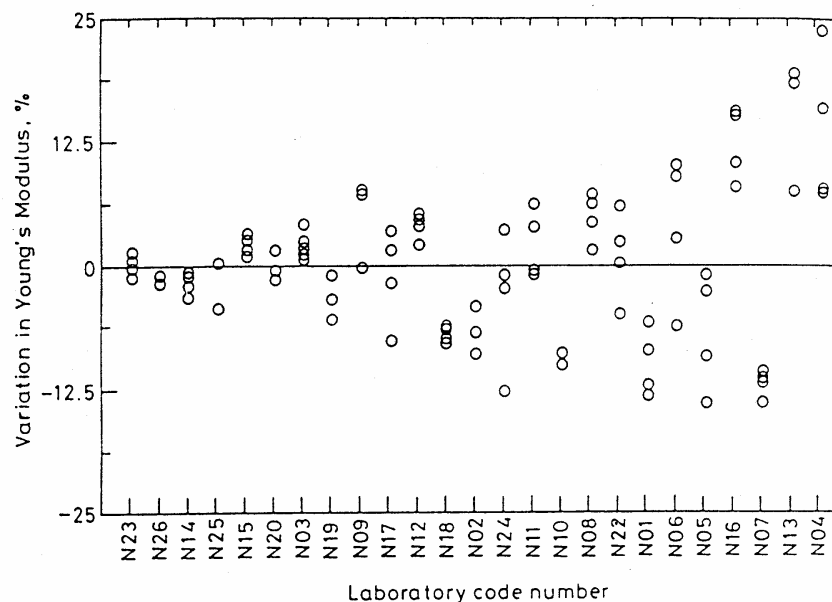


Figure 2. Results of round robin determination of Young's modulus.

3. THE CIPM WORKING GROUP

Following the 2005 CIPM decision, the *ad hoc* Working Group has been established with experts from NMIs and other institutes in some 10 countries. The first meeting of the Group, in May this year, began with a discussion of the materials properties which are important for science and manufacturing, and explored some of the issues associated with establishing traceability to appropriate standards. To the list of obvious properties (mechanical, electrical and thermal coefficients of solids) were quickly added a number of properties of liquids and the distinct properties of materials on the nano-scale.

No experimental studies or intercomparisons are planned at this stage, as the Working Group decided it was more important to concentrate on collecting information about previous exercises and to study existing provisions for traceability when materials properties are being measured in testing laboratories and elsewhere. The Group recognised that in some cases traceability may be to a standard or a procedure, rather than to the SI in the generally accepted sense, and that the reliability, repeatability and reproducibility of results will be affected by a number of factors. There is also a need to seek the views of the user community in order to identify those properties for which repeatability and comparability are particular problems.

The Working Group will meet again towards the end of the year to examine the available evidence and determine what further work should be undertaken.

4. PROPERTIES AND PROBLEMS

A key question is to differentiate between intrinsic properties of materials and other parameters related to the form and scale of a specimen. Thus thermal expansion or Young's modulus are quite clearly intrinsic properties, while surface finish or particle size describe individual samples and may effect the results of measurements of properties. The use of standardised measurement procedures, as for hardness, creates a repeatability which depends on careful adherence to the accepted measurement sequence and a form of traceability when everyone uses the same procedure. Separating the properties of materials from the factors and problems which influence the results of measurements is seen as an important task to be undertaken by the Working Group before they can identify the genuine traceability issues which will form the core of their final report.

5. THE WAY AHEAD

The Working Group will meet again in December 2006. Meanwhile, as well as collecting historical data about previous intercomparisons and identifying issues associated with specification standards and measurement procedures, an attempt will be made to obtain views and information from the user community. For which material properties is it particularly difficult to demonstrate traceability as the *"property of the result of a measurement ...whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties."*(VIM 1993)? Which measurement results is it difficult or impossible to express in terms of SI units? Where is there a particular need for intercomparisons to establish equivalence and repeatability between different laboratories and various procedures?

Following the December meeting, the Working Group will undertake further work, possibly including some very limited pilot intercomparisons, before preparing its report for the CIPM meeting in October 2007. This report may include recommendations for new initiatives to improve the comparability and traceability of the measurement of materials properties worldwide.

One reason for making this presentation to NCSLI this year is to put these questions to a wider audience. If you represent a testing laboratory, an accreditation body, a materials producer or a manufacturer needing to obtain accurate values for the properties of the materials you use, the Working Group would like to hear from you. Information and case studies on past difficulties are of particular value. Why not come to the session, ask questions and let us know your views?