XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

TEACHING MEASUREMENT AND INSTRUMENTATION: SYSTEMATIC APPROACH

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Abstract: Teaching of Measurement and Instrumentation for different levels of students at undergraduate courses, graduate courses and post-graduate courses and later during professional activities in today world needed to be tailed to individual needs, but should it be one chain of development, offered in such a way that everyone who feel a need to become acquainted with some particular subject could find his suitable track for him.

Keywords: metrology, teaching, system.

1. INTRODUCTION

The authors argue that the basic human activities need measurement and instrumentation for all activities starting from economical needs (production needs) going through production process ending on cultural activities.

Measurements and instrumentation are put into system by metrology which is directed on measurement unity and instrumentation uniformity. The metrology as a science on measurement and instrumentation play a key role in today's human activities, as we can easily raise a slogan: "no human activities without measurement" [1].

As metrology is systemic science and activity [2], the authors approach to the problem of teaching metrology systematically, from the close over-systems.

Besides, s*cientific metrology* is considered as the element of the *techno-sphere science system* based on the new scientific paradigm [3].

2. THE TECHNO-SPHERE SCIENCE SYSTEM

Up to the early 20th century, human being activity led to relatively weak influence over the nature. But human being principal contraposition to the nature had led progressively to creation and permanent expansion of the artificial habitat, i.e., **anthropo-sphere**, or **techno-sphere**. The power of its operation processes, by this time, is comparable to natural ones.

For instance, the total volcanic throw is equal to $3\cdot10^9$ т per year, but the mining industry gives useful minerals of $7\cdot10^9$ т and passing rock of $70\cdot10^9$ т. So the exceeding is equal to 25 times. In the whole, anthropogenic receipt of chemical elements from entrails is 100 times bigger than natural one.

Enlargement and intensification of techno-sphere functioning processes go by accelerating rate. This has led, in some directions, to breach of Le Chateiller-Brown's principle. So the process has become irreversible.

Let us remind of that the indicated principle means that external affect, which puts out a system from its thermodynamic balance, causes system processes aspiring to loosen the result of the affect. The principle can be strictly inferred from general condition of thermodynamic balance, i.e., entropy maximum.

Now, we can say realistically not about biosphere evolution but two coming parallel and correlated evolution processes in biosphere and techno-sphere. As techno-sphere ousts biosphere, human being becomes more and more the techno-sphere element. He initiates and creates but is subjected to affect from techno-sphere.

Techno-sphere development to the level, which is comparable, on the Earth's surface, with bio-sphere made scientific paradigm change to be inevitable.

3. THE NEW SCIENTIFIC PARADIGM

Previously in human knowledge and scientific research, accordingly to economical development, the nature saluted researcher as ontologically invariable, that is, true **object** of study. Clearly, in traditional, so called Galileo's, paradigm, a researcher acts as true **subject**. With penetration deep into the matter, it has become impossible to ignore a subject's impact on an object. Let us point out here the Heisenberg's equation and analogous ones, for instance, in radio-physics, and Bohr's supplementation principle. Recognition of subject affect on the object and, as a result, of ontological changeability had impelled to start to rethink Galileo's paradigm. As it is noted above, the techno-sphere development was the governing factor in this matter.

Engineering, which serves as all-purpose tool for maintenance of techno-sphere, was needed, and is needed, the special scientific basis. Development of applied scientific disciplines was the evident response to this challenge.

Besides of the above-mentioned disciplines, the information theory, aero- and hydro-dynamics, cosmonautics, physical metallurgy, medicine and pharmaceutics, a. o. should be referred to the applied sciences.

The disciplines above are separated in accordance with the particular elements of techno-sphere. What is more important for the problem being discussed, the special methodology turned out to be necessary for techno-sphere at all and for engineering in particular. Germs of this methodology matured in deep interior of natural sciences. The methodology above has taken on the form of scientific disciplines, the general subject matter of which is **human being's work under** nature and techno-sphere. System science, cybernetics, control theory and other disciplines of the same rank are kept in mind.

Development of the above-mentioned methodological, and applied, disciplines had eventually led to conceptual formulation of information as second reality, which is disparate from matter. This reality has complicated structure and many aspects.

As information processes are developed, they form more and more powerful sub-system of techno-sphere, i.e., its "upper floor", which is some more alienated from natural environment, and which tears off human being from it. Information conception is becoming to be integrating for many techno-sphere scientific disciplines. It calls forth their conversion, or "over-coding", and stimulates their development.

It can be considered that collision, or synthesis, techno-sphere development conception, or human practical activity, on the one hand, and information conception, on the other hand, has brought to the appearance of conceptual term "thought-activity" [1], which had been proposed by G. P. Schedrovitsky [1].

The thought-activity is determined as indivisible integrity uniting of mythological, design-technological, proper scientific, engineering, designed and other forms of human thought-acting. The following initial statements lead to the thought-acting and thought-activity concepts:

(i) no process but system is recognized as adequate notion for activity;

(ii) activity is not the attribute of person, i.e. figure, or worker, but it is, by Hegel and Marx, initial universal integrity, which is more wide than people themselves.

No individual persons create and execute activity but the latter absorbs them and compels them to behave themselves specifically.

W. v. Humboldt had said: 'no people master a language but the language master people';

(iii) all objects are given to human being through the activity, and their determinacy as articles is conditioned by the specifity of the human social activity.

Activity determinates both organization forms of the material world, or techno-sphere, and forms of human consciousness.

"Things", "properties", "relations" are temporal "clots", which are created by human activity.

(iiii) reflection is the most important element in mechanisms of activity development.

Reflection is the form of theoretical activity of social cultured person; it directs to conceptualisation of all his own actions and their laws.

So, the conception is formed, the gist of which is in that knowing and transformation of the world are considered as interlocking and interpenetrating elements of the same system. They serve for each other, alternately, as contributor of development and its result. The conception serves as the base for new scientific paradigm expressing activity principle. This paradigm is the alternative, with relation to Galileo's paradigm expressing naturalism principle. In accordance with the latter principle, natural objects, which are independent from an activity, oppose human being. The objects interact with human being, impact on him, i.e. are given to him.

Naturally, the new scientific paradigm has to reconsider the separation of the disciplines into fundamental and applied ones, into natural and technical ones. Such a separation makes sense only in the framework of existing paradigm.

4. METROLOGY IN THE NEW SYSTEM OF SCIENCES

Metrology arising as particular branch of applied physics will nevermore be avowed, by natural sciences, to be independent discipline, which is equal to them. So the search of metrology position in the natural sciences system has no outlook. Metrology could pretend to be scientific discipline only after "of techno-sphere" sciences corps had been formed. Really, the object of metrology, i.e., measurement, is kind of purposeful applied activities. The subject matter of metrology, i.e., unity of specifications and procedures, is particular characteristic of human being's work. Metrology output, i.e., quantitative data, is kind of information. So the legitimate position of metrology is in the number of "applied" sciences addressed, in the firs line, to techno-sphere. The word "applied" is placed in inverted commas because the term has received meaning only in Galileo's paradigm and, respectively in natural science classification system. Contrariwise, these sciences are fully of fundamental character in paradigm, which is considered as real alternative to Galileo's one. Metrology exemplifies actualization of this paradigm as the discipline determining regularities and rules for human being activity directed to getting reliable, potentially comparable, quantitative data for material objects.

Both metrology position in the line of scientific disciplines and its structure are revealed under analysis of metrology's relations with other disciplines. It is kept in mind both the natural sciences (mathematics and physics), and the applied ones, system science, information theory, theory of standardisation. The relation between metrology and epistemology is especial and fundamental one.

Metrology and mathematics are "intersected" in the region, content of which is at least theory of measure, theory of categories and/or morphisms. Metrology and physics are united by theory of quantity system, respectively system of units, and dimension theory. It goes without saying that all other branches of mathematics and physics *are used* in metrology. System science serves as fundamentals for metrol-

[1] The term is obtained by translation the Russian word "мыследеятельность", which consists of two words – "мысль" (thought) and "деятельность" (activity).

ogy because the latter is, by definition, systematic thought-activity directed to getting, confirmation, and/or ensuring material object's properties. As applied to information theory, metrology acts both as customer and applied branch of the theory, which is aimed at processes for getting quantitative semantic and pragmatic information. It can be shown that metrology is, in methodological aspect, special kind of standardisation [2].

Actually, metrology as a whole, i.e. both science and activity, is directed to putting measurement affairs in good order. In other words, metrology meets the definition of the term "standardisation".

Unification is the all-purpose method of the standardisation, and the unification is treated as consent by reduction of diversity.

So, metrology uses the one of the general standardisation methods and, on the other hand, it shows the deep relationship with information concept. The latter, as is well known, is determined as 'reflected diversity'.

Additionally, methodology of metrology and standardisation methodology are closely connected through central concept 'scale' and by its role in practical procedures.

As to epistemology, metrology serves as one of practical tools for verification of prime knowledge of natural and artificial world.

Basic characteristics of metrology are connected uniquely with its place in the system of applied disciplines, which are being organised by the "thought-activity" conception. First of all, as stated above, *systematicness* is characteristic, inherent, attribute of metrology. Systemic aim of metrology is vector with two orthogonal components, measurement unity and measurement accuracy. Either component embodied as systemic effect, i. e., manifestation of emergency phenomenon, which is incident to the corresponding metrological system.

Really, metrology system aim is in objectivisation of measurement results. The aim is achieved only in the full system of measurement unity, or, more widely, measurement assurance. The aim is never attained in any subsystem, in particular, quantity subsystem, unity subsystem, and calibration subsystem.

Farther, metrology is being formed by inseparable unity of scientific and applied sides, i. e., by aspects of reflection and activity. At the same time, metrology, in the aggregate, is the tool for reflection for more general categories of activity. It is true at least for the sphere of making and use of technical devices. And lastly metrology is compositive discipline: its structure contains groups of heterogeneous components, of model and of "thingish" ones, with heterogeneity is characteristic of each group individually.

Metrology's place among the «of techno-sphere» disciplines including standardisation. is shown above. To this must be added that metrology as *activity* is immediately affiliated also to another over-system, namely, *quality assurance* (see fig. 1). It is well-known that metrological ensuring plays a key role for quality assurance, so the metrological system plus the additional part of standardisation is a base sub-system of any TQM system.

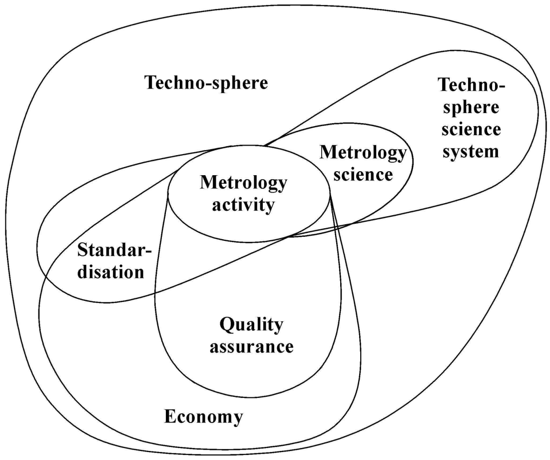

Fig.1. System immersion ("plunging") of metrology as science and activity; the techno-sphere science system based on the new scientific paradigm presented at Joint Imeko TC1+TC7 Symposium [3].

On the *economy* are both quality assurance and the definite part of standardisation.

The over-system for economy and science system together with many other humanitarian and technological/production systems is *techno-sphere*.

5. PLACE OF METROLOGY IN OVER-SYSTEMS

Fig. 2 presents the pace of metrology in the techno-sphere in a direct way introducing interfaces between *human bio-system* and *universal environment.*

The human bio-system consists of abilities to sense and to work. Both working and sensing upon an environment can be done a direct way or through *machine system*, which is extending through instrumentation human abilities to sense and to work. The communication between machine system and human system need an interfaces (*human-machine interface* and similarly between interfaces are needed between machine system and universal environment.

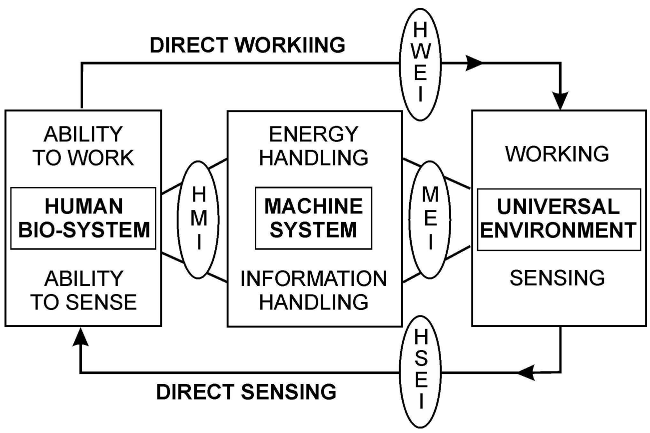

Fig.2 Interface between humans, machines and the universal environment [4]. HMI- Human Machine Interface, HWEI – Human Working Environment Interface, MEI – Machine Environment Interface; HSEI – Human Sensing Environment Interface.

For sensing and working, machine system consists of two elements: *energy handling* subsystem and *information*.

6. PRINCIPLES OF TEACHING METROLOGY, MEASUREMENT AND INSTRUMENTATION

The teaching activities in measurement and instrumentation are based on distinction, in metrology, two main types of measurements: direct measurements and inferential measurements. Direct measurement is a process of direct sensing of quantities, which characterize the energy flow. Inferential measurements lead to identifying the ability of the system to store, transform, transmit and dissipate the energy flow.

7. CURRICULUM FOR PRACTICAL METROLOGY AND INSTRUMENTATION

The curriculum of practical metrology is built, upon the needs coming from assurance of quality, so the focus is on:

a. Training in Precision Measurement Technique including calibration procedures.
b. Training in interface instrumentation, configuration of SCADA systems, Desk Top Instrumentation
c. Teaching in Data Acquisition Systems, Data Handling, Instrument Interfacing.
d. Designing an Instrumentation. Virtual instrumentation, with PCI Extension for Instrumentation (PXI), Signal Conditioning Extension for Instrumentation (SCXI), are used for teaching methods of digital signal processing, data acquisition, data handling. Software soldering bolts realised in Virtual Instrumentation gives the most economical way to te**a**ch an instrument construction.

8. CONCLUSIONS

Contemporary teaching measurement and instrumentation of engineers should prepare of them to understand the role of metrology in Bio-system, and to follow the latest achievements in his and related disciplines, to know how to apply theoretical technical knowledge and gained experience and to understand economy aspects.

We should teach young people to be subjects of culture in technological world. They should be able to show that accurate speech and accurate actions and, of even greater importance, accurate intellection lead to culture of making, to culture of production and, as the result, to quality of work and moreover to quality of life.

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