

THE AUSTRALIAN METROLOGIST

A publication of the Metrology Society of Australia. ISSN 1321-6082



NO 20 FEBRUARY 2000

MSA'99 ISSUE

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FROM THE PRESIDENT

The festive season has come and gone and we are in a new century. You might have recognised the names of some of our MSA members in the media in discussions of the "beginning" of the millennium. Enough said on the matter, where the power of the popular press proved unstoppable. Never mind, we true believers get to celebrate twice.

The planning for 2001 has begun – Tony Collings (CSIRO Lindfield) has taken on the role of conference chairman. The meeting will be held in Queensland, on the Gold Coast. It will be a good test of organisation mostly from afar, with a local support group. On the topic of distance, the national committee now has 2 interstate members, and has adopted Mr Bell's invention of the telephone for its meetings, with conference calls so that the interstate representatives can more fully participate in the general business of the Society.

The networking advantage of society membership has come to the fore recently. Alex Smart and Carl Sona have been organising, at short notice, a series of seminars on geometric tolerancing in 3 or 4 centres. This came about because Alex became aware of a well regarded international expert in the area coming to Australia and offering courses as a break in what is essentially a holiday. At minimal cost, participants will reap the benefit of the society lists being used for rapid dissemination of information necessary to

coordinate the event, despite co-timing with the holiday (silly?) season.

On a more personal note, I'm of an age such that my schooling coincided with the heydays of construction of the Snowy Mountains Scheme. I've recently had the opportunity to visit some of the scheme's structures and now-abandoned sites, in company with ex-SMA workers, who identified the features and problems that had to be overcome. The scheme remains a marvel of engineering, but one backed by a great deal of measurement and metrological skill in both planning and construction stages.

Most areas of measurement were important, not just dimensional metrology, and there is a parallel with modern times where many people are performing good quality metrology without being identified as metrologists, i.e. specialists. As a society, we have much to offer those engaged in metrology in a part-time role – our problem is to identify and appeal to these people.

- Jim Gardner

FROM THE EDITOR

This issue has been mainly devoted to MSA'99 conference material. Some articles have been held over to the next issue. **Pictured below** is President Jim Gardner welcoming Prof. Finkelstein (left) and presenting the MSA Award to Len Kerwood (right).

- Maurie Hooper



Measurement for a Sustainable Future MSA 99 - A Great Success

Kerry Marston provided this overview of MSA99.

Metrologists from many different fields of endeavour came from all over Australia and the world to share their expertise, to listen, to discuss and to offer their opinion on the wide ranging issues surrounding 'measurement for a sustainable future'. The occasion was our third biennial conference of the MSA held at the University of New South Wales, Sydney in September 1999.

The conference opened on a high note with an excellent keynote address by Professor Ludwik Finkelstein, Head of the Measurement and Instrumentation Centre at the City University, London. Professor Finkelstein in his address 'From Measurement to Knowledge and Thought' explored the fundamental concepts of measurement including it as a source of information, a language and its philosophical import.

The challenge was indeed opened to explore the fundamental importance of measurement in order to have a sustainable future. Professor Finkelstein challenged all metrologists as 'the guardians of the fundamental concepts of measurement to exercise their rightful influence on the affairs of society'.

The warm balmy Spring days did nothing to discourage enthusiastic participants from taking this challenging discussion outside into the sunshine during tea and coffee breaks. A wild Spring hail storm during the opening cocktails only served to increase the high spirits and good talk evoked by a satisfying day, the delicious food and drinks and a thought provoking address from Peter Roberts, a journalist from the Financial Review.

In his address Mr Roberts gave us his thoughts on a New Industry Policy for the New Millennium and made it clear that knowledge would be the competitive edge for the 21st century. So it will be 'those industries that harness their knowledge, that manage their knowledge and that exploit their knowledge that are going to get ahead'. Metrology, a vital source of knowledge underpinning industry must be harnessed, managed and exploited by Australian industry if it is going to get ahead and compete with the rest of

the world. (For the complete paper see the last issue of TAM.)

Bernard King was no less challenging in his address to open the second day of the conference, as he explored and explained the current developments happening within chemical metrology and highlighted some of the many challenges that still lay ahead.

The second day saw happy groups of people climbing into buses en route to a variety of technical visits. This was followed by the conference dinner held overlooking Sydney's famous harbour at Taronga Zoo. The view from the balcony as the sun set over the opera house and bridge was stunning as we sipped our pre-dinner drinks.

During the dinner Jim Gardner took the opportunity to present the MSA Award 99 to Len Kerwood of Gawler Instrument Company. This was followed by a very entertaining address given by 'Dr. Yannis Carraganis, President, Hellenic Metrology Society'. Only those at the dinner can tell you the content of his address, but the laughter was loud and the smiles very broad as 'Dr. Carraganis' took us a journey of metrological discovery. So thoroughly did he enthrall us with his metrological tales, that on cue 100 well respected, intelligent and highly skilled metrologists rose as one person, put hands on each others' shoulders and danced the dance of 'Zorba the Greek'. Who would have believed it possible?

The next day it was back to work with an opening address by Dr. Bruce Cornell on 'Purpose built Biomimetic Molecular Sensing Systems', cutting edge material indicating future directions for metrology in a highly competitive industrial world. This was followed by debate/discussion concerning the tension between the need to make a profit and the need for quality metrology - to further explore important aspects of the economic issues in metrology. No conclusion can of course be reached on this important topic, but many wide ranging and different points of view were debated and aired with discussion continuing well into lunch.

During the morning tea break, many participants took the opportunity to examine and talk to

trade measurement inspectors at the conference to explain the mobile test equipment displayed by NSW Department of Fair Trading. The equipment is used to inspect measuring instruments used for trade.

The papers during the technical program were very varied and of a high standard, one of the most gratifying comments heard by the organising committee was that some participants were having difficulty choosing which paper to attend. As well as a very good range of papers covering core metrology, there were also a significant number of papers covering the broader range of metrological topics such as: the role of measurement in environmental management; metrological control in medicine; metrology and the community; measurement and economics, and international developments; just to name a few.

A very successful highlight was introduction of a number of mini-training workshops into the conference program. These were very popular and were over subscribed in every case. The workshops covered such topics as:

- * Implementing ISO 17025 in the Laboratory,
- * Internet Application and Services in the Metrology Laboratory,
- * Introduction to Uncertainty,
- * Preparing an Uncertainty Budget,
- * Uncertainty - Advanced Calculations, and
- * New Verification Requirements for Non-Automatic Weighing Instruments.

The workshops proved to be so successful that it has been suggested that they might become a regular feature of future MSA Conferences. A number of additional topics have already been suggested for the next conference, perhaps you too have some topics you would like to see cov-

ered in a workshop at the next conference. If so let the next organising committee know.

Another feature of the conference was an Australia wide School Poster Competition sponsored by the National Standards Commission. Schools were asked to have their students submit posters of the experimental work they had done based on the schools' resource kit 'Measurement in Sport' developed by the Commission. More than fifteen posters were displayed in the main conference area making an interesting conversation point for many participants.

The conference was an ideal opportunity for old friends to meet, for businesses to make new contacts and for a whole range of metrology networking to take place. The opportunity was also used for MSA specialist groups such as the Pressure Measurement and the Torque Measurement Groups to meet and discuss business.

Special thanks must be given to all our sponsors and trade exhibitors. Without the support of industry and the national metrology organisations the conference just would not be possible.

MSA 95 was an excellent beginning, MSA 97 was even better and established an international reputation, MSA 99 built on this experience and established the biennial conference as an important pivotal activity for the Society. It has established an international arena for new research and ideas to be shared, a place where information can be gathered, old as well as new issues aired and different points of view shared, HRD to take place, networks to be established, a venue for the Society's special interest groups to meet, and much more.

Start planning now to come to MSA '01 towards the end of the next year, it will be even better.

FROM MEASUREMENT TO KNOWLEDGE AND THOUGHT

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ABSTRACT

The paper reviews the fundamental concepts of measurement. It asserts their significance and traces their historical development. It presents an informal definition of measurement, followed by an outline of a formal analysis using the model

theory paradigm. The concept of representation by measures is extended to general representation by symbols. The concepts of information, language and information machine are discussed in that framework. General principles of the pragmatics of symbolic representation, with spe-

cial reference to measurement are reviewed. The paper also reviews problems of the fundamental concepts of measurement in the physical sciences, as well as in the behavioural and social sciences.

INTRODUCTION

Our society has adopted the call of Galileo to: "Count what is countable, measure what is measurable, and what is not measurable, render measurable". Because of its key importance to us, it is incumbent on us, especially on metrologists, to understand clearly the fundamental concepts of measurement and their philosophical import. The objective of this paper is to review them.

OUTLINE OF HISTORICAL DEVELOPMENT

The technology of measurement and its instrumentation dates from the dawn of material civilisation. It developed from intuitive understanding of its fundamental concepts and it can be said that it still continues to do so,

The early thought about the philosophical nature of measurement dates from the Greeks. It has been developed by the Schools of Pythagoras, Plato, and Aristotle. The Middle Ages saw much scholarly thought about the theory of measurement, but little thought about application of measurement to empirical observation. With the rise of modern science Newton, in his development of mechanics developed a theory of magnitudes based on arithmetic.

The true foundations of the modern theory of the basic concepts of measurement were laid down by Helmholtz in 1887, in a thorough analysis of the epistemological basis of counting and measurement, followed in 1901 by an examination of the measurement of additive quantities by Hoelder. In 1920 Campbell provided a thorough analysis of the foundations of the measurement of the quantities of physics. This came to be widely accepted.

The development of the behavioural, social, and management sciences offered major methodological and philosophical problems. Classical measurement theory rejected measurement in these sciences, but their urgent needs caused radical revisions of thought about the foundations of measurement.

The needs to provide a solid logical foundation for the new, wider, concepts of measurement led to the next step. The tools for this were provided by the influential and powerful model theory, and led to the development of the representational theory of measurement that has now been broadly accepted.

In considering the significance of measurement in modern philosophy it is necessary to mention operationalism, which holds that all physical entities, processes and properties are definable in terms of the operations by which they are observed, or measured. More generally, the school of logical positivism, took as its basis the verification principle, which held that the meaning of a proposition consists of the method of its verification; that is in whatever observations, determine whether, or not it is true or false. Operationalism and positivism, have been criticised and have receded from the centre of philosophic concerns, but their approaches remain a powerful influence on scientists.

In the last twenty five years the foundational concepts of measurement have been extensively discussed in the frame of measurement and instrumentation science and technology.

INFORMAL DEFINITION OF MEASUREMENT

Measurement is the process of empirical, objective assignment of numbers to the attributes of objects and events of the real world in such a way as to describe them.

Before embarking on a formal presentation of the logical basis of measurement it is useful to discuss the definition of measurement informally.

Firstly, measurement is the assignment of numbers to properties of objects and events and is thus the description of properties of objects or events and not of the objects or events. Measurement is based on a clear concept of a property or attribute, as an abstract aspect of a whole class of objects, of which individual instances or manifestations are the subject of measurement.

The definition states that the assignment of numbers in measurement is such that the numbers describe the property of the object or event. The meaning of this can be explained as follows. Consider that a number, or measure, is assigned by measurement to the property of an object, and other numbers are assigned by the same

process to other manifestations of the property. Then the numerical relations between the numbers or measures, imply, and are implied by, empirical relations between the property manifestations.

It follows that measurement is a process of comparison of a manifestation of a property, with other manifestations of the same property, a common feature of informal definitions of measurement.

ELEMENTS OF FORMAL THEORY OF MEASUREMENT

The concept of measurement, informally presented above, will now be presented formally, using the representational or model theory approach.

A representational theory of measurement has four parts:

(i) an empirical relational system corresponding to a property; (ii) a number relational system; (iii) a representation condition; (iv) a uniqueness condition. These will now be considered.

(i) Property as an empirical relational system

Consider some property and let q_i represent an individual manifestation of the property Q , so that we can define a set of all possible manifestations as

$$Q = \{q_1, \dots\}$$

Let there be on Q a family R of empirical relations R_i

$$R = \{R_1, \dots, R_n\}.$$

Then the property is represented by an empirical relational system $Q = \langle Q, R \rangle$

(ii) Numerical relational system

Let N represent a class of numbers $N = \{n_1, \dots\}$

Let there be on N a family P of relations $P = \{P_1, \dots, P_n\}.$

Then $N = \langle N, P \rangle$ represents a numerical relational system. Commonly N is just the real number line.

(iii) Representation condition

The representation condition requires that measurement be the establishment of a correspondence between property manifestations and

numbers in such a way that the relations between the referent property manifestations imply and are implied by the relations between their images in the number set. Formally, measurement is defined as an objective empirical operation M

$$M: Q \rightarrow N,$$

so that $n_i = M(q_i)$, and $Q = \langle Q, R \rangle$ is mapped homomorphically into (onto) $N = \langle N, P \rangle$

The above homomorphism is the representation condition.

Firstly it implies that if q_i is related to q_j by an empirical relation R_k , that is $R_k(q_i, q_j)$, and P_k is the numerical relation corresponding to R_k , then $R_k(q_i, q_j)$ implies and is implied by $P_k(n_i, n_j)$

Measurement is a homomorphism, rather than an isomorphism because M is not one-to-one; it maps separate but indistinguishable property manifestations to the same number.

$$S = \langle Q, Z, M \rangle$$

constitutes a scale of measurement for Q .

$n_j = M(q_j)$, the image of q_j in N under M is called the measure of q_j on scale S

(iv) Uniqueness condition

The requirement that the fundamental measurement procedure of a scale should map the empirical relational system Q homomorphically into the numerical relational system N does not determine the mapping uniquely.

There is an element of arbitrary choice in the setting up of scales of measurement. For example in the case of scales based on additive combination, for instance the choice of the unit standard is arbitrary.

The requirement of homomorphism thus defines a class of scales that may be called equivalent. The class of transformations that transform one member of a class of equivalent scales into another is called the class of admissible transformations. The conditions which admissible transformations must satisfy are known as the uniqueness conditions.

GENERAL SYMBOLIC REPRESENTATION

Measurement as defined above can be seen as a special case of general representation of entities

by symbols.

An object termed the symbol may be said to represent another object or event termed the referent, by bearing a known relation to it.

We can now briefly present the formal theory of symbolic representation, which essentially follows the discussion of measurement above.

Let q_i be a referent entity. Consider further that q_i is a member of a family or set of similar entities Q , $Q = \{q_1, \dots\}$,

Q is termed the referent set. Let there be on Q a family R of relations $R = \{R_1, \dots, R_n\}$. $Q = \langle Q, R \rangle$ is termed the referent relational system.

Let now z_i be a symbol entity. Consider further that z_i is a member of a family or set of similar entities Z , $Z = \{z_1, \dots\}$,

Z is termed the symbol set. Let there be on Z a family P of relations $P = \{P_1, \dots, P_n\}$. We may term $Z = \langle Z, P \rangle$ the symbol relational system.

Let there be a mapping $M: Q \rightarrow Z$, so that $z_i = M(q_i)$.

Further let there be a mapping $F: R \rightarrow P$ so that $P_i = F(R_i)$.

Let the mappings represent an isomorphism.

We may define $C = \langle Q, Z, M, F \rangle$ where C is the representation code, and its inverse, the interpretation code.

z_i is termed symbol of or for q_i .

SEMIOTICS

The term semiotics describes the general science of description by symbols. Measurement representation may be considered to be a special aspect of semiotics.

Semiotics has four branches or aspects. They are:

- (i) Syntactics, the rules of permissible combination of symbols,
- (ii) Semantics, the relation of symbols to the entities and relations they represent
- (iii) Pragmatics, the relation of the symbolic representation to the information handling system in which they are employed, and in particular its

objectives, and finally

(iv) Sigmatics, the study of the nature of the semantic relations between referent and symbol. In general these relations are established by convention, and do not present problems, there are nevertheless symbol representation systems in which there are extra-linguistic relations between symbol and referent.

INFORMATION

The most important concept of information can be defined and explained from the above formulation of general symbolic representation.

Information about the referent consists of a symbol for the referent together with the representation relation. The foregoing informal definition can be expressed formally and more widely as follows:

If z_i is a symbol of or for q_i , then information about q_i given z_i can be denoted by $J(q_i|z_i) = \langle z_i, C \rangle$.

This definition of information is wholly consistent with the Shannon definition of quantity of information, indeed it is implied by it.

LANGUAGE

For the purposes of this paper it must suffice to state briefly that a language is a collection of symbols, together with the rules of their combination, or syntax., in other words, a general symbol representation system

Thus using the kind of notation employed above, a language L for the description of objects and their relations, may be defined as $L = \langle Z, P, G \rangle$, where Z is a set of individual symbols, P is a set of relation symbols and G is a set of function symbols.

A typical sentence in such a language is $P_i(z_1, \dots, z_n)$.

A code, such as C above, describing the correspondence of the linguistic symbols to the real world, or more generally to extra-linguistic entities and their relations, constitutes the semantics of the language.

Measurement statements are statements in a language.

KNOWLEDGE

Knowledge is a fundamental philosophical con-

cept, the subject of the branch of philosophy termed epistemology. Essentially it consists of a set of propositions which are true, which a subject believes to be true and which the subject is justified in believing to be true. It is a complex concept and especially the justification of belief is a matter of substantive philosophical disagreement. The concept of knowledge in a narrower, special sense, has become a key concept of information technology and will be adopted in this presentation.

Measurement statements, are knowledge statements, of a particular value, because of their objectivity and base in empirical observation.

INFORMATION MACHINES

The concepts of symbolic representation outlined above, and the definition of information, offer a perspective on the nature of information machines.

Information machines are machines or systems of machines which have as their function the acquisition, processing, outputting and effectuation of information. They comprise computers, communication systems and what we term instrumentation. Information machines operate by transforming input symbols into output symbols by defined transformations.

Thus, if L_i is the input symbol representation language and L_o is the output symbol system, an information machine may be defined as a machine which carries out a prescribed transformation: $T: L_i \rightarrow L_o$

Measuring instruments and instrumentation systems are information machines.

One of the most promising approaches to understanding thought is by using the information processing approach. There is thus a clear line from measurement, to knowledge and to thought.

PRAGMATICS

An attempt will be made to formulate some general principles of Pragmatics, dealing firstly with measurement representation and then with more general symbolic representation.

One of the principal values of measurement is that it is an objective process, that is the numbers assigned to a property by measurement are, within the limits of error, independent of the observer.

The relations represented by measures are empirical, that is they must be established by observation and not convention.

It is held by many theoreticians of measurement that true measurement must be a numerical representation. However it has also been argued that there may be objective, empirical representations which are symbolic and not numerical.

For symbolisation in general the following rules of pragmatics apply:

The value of a symbolism increases with its precision.

The value of a symbolism increases with its completeness.

The value of a symbolism for a relational system increases with the richness of the relational system involved. More formally it increases with the cardinality of Q and R .

The value of a symbolism depends upon the pragmatic value of the relational system Q in the supersystem of which the semiotic system forms part. Trivial relational systems, such as for example trivial classifications are of no value. The value of the symbolic representation of a property depends upon the relations into which it enters with other properties.

The purpose of symbolisation is that it should be further processed effectively by information processing systems. The value of a symbolisation depends upon its convenience for information processing and in particular on two aspects:

- Compactness: The ease of processing of a symbol depends of the its compactness that it requires less time for processing and less capacity for storage. The comparison of compactness must take place with all other factors equal, that is for example for symbolisms of the same precision.

- Immunity from error: The form of symbolism should be such, that it is as far as possible immune for errors in processing

The value of a symbolism depends upon its compatibility with a symbolic system of inference and reasoning. Thus the value of measurement on a ratio scale is that it is compatible with algebra and calculus.

MEASUREMENT THEORY IN THE PHYSICAL SCIENCES

The classical theory of measurement was developed to give an account of measurement in the physical sciences. In terms of this classical theory, measurement in the physical sciences is based on establishment of direct additive scales of measurement for a number of physical quantities. These quantities are used as the base of a system. Scales for other physical quantities are obtained as derived scales, that is indirect scales in terms of the base quantities, in the form of multiplicative monomial functions of the base quantities. This account is not totally satisfactory even for classical physics. The situation of physics is that it consists of a number of axiomatised theories such as Euclidian geometry, classical mechanics, thermodynamics, electromagnetism, and so on. The scales of measurement of classical physics are based on the acceptance of these theories as representations of the real world and defining the units on that basis rather than on the individual axiomatization and establishment of scales of particular physical quantities.

Special problems arise in quantum and relativistic physics that cannot be handled by the theory of measurement presented above. In quantum physics the interaction between observer and observed system imposes a limit on the certainty of the joint measurement of the attributes of the system such as position and momentum. This imposes a fundamental difficulty for measurement theory. The theory of relativity has a large impact on the theory of measurement in the physical sciences. In terms of the view presented above it attempts to represent reality using a theory different from those used in classical measurement, for example classical mechanics. The rejection of the concept of simultaneity and an upper limit to velocity are examples of such differences. There are thus fundamental developments of application of measurement theory to the physical sciences to be undertaken.

MEASUREMENT THEORY IN THE SOCIAL AND BEHAVIOURAL SCIENCES

A complete analysis of the theory of measurement in the social and behavioural sciences would require a detailed discussion of their nature, content and methodology. The subject would be too extensive to tackle in this presentation. However, some of the key problems of the

theory and philosophy of measurement in these sciences can be simply summarised. The social and behavioural sciences are concerned very much with such attributes or properties as standard of living, alienation, intelligence, and the like. The first problem in attempting to measure them is the difficulty of establishing an adequate objective concept of these properties based on empirical operations. The conceptual framework is often absent. There is a fundamental problem of establishing that the measure and concept correspond.

Further measurement in the social and behavioural sciences is often based on responses of human observers. Data have limited repeatability. There are no wholly axiomatised theories in the social and behavioural sciences, which correspond to, say, classical mechanics or thermodynamics.

In conclusion it may be stated that in these sciences it is by no means universally agreed that the clear formation of objective, value-free concepts in terms of empirical observation, is possible or desirable.

DECISION MAKING

Decision is the most fundamental of human activities; the basic operation of management and politics. It is the choice between a number of possible courses of action, based on the analysis of their possible outcomes and the perceived utility of the outcomes. From the point of view of measurement, it involves, in particular, the assignment of numerical values to the outcomes, representing the preferences of the decision-maker. The processes of this numerical assignment are closely similar in concept to those involved in measurement. They may be objective, in the sense that given the rules of the assignment, different decision-makers may attribute the same utility values to an outcome. They do not in general reflect anything empirical about utility.

Such methods are rational and transparent and may have a high degree of objectivity, but they may nevertheless cloak irrationality and prejudice of preferences.

CONCLUSIONS

Measurement is basis of knowledge and thought; Metrologists are the guardians of the fundamental concepts of measurement, and should exercise their rightful influence in society's affairs.

METROLOGY IN CHEMISTRY: APPROACHING THE AGE OF MATURITY

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Abstract

This paper reviews recent developments and argues that metrology in chemistry has been through its infancy and difficult toddler stages and is now approaching the age of reason. It reports developments in Australia, the Asia Pacific region, Europe and the USA. Particular attention is paid to the work of the National Analytical Reference laboratory in Australia and to the work of the Consultative Committee for Amount of Substance. Some emerging strategies for establishing traceability at a practical level and for linking the more pragmatic 'consensus reference materials' and 'standard methods' into a traceability system are discussed.

Introduction

There can be no doubt that a sustainable future depends on reliable, comparable and traceable chemical measurements. Failure to provide such measurements will be costly in financial and human terms. The demands being placed on chemical measurements are increasing, as society requires more complex, quicker and cheaper measurements. Analytical chemistry has served society well over the last 100 years but the concepts and systems that underpin the quality of chemical measurements are cracking under the stress of the increasing requirements.

Following a slow start, analytical chemists and metrologists are working together to apply metrological principles and practices to chemical measurements.

Over the last ten years work has been carried out by international groups such as Eurachem, Euramet, CITAC, and CCQM, to build an improved support infrastructure (1). Compared with physical measurements, where such systems have existed for up to 100 years, the work supporting chemistry is in its infancy, with only partly developed concepts and systems in place. None-the-less sufficient work has been completed to demonstrate the feasibility of the approach and an increasing number of countries and economic regions are setting up new metrology in chemistry facilities.

A Short History

Table 1 summarizes some of the key developments, as seen from the author's perspective. It is clear that the rate of developments is increasing, with more and more complex measurement issues being addressed. Not content to address all the complexities of trace chemical analysis, attention is now also turning to analytical molecular biology.

Table 1 Key Developments in Metrology in Chemistry

UK Laboratory of the Government Chemist established	1842
RM program started at NIST	1906
European BCR RM program started	1973
ISO REMCO Guide 30 published	1981
Eurachem established to provide a focus for analytical quality in Europe	1989
CITAC established to help provide traceability for chemical measurement	1993
CCQM established to provide primary standards and demonstrate the equivalence of national standards	1994
First chemical "key comparison"	1998
Biomeasurements added to the work program	1999

Progress has been achieved as a result of the combined input from analytical chemists, who understand the complexities of chemical measurement processes and metrologists, who have provided the rigorous disciplines of traceability and measurement uncertainty. As always, when two cultures interact there are some tensions and some misunderstandings due to different languages and different customs, but the benefit is a synthesis of new ideas.

This certainly has been the case with chemical measurement. Some of the different but parallel terminology is illustrated in Table 2.

Chemists have always recognized the importance of identity and sample preparation and separation, but these are new issues for most metrologists.

Table 2 Comparison of the traditional analytical chemistry and the metrological approaches

Analytical Chemistry	Metrological
Standard method	Link to standard
Precision	Uncertainty
Comparability	Traceability
Fitness for purpose	Excellence
Recognized importance of	Recognized importance of
• Identification • Sample preparation and separation • Measurement	• • • Measurement

EURACHEM and CITAC

Much of the current progress originates from work initiated within these networking groups. Eurachem provides a mechanism for discussion and collaboration on all matters relating to the quality of chemical measurements at the European level and CITAC provides a similar function at the international level. Considerable progress has been made on the development of concepts, terminology and models of a structured chemical measurement system and these have been tested and refined at a number of working group, plenary and workshop meetings. The broad-based input drawn from government sponsored institutes, academe, and industry and accreditation bodies has been a major asset. Some of the other specific achievements include the development of guides on Quality in the Analytical Laboratory, Measurement Uncertainty, Method Validation etc.; the promotion of the benefits of the metrological approach within the analytical community and within both regional and national government organizations. There has been difficulty in gaining access to resources to progress laboratory based studies, but CITAC has successfully carried out inter-laboratory studies (2) at the reference measurement level, with the aim of providing a bridge between high level primary measurements and working level measurements.

Comité Consultatif pour la Quantité de Matière (CCQM)

Work within the above organizations led to the establishment of metrology focus groups at both the regional and international levels. CCQM provides the international lead at the top of the metrology chain. Since its establishment in 1994,

CCQM has made considerable progress on the agreement of definitions and the organization of inter-laboratory studies to evaluate primary methods and to study the equivalence of national standards (3). Areas of work include gas analysis, trace element analysis, trace organic analysis and the characterization of the purity of pure substance standards. The work is focused on the development of metrological tools and the demonstration of the feasibility of the metrological approach. CCQM aims to provide a framework for the demonstration of the equivalence of national standards through interlaboratory comparisons, known as 'Key Comparisons' which can be linked through regional and sectoral networks. It will only be possible to conduct a limited number of key comparisons, due to resource limitations. Each comparison will be carefully selected to cover an important measurement area and as far as possible address specific matrix, analyte and measurement technique problems. For example, the measurement of trace levels of pp' DDE in olive oil by IDMS is relevant to food safety and environmental concerns and represents the analysis of a complex organic material in a complex matrix by IDMS. It is envisaged that about 80 key comparisons will be needed to cover chemical measurements. Although it remains unclear how far 'the light will shine out' from a specific key comparison to other related measurement areas, the demonstration of equivalence of national standards in selected areas will be of great importance in international trade. Also, key comparisons will need to be underpinned by QA systems and processes to cascade measurement traceability to the working level, for them to enhance international comparability of measurements and facilitate one stop testing. To date 3 key comparisons have been conducted, 6 are planned for 1999 and areas in Table 3 are on the agenda.

Table 3 Examples of Proposed Topics for CCQM Key Comparisons

Health: e.g. cholesterol in serum
Food: e.g. arsenic in fish
Environment: e.g. permanent gases in air
Advanced materials: e.g. semiconductors
Commodities: e.g. sulfur in fossil fuels
Forsensics: e.g. ethanol in air
Pharmaceuticals
Biotechnology: e.g. DNA profiling
General Analytical Applications: e.g. pH

Progress is illustrated by the following statistics. In 1998 CCQM organized 4 interlaboratory studies; in 1999 over 24 studies are planned. The progress made by laboratories participating in CCQM studies over time and their improved performance compared with working level laboratories is illustrated by the following performance data:

Only 2 out of 8 laboratories met the target accuracy by being within $\pm 1\%$ of the assigned value in a 1994 study of trace lead, compared with 9 out of 10 laboratories meeting the same target accuracy in a repeat exercise in 1997.

Also, in a 1998 trace element study involving much lower concentrations (1/1000) 9 out of 10 metrology laboratories established equivalence to within $\pm 2.6\%$. This performance level can be compared with other laboratories (routine) where the range of results exceeded $\pm 50\%$.

Regional Developments

Over the last 5 years there has been an explosion of literature (and workshops and symposia) directly or indirectly concerned with traceability and metrology in chemistry. It is not the purpose of this paper to conduct a review of the literature but a useful review is available (4). Other literature reports developments in specific countries or regions, such as, the UK (5) Denmark (6), Australia (7) and the Asia Pacific region (8).

Europe: European countries (UK, Germany, France, The Netherlands etc) have been major contributors to the development of reference methods, reference materials and the development of the metrology in chemistry approach. In addition, the EC has provided input at the highest level (Avogadro's Number and Atomic Mass measurements) and through its reference materials and interlaboratory studies programs. The EU has established networks of community and national reference laboratories in the environmental and food areas to provide a hierarchy of support. Recently, studies have been carried out of current metrology in chemistry facilities and an assessment made of future requirements, with a view to the development of a metrological strategy for the future (9). Eurachem and Euramet provide the networks for fostering harmonization and conduct of regional studies.

North America: NIST in the USA has one of the largest facilities for chemical standards in the

world and over recent years an increasing focus on traceability issues has been evident. In addition to contributing to international developments, mechanisms are being developed to link the large number of secondary USA reference materials to NIST standards. NIST reference materials are widely used world wide, resulting in the commonly used 'NIST Traceable' terminology. Canada is also a significant contributor and Mexico has established a metrology in chemistry facility as part of its national measurement laboratory. The North American Metrology Program has input from USA, Canada and Mexico and provides the regional link to CCQM.

Asia-Pacific: The Asia-Pacific Metrology Program has established a Technical Committee on chemical measurements with working groups on inorganic, organic and gas analysis. The National Institute of Materials and Chemical Research of Japan is leading this initiative and NARL from Australia has agreed to lead the organic analysis working group. A recent survey (8) of current activities and future plans resulted in responses from Australia, Chinese Taipei, Indonesia, Malaysia, New Zealand, Singapore, Thailand, China, Japan and Korea. The survey showed that many countries in the region have or are planning some level of activity and are interested in regional collaboration. Plans are being made to setup regional interlaboratory studies linked to CCQM work in the areas of inorganic, organic and gas analysis. A number of countries are building up their metrology in chemistry capability and as in other regions of the world the work is split between National Measurement Institutes and National Chemical Institutes.

Sectoral Developments

Developments concerned with improving the validity, comparability and traceability of chemical measurements are also taking place in specific sectors, such as the following: food and agriculture, environment, clinical, pharmaceutical, forensic and some areas of industry. For example, the clinical chemists (10) have adopted the metrological approach, expressing results in SI units and progressively developing measurement traceability at the working level. Another sector where the metrological approach is being pursued is gas analysis concerned with car exhaust pollution, environmental measurements and drinking and driving prosecutions. International

trade and regulation are driving improvements in the food and agriculture analysis but a different approach is often being taken in this particularly difficult sector. Some of the developments in this sector are the same or similar to the metrological approach, even if different terminology is used, but some of the champions have much less ambitious aspirations with regard to measurement accuracy and are content to establish comparability rather than traceability. The work in any one sector tends to be isolated from that in other sectors and to a degree from the generic developments in the metrology in chemistry laboratories. The champions of the metrological and what might be called the pragmatic approaches can learn from each other, making it important to ensure cross-fertilization, in order to bring both approaches to a common focus. Failure to collaborate would result in parallel and unconnected measurement systems being developed with cost penalties and inferior measurement potential.

The National Analytical Reference Laboratory (NARL)

The National Analytical Reference Laboratory (NARL) was established by the Commonwealth Government within the Australian Government Analytical Laboratories (AGAL) Public Interest Program in 1997, to lead the development of an Australian chemical measurement system (7).

An example of the type of measurement that could be vital to the Australian economy is the accuracy of measurements of trace levels of pesticide residues in agricultural products, ranging from meat to wine and wool. Exports worth billions of dollars are critically dependent on demonstrating that Australian produce meets importing countries' regulations and also, having the ability and confidence to defend unfair trade disputes. Another topical area of interest is the Sydney Olympic Games in year 2000, where The Australian Sports Drug Testing Laboratory will be at the eye of the storm over the monitoring of competing athletes for banned performance enhancing drugs. Sophisticated regimes are employed to cheat and equally sophisticated chemical measurement is required to ensure that cheats are detected whilst the innocent are not falsely accused. The potential damage to Australian prestige and trade that could result from any failure in this program is incalculable.

AGAL has for many years conducted a program of quality of analytical measurement, supplying chemical standards and conducting proficiency testing (PT). Other organizations such as the National Measurement Laboratory (NML), the National Standards Commission (NSC), the University of New South Wales and the National Association of Testing Authorities (NATA) also contributed to the establishment of NARL and it is intended that these organizations will continue to be involved and contribute to the wider NARL program.

The NARL aims can be summarized as follows:

1. To develop an Australian chemical measurement system, based on metrological principles, that meets the needs of both the scientists who make chemical measurements and their customers.
2. To build on existing work in analytical chemistry, but establish more rigorous traceability links between different countries and between high level standards and working level measurements.
3. To establish a world class chemical metrology facility that commands the respect of metrologists worldwide, and provides the chemical standards needed by scientists to make measurements that are fit for purpose.
4. To develop primary measurement capability and to use this to undertake reference measurements for other customers, to certify reference materials for use as transfer standards and to demonstrate the equivalence of Australian standards to recognized international standards.

The core NARL work will be undertaken by the following teams: Primary Methods Team; Pure Substance Reference Materials Team; Matrix Reference Materials and Proficiency Testing Team; and the NARL Secretariat. Priority tasks are summarized below

NARL Priority Tasks

Recruitment of specialist staff and establishment of laboratory facilities, including organic high-resolution mass spectrometry (HRMS), inorganic inductively coupled plasma-mass spectrometry (ICP-MS), sample preparation and clean room facilities.

Establishment of the capability needed to estimate full measurement uncertainty budgets.

Study of methods for improving the accuracy of the digestion and extraction stages of analysis.

Evaluation and development of NMR as a technique for the characterization of organic mixtures.

Provision of facilities for reference measurement and for the certification of reference materials.

Synthesis, preparation and certification of steroids, steroid metabolites and deuterated analogues, drugs of abuse, pesticides and agricultural chemicals.

Development of improved traceable methods for the characterization of the purity of reference materials using chromatography, mass spectroscopy, classical techniques, nuclear magnetic resonance spectroscopy and differential scanning calorimetry.

Participation in both regional and international comparisons through Asia-Pacific Metrology Program (APMP) and CCQM.

Review of future requirements for pure substance reference materials and establishment of systems for the promotion and marketing of reference materials.

Development of certified matrix reference materials (CRMs) in the food, agriculture and forensic fields.

Review of current PT strategies and establishment of traceable links to international standards.

Establishment of a shop-front for NARL to disseminate information and receive input from the users of NARL services.

Development and provision of training courses in key topics related to metrology in chemistry and analytical quality.

Preparation of promotional material and provision of presentations about NARL.

Development of an Australian / New Zealand Metrology in Chemistry collaboration.

Practical Realization of Traceability

For metrology in chemistry to be considered mature it is necessary to have clarity about the underpinning concepts and to be able to demon-

strate the traceability of, at least some, measurements. A number of authors have described the traceability of chemical measurements (11-15) with a good level of agreement. We are also getting close to a model that addresses the important issues as seen from both the analytical chemistry and metrological perspectives.

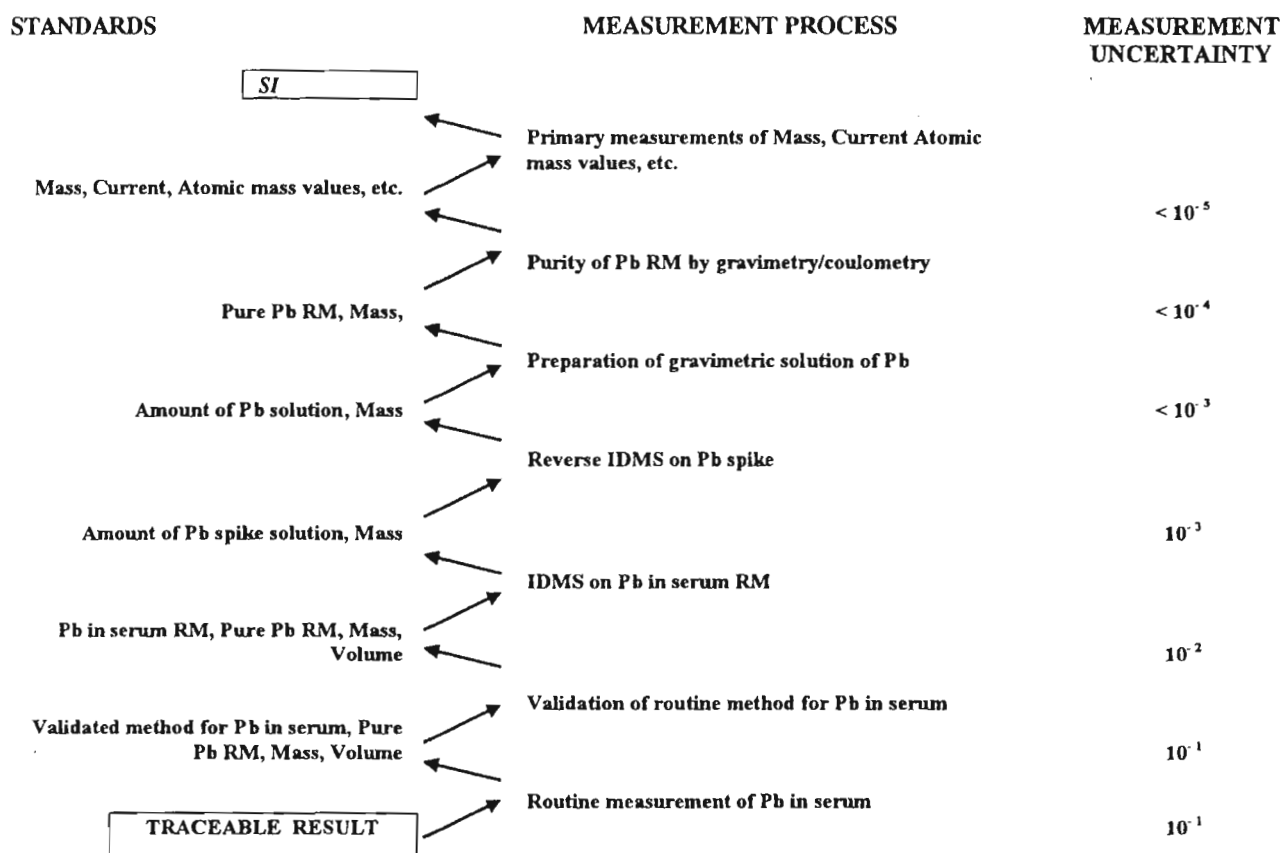
The difficulty in dealing with bias has traditionally led analytical chemists to settle for comparability, rather than traceability to SI. This approach employs standard methods as the traceability reference point. However, providing the measurand can be defined in SI units, measurements made using a standard method can be considered as part of a broader traceability system, which ultimately is traceable to SI. It is a matter of convenience to stop the traceability chain at the standard method. The associated estimate of uncertainty would need to be made relative to the stated reference and would not include consideration of all systematic effects.

Increasingly, however, there is a drive to establish traceability to SI, even if this results in a large uncertainty.

Another of the difficult issues that needs to be addressed is identity. No other area of metrology has to define the identity of the quantity being measured. For example it's not necessary to ask, "is this a mass" in the way that it is critical to ask, "is this lead" before attempting to measure the amount of lead. It is because of the vast number of different chemical identities that it is necessary to sample the item to be measured and to separate the specified chemical entity from all other possible chemical entities. This leads to different measurement processes, compared with the measurement of physical quantities, with much greater emphasis needing to be placed on validating the measurement method.

Figure 1 illustrates a traceability chain for a real world trace analysis, that of lead in blood serum. The roles of pure substance reference materials in calibration and of matrix reference materials in method validation are highlighted, as is the essential position of method validation in the traceability chain. Examination of the levels of uncertainty also shows the problem area to be the validation of the routine method, as if it is desired to reduce the uncertainty associated with routine measurements, then this is the step in the traceability chain that needs to be improved.

Figure 1 Example Traceability Chain For Lead In Blood Serum



Conclusions

The availability of metrologically sound high level standards, such as mass standards and pure substance reference materials are necessary but not sufficient and not the most problematic aspect of establishing the traceability of a routine trace analysis. As every analytical chemist knows, issues such as sampling, sample stability, contamination, interferences and incomplete recovery of the analyte are normally the major contributors to measurement uncertainty. Nonetheless, these issues can be usefully addressed within a metrological framework, and are just as much part of the traceability chain as the transfer standards. It follows therefore that if we wish to improve the traceability of chemical measurements, then we need to put the effort where the chemical problems are, and not where the problems are in physical measurement. We are just beginning to show the level of maturity needed to do that.

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The Metrology Society of India

The MSA has received details of a sister society, the Metrology Society of India (MSI). The MSI was formed in 1984 and is based in the National Physical Laboratory in New Delhi. It has about 50 individual members and 50 company members at present.

Despite its relatively small size, the MSI is very active, publishing a quarterly journal and holding a number of seminars, workshops, courses and conferences. It includes amongst its objectives the maintenance of a metrology library and appears to have formal links with the Indian government in an advisory capacity for metrology.

We have received three of the 1999 editions of its journal, MAPAN – Journal of Metrology Society of India, which is quite impressive. The copies we have received contain the following articles:

- Establishment of the national pressure standards – A case study for uncertainty statements
- Type A uncertainty in curve fitting
- How to select a coordinate measuring machine
- An overview of the activities of the CIPM
- Global traceability of measurement and its relevance to testing and quality

Current trends in laboratory accreditation and the requirements needed to be fulfilled by the accreditation bodies

Laws of legal metrology and consumer protection

Metrology Society of India – Report on 2nd International Conference on Metrology, Quality & Global Trade (MQGT-'99)

- *Errors caused by variation in acceleration due to gravity in electronic weighing instruments – A practical approach*

- *Competition and cooperation among the national metrology institutes for achieving an efficient and sustainable global metrology*

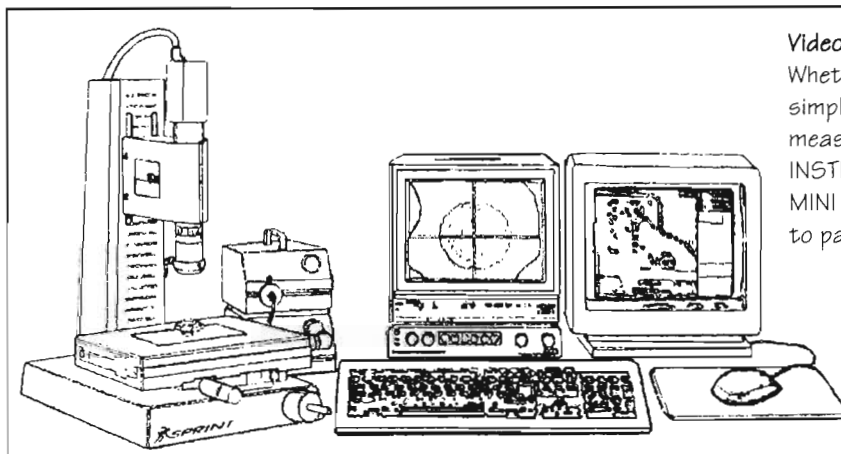
Trends in legal metrology and relevant activities of the International Organization of Legal Metrology (OIML)

- *Comparison of relative humidity standards by different techniques*

If any MSA member would like a copy of any of these articles, please contact the MSA Secretary who will be pleased to provide them.

The MSA has suggested to the MSI that we maintain regular contact and a routine exchange of society journals.

- Laurie Besley



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