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# Measurements: developments in the USA

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**Summary.** Sales and use of analytical instruments have expanded in the United States over the past two years, despite the recessionary nature of the economy. Interest in increasing the quality of analytical measurements seems to be undiminished, if not growing. Trends in several measurement areas, including health, environment, manufacturing, and commerce, are described as they bear on this growth of interest in reliably accurate measurements. The paper also considers trends in the development of reference materials and accreditation of laboratories in the USA. United States of America participation in efforts of the International Organization for Standardization, and a study by the International Bureau of Weights and Measures of how to provide for international traceability for analytical chemical measurements are mentioned.

## Introduction

This paper is intended to provide the background and context within which BERM-related developments are taking place in the USA. Some economic background is essential when considering America's current responses to environmental and biological issues. Tables 1 and 2 give a clear indication of weakness in the U.S. economy over the past three years. [1] Even with prospects improving for 1992 and future years, the Government is giving high priority to maintaining a climate favorable to economic development. Thus we are likely to see a very careful approach to realizing environmental objectives while maintaining consistent, beneficial economic development. In the past, the USA has taken a leadership role in many environmental issues, including removal of lead from gasoline, ensuring the safety of drinking water, banning destructive chlorinated pesticides, and reducing emission of oxides of sulfur and nitrogen from the nation's electric power plants. In a democratic society where people are concerned about their health, this trend can only continue.

The strength of the scientific and medical equipment industry is a basic indicator of a strong interest in environmental and biological measurements in the USA (Table 2).

The well-reasoned balance of considering needs, both for environmental controls and economic growth sufficient to sustain an increasing world population, will be considered at the "Rio meeting" in June 1992. The meeting is not only about the environment; it is entitled "The United Nations Conference on Environment and Development." Another international activity with an interest in this balance is SAGE – the Strategic Advisory Group on the Environment. This group was established in 1991, by the International Organization for Standardization, to make recommendations on policies and techniques that encourage development with positive impact on the environment.

**Table 1.** Percent change in Gross Domestic Product 83-92*

| | 83-87 | 88 | 99 | 90 | 91[E] | 92[F] |
|---|---|---|---|---|---|---|
| EC | 2.4 | 3.9 | 3.4 | 3.5 | 2.0 | 1.9 |
| US | 4.0 | 4.5 | 2.5 | 1.0 | (0.3) | 2.8 |
| Japan | 3.8 | 6.2 | 4.7 | 5.7 | 4.0 | 3.0 |

* Data from U.S. Industrial Outlook, '92, U.S. Dept. of Commerce, based on IMF (International Monetary Fund) data sources
[E] Estimate
[F] Forecast
( ) Negative value

**Table 2.** Growth rates (percent) for selected industry groups, 89-92*

| Industry | 89 | 90 | 91[E] | 92[F] | 92 as % of 89 |
|---|---|---|---|---|---|
| Scientific & Med. Equip | 3.6 | 4.7 | 2.9 | 3.8 | 111.8 |
| Electronics | 4.5 | (2.3) | 3.0 | 4.7 | 105.3 |
| Chemicals | 1.3 | 2.8 | 0.6 | 1.4 | 104.9 |
| Food & Bev. | (1.6) | 2.0 | 0.8 | 1.5 | 104.5 |
| Computers | (4.8) | 0.0 | (2.1) | 4.3 | 102.1 |
| Industrial Machinery | 4.7 | 1.0 | (1.8) | 2.2 | 101.3 |
| Plastics & Rubber | 1.7 | (2.0) | (2.4) | 3.0 | 99.1 |
| Steel Mill Products | (2.6) | 1.4 | (10.0) | 3.9 | 94.8 |
| Motor Vehicles | (1.1) | (5.4) | (8.3) | 7.5 | 93.3 |

* Data from U.S. Industrial Outlook, '92, U.S. Dept. of Commerce
[E] Estimated
[F] Forecast
( ) Negative Values

## Trends in analytical measurement

The past twenty-five years have seen rapid growth in the development of principles, instruments, methods, and reference materials for use in environmental and biological analysis. To some extent, the start of the era of reference materials was marked by the issue of the Standard Reference Material, Orchard Leaves, SRM 1571, by the National Bureau of Standards (now NIST) in 1971. Much effort is still needed on all four fronts mentioned. The need for new reference materials is obvious. Just as clear are the current gaps in methods and instrumentation.

Even in the case of analytical principles, every conceivable combination of probing matter and species-detection mechanism has not yet been tried. Table 3 provides 320 possible combinations, but is not complete in any of the three columns. For example, the solid state could be subdivided into various sub-states, e.g., crystalline/amorphous, and conducting/semiconducting/nonconducting. If this table were fully developed and the possibility of hybrid, compound instruments was included, the combinations would surely rise into the thousands.

Table 4 provides a highly simplified schematic for chemical analysis, together with six key words, noting future points of development.

Clear differences in definitions of the terms, principles, methods, and procedures are provided by the *International Vocabulary of Basic and General Terms in Metrology (VIM)* [2] as follows:

2.05 Principle of measurement - The scientific basis of a method of measurement.

2.06 Method of measurement - The set of theoretical and practical operations, in general terms, involved in the performance of measurements according to a given principle.

2.07 Measurement procedure - The set of theoretical and practical operations, in detailed terms, involved in the performance of measurements according to a given method.

If harmonization of measurements is to be realized among various regions of the world, considerable effort will be required to refine measurement methods and procedures. Procedures will need clear definition, robust reproducibility and proven accuracy for the range of materials analyzed. Reference materials will have an increasingly vital role in evaluating analytical methods and procedures, and will be valuable components of any harmonization effort.

The role of the classical chemist should be pre-eminent in the certification of reference materials, for it is the classical method that will provide traceability to the mole, with a proper evaluation of uncertainty. The USA Environmental Protection Agency has set maximum limits, to be reached during 1992, for 84 constituents in drinking water. The future will require analyses to be carried out in accredited laboratories by technicians having recognized competence and who use certified reference materials to validate their results.

## USA participation in international developments

The United States has been participating in several international activities dealing with accurate chemical measurements for environmental/biological monitoring and protection (Table 5). Separate papers in these proceedings will provide more details on these activities.

**Table 3.** Partial taxonomy of available principles for chemical analysis

| State<br>4 | Excitation Probe<br>10 | Detection<br>8 |
|---|---|---|
| Gas | IR | Emission |
| Plasma | Visible | Fluorescence |
| Liquid | UV | Absorption |
| Solid | | Scattering |
| | | Diffraction |
| | X-rays | |
| | $\gamma$ -ray | |
| | | Current |
| | $\alpha$ Particles | Mass |
| | Electrons | Elution time |
| | Neutrons | |
| | Ions | |
| | Atoms | |
| Combinations = 320 | | |

**Table 4.** General schematic for chemical analysis

| | | |
|---|---|---|
| | Sampling | |
| | ↓ | |
| | Preparation | |
| | (Separation) | |
| Principles | ↓ | Instruments |
| | (Excitation) | |
| Methods | ↓ | Computers |
| | Differentiation | |
| Procedures | ↓ | Reference Materials |
| | Calibration | |
| | ↓ | |
| | Quantitation | |

**Table 5.** International Developments

| | | |
|---|---|---|
| UN | - | Environment Program, Harmonization of Environmental Measurement (HEM) |
| ISO | - | Strategic Advisory Group on the Environment (SAGE) |
| ISO/AOAC IUPAC | - | Harmonization of Quality Assurance Systems in Chemical Analysis |
| CIPM | - | Traceability for Chemical Measurements |
| ISO/IEC OIML/BIPM | - | Guide on Statement of Uncertainties |
| ISO/REMCO | - | Guide on Accreditation of CRM Producers |

In 1991, the International Committee on Weights and Measures (CIPM) established a subcommittee (chair provided by the USA) to consider how to establish chemical measurement traceability at the international level to help provide an accurate basis for analysis and thereby facilitate worldwide harmonization of chemical measurements. The subcommittee will report to the Working Group on Chemical Metrology in 1994.

Table 6 presents the seven SI base units in such a way as to emphasize that they are not completely mutually independent. In fact only the kg, s, and K are independently

**Table 6.** SI Base Units

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Unit Symbol | m | kg | s | K | A | cd | mol |
| | ↑ | | | | ↗↑↖ | ↗↑↖ | ↑ |
| Defining Units | s | | | | m kg s | m kg s | kg |
| | | | | | ↑ | ↑ | |
| | | | | | s | s | |
| Approximate accuracy of realization | $2\times10^{-10}$ | $10^{-8}$ | $10^{-14}$ | $5\times10^{-7}$ | $5\times10^{-7}$ | $5\times10^{-5}$ | [a] |

[a] Molar masses of high purity, nearly ideal gases can be realized to about $5\times10^{-7}$

defined. The seven are also divided into three groups to indicate level of attention they have received in classical metrology, with the mol having been given the least consideration. It is perhaps reasonable that the three on the left have been the best defined given that they are included in the definition of the A and cd, and that the kg is required to define the mol. Now that the CIPM has turned some attention to the mol, it will be quite interesting to see what mechanisms are suggested for producing an international traceability mechanism.

The International Organization for Standardization (ISO) has a working group developing a guide on the statement of uncertainties (ISO/TAG 4/WG 3). The guide is a joint effort of ISO, the International Electrotechnical Commission, the International Organization of Legal Metrology, and the International Bureau of Weights and Measures, and should be issued in 1993. Use of the terms "random" and "systematic" are discouraged. Instead "Type A" components are described as those treated with statistical methods. "Type B" contributions to uncertainty are those evaluated by all means other than statistics.

## Laboratory accreditation in the USA

The USA National Voluntary Laboratory Accreditation Program (NVLAP) began with publication of formal procedures in 1976. Operated by the National Institute of Standards and Technology, it accredits public and private testing laboratories by evaluation of their technical qualifications and competence for conducting specific test methods in specified fields of testing. While the program has not moved extensively into the field of chemical analysis of environmental materials, it has accredited laboratories in related areas, such as asbestos analysis. The program has approximately 1000 accredited laboratories.

The NVLAP program is one of 31 Federal Government laboratory accreditation programs [3] and 48 such programs in the USA private sector [4]; analysis of environmental materials has received only a small amount of coverage. The American Association for Laboratory Accreditation (AALA), has moved into the field of accrediting secondary producers of reference materials, that is, producers other than national or international organizations.

Laboratory accreditation is viewed in the USA as method-based, i.e., the laboratory should not receive a general accreditation, but rather be accredited for its capability to perform a specific method. The two keys to granting accreditation are peer review assessment and periodic proficiency testing. Normally the laboratory is required to demonstrate adequate equipment, quality procedures, and staff training. Further, it must show measurement traceability, either through appropriate calibration procedures or use of certified reference materials. There will be greater need for certified reference materials as accreditation of laboratories becomes more widespread. In the USA, this higher demand for reference materials is causing increased reliance on secondary producers of reference materials.

## References


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