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RESEARCH ACTIVITIES AND NATIONAL STANDARDS AT THE ISTITUTO DI METROLOGIA “G. COLONNETTI” OF CONSIGLIO NAZIONALE DELLE RICERCHE (IMGC-CNR), TORINO, ITALY

Carlo Ferrero

IMGC, Torino, Italy

The *Istituto di Metrologia “G. Colonnetti”* (IMGC-CNR) is one of the Italian NMIs: its studies and realisations are related to mechanical and thermal quantities and to metrology in chemistry.

Its activities are aimed at the realization and maintenance of national standards, their international comparisons and their dissemination in Italy. IMGC-CNR assures the international recognition of the measurements in Italy and contributes to the fundamental and industrial research for the improvement of measurement standards and measuring methods.

The IMGC-CNR actively participates, together with the two other Italian NMIs (*Istituto Elettrotecnico Nazionale “G. Ferraris”* in Torino and *Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti-ENEA* in Rome) in all the international metrological organisations and within the framework of the Italian Law n. 273/91, that defines the National Calibration System in Italy, has responsibilities for the accreditation of calibration laboratories of the Italian Calibration Service (*Servizio di Taratura in Italia, SIT*).

The IMGC-CNR has some unique facilities and installations (force standards up to 1 MN by dead-weight machines, torque standards up to 2 kNm, precision underground laboratories for length, mass and density measurements, laboratories where the international temperature scale ITS-90 is realised, cryogenic laboratories, pressure laboratories from 1 μ Pa to 1 GPa, laboratories for optical and X ray interferometry and for nanometrology, stabilised lasers, gas flow-meters, ...) and many others instruments for the realization of national standards and the provision of services of high scientific and technological interest.

The IMGC-CNR has direct responsibilities of national standards (length, plane angle, mass, thermodynamic temperature, density of solids and liquids, flow, force, pressure, hardness scale, humidity, viscosity, vibration, torque) that are continuously improved in terms of their metrological characteristics.

The outcome of research activities is the design, development and realisation of a number of instruments, e.g.:

- multicomponent dynamometers and multicomponent calibration systems;
- visible and near infrared stabilised lasers;

- automatic systems for angle, dimensional and roundness measurements;
- balances for mass measurements;
- flow measurements in cryogenic conditions;
- absolute gravimeter;
- interferometric barometers for relative and absolute pressure up to 120 kPa;
- hardness measuring systems (prototype transferred to NIST-USA);
- optical and X ray interferometric measuring systems;
- standards for gas flow up to 45L/s;
- systems for dynamic thermo-physical properties;
- primary and transfer standards for medium and high temperatures;
- fixed points and sealed cells as temperature and pressure standards;
- heat pipes for accurate temperature and pressure measurements

IMGC co-operates with research institutes and industries. Many contracts are within the research framework of the European Commission (new standards for temperature measurements, precision engineering and nanometrology, material properties and quality systems, multicomponent calibration systems). Contracts are also made in Cupertino with national or European Space Agencies for metrological studies in space activities. Different projects and contracts are routinely developed in cooperation with Italian companies in different fields (force, pressure, temperature, humidity, flow), or for studies in support of written standards or to solve specific needs of legal metrology in areas of large economical impact (e.g. natural gas distribution).

This report illustrates the main results (new national standards, new instrumentation and/or methods for measurement, international and national publications, technical reports, prototypes and patents, calibration procedures, quality procedures, etc.).

The most significant results achieved in the last years were orientated towards:

- developing primary metrology skills by increasing basic research, in order to realise and maintain measurement standards;

- testing new measurement methods, including the study and development of new transfer standards and measurement sensors, in the fields of mechanical and thermal quantities, and providing traceability to some measurements for chemistry;
- establishing new laboratories (nanometrology, gas mixtures, thermometry, measurement of force, torque and pressure);
- applying advanced calculation techniques and numerical models of particular interest for metrology;
- participating in international activities, in particular those promoted by the Meter Convention, EUROMET, EA, IMEKO, and by the CEC.

1) INSTITUTE'S MOST SIGNIFICANT ACHIEVEMENTS

Results in primary metrology

- Development of a new primary torque calibration system.
- Development of a 3 MN build-up system.
- Development of a method of digital frequency locking on a Nd:YAG laser, stabilised on the iodine 532 nm transitions.
- Measurement of the frequency of five transitions in the ν_3 roto-vibrational band of OsO_4 .
- Study of the critical influence of isotopic composition on the precision of the hydrogen triple point.
- New apparatus for the measurement of thermophysical properties with the pulse-heating method.
- Primary standard 3-L piston prover to be used in 10^{-3} - 10^{-6} mol/s flow measurements.
- New instrument for the interferometric characterisation without contact of diamond indenters used in hardness measurements.

Experiments on new measurement methods and techniques

- Optical set-up and electronic control to measure spectroscopic parameters of the SF_6 gas. Evaluation of the ozone content measurement uncertainty through spectrophotometric techniques.
- Prototype of the instrument to be used in video-camera based geometrical measurements on artistic manufactures.
- Comparison of different methods to measure the non-linearity of photosensors used in radiation thermometry.
- Investigation on the possible use of synchrotron light for structural characterisation.

1. At the ESRF (Grenoble):

- a) analysis of X-ray simultaneous diffraction from lattice planes of a silicon crystal of different orientation.
- b) Preliminary tests on single-crystal silicon powders to be compared to reference samples from NIST.

2. At the ELETTRA (Trieste):

- a) investigations through a X-ray, phase contrast topographic system on silicon crystal defects

- b) possible use of an X-ray interferometer to obtain phase contrast radiographs of radiation-transparent materials.

- Scanning probe microscope
- Instrument to measure the refractive index of optical glass
- Pressure controlled heat pipes
- Humidity standard in the dew point temperature range from -75 to 90°C
- Pure gas flow rate measurements in the range 10^{-7} – 10^{-8} mol/s
- Project for a new absolute gravimeter

Computational tools and numerical models

With the purpose of improving measurement results and complying with the Guide on the Uncertainty of Measurement (GUM), new algorithms for data acquisition and treatment, and uncertainty evaluation have been studied and the corresponding software produced in various fields:

- Roundness measurements
- Coordinate measuring machines
- Cryogenic thermometers
- Thermo physical properties
- Hardness measurements
- Pressure measurements
- International comparisons
- Calibration of thermometers.

Transfer standards and sensors

New sensors have been built or characterised in the fields of:

- Scanning probe microscopy
 - High and atmospheric pressures
 - Force measurements
- New transfer standards have been developed:
- Infrared standard thermometer in the range from 150°C to 1000°C
 - New cryogenic miniaturised sealed cells
 - compact capacitance sensors for nanometric metrology with tunnel-effect and atomic force microscopy;
 - development of a new interferometric system to characterize penetrators in hardness measurement;
 - sealed cells with different gases to achieve various fixed points on the International Temperature Scale ITS-90, for distribution to International Metrology Institutes;
 - a 0,5 kg inertial balance with 100 mg uncertainty to measure mass in space.

2) INTERNATIONAL ACTIVITIES

The Institute participated in all activities promoted by the bodies of the Meter Convention:

- Meetings of the Consultative Committees and Working Groups Length (CCL), on Amount of substance (CCQM), Temperature (CCT), Mass and related quantities (CCM), including viscosity and the Avogadro constant; activity of the Joint Committee for Guides in Metrology (JCGM), and of the Working Group on the

revision of the Guide on the Uncertainty of Measurement (GUM).

- Activities related to the Mutual Recognition Arrangement (MRA), as international comparisons, definition of the Calibration and Measurement Capabilities, quality systems.

The Institute continued its commitment within the European Collaboration in Measurement Standards (EUROMET) in all subject fields, with an active participation in projects of comparison, traceability, consultancy, cooperation

The Institute is active in all the initiatives of the European co-operation for Accreditation (EA), particularly for the activity of the Italian Calibration Service (SIT), signatory to the Multilateral Agreement.

The Institute participates in a growing number of projects of the European Commission, within the Fifth Framework Programme for research and technological development, namely in the following projects: MULTICELLS, sealed cells for cryogenic temperature fixed points, TRIRAT, transfer standards for radiation thermometry, SIMUS, purity of silicon, MESTRAL, coordinate measuring machines; organising international conferences on “Advanced mathematical and computational tools in metrology” (AMCTM) and for the European Society for Precision Engineering and Nanotechnology (EUSPEN).

The Institute represents CNR in IMEKO, as the Italian representative in the General Council, and is active in various technical committees on temperature, force and mass, metrology, geometrical quantities, robotics, chemistry and environment.

The Institute has many co-operations with other metrology institutions in different economies (China, India, Japan, USA, South America) through bilateral contacts aimed in sharing the research goals defined under specific agreements.

3) THE MUTUAL RECOGNITION ARRANGEMENT (MRA)

- For many of the Institute's activities, the MRA involves a very considerable commitment aimed at demonstrating the degree of equivalence of international measurement standards, by taking part in many of the international comparisons promoted by the International Advisory Committees for Weights and Measures (CIPM) or by EUROMET. For the Institute, this agreement also entailed a better definition of its own calibration and measurement capabilities in harmony with EUROMET and a complete operation of its quality system.

4) ACTIVITIES AT NATIONAL LEVEL

- Co-operations with many CNR Institutes.
- Participation in the activities of the Central Metric Office of the Ministry of Productive Activity (MAP), particularly on studies on natural gas and on national mass standards harmonisation.

- Cooperation with Italian NMIs (IEN and INMRI-ENEA) with common participation in all EUROMET activities and in some actions at international level (e.g. USA, China).
- Cooperation with Italian Universities, in various scientific and educational projects.
- Cooperation with National Associations and National Standardisation Agencies; IMGC actively sponsors and participates in the following associations: CMM Club Italia (coordinate measuring machines), Thermophysical Properties Italian Association (AIPT), Italian Vacuum Society (AIV) and Association for Research and Permanent Education (COREP); IMGC participates in many working groups of UNI, the Italian Standardisation Body.

5) PUBLICATIONS

The total number of publications, 120 in the year 2002, is of the same order of the last few years, on an average of more than 100 scientific papers/year. It must be mentioned that there are many activities in our field (MRA, comparisons, cmc, quality and procedures) which, although extremely important for the scientific and technological improvements in the country, result in only a few publications.

6) DISSEMINATION ACTIVITY

The IMGC-CNR has continued to provide national industries with an important service of technological transfer, through dissemination of measurements and by issuing calibration certificates.

Frequent contacts with industry and public administrations have generated profitable collaboration, frequently aimed at improving measurement systems or products. In the last years the Institute seconded five technical collaborators to small and medium industries, as part of a series of initiatives to support research activities and technological development.

All national and primary standards of IMGC are involved in the dissemination process, which consists mainly of high-level calibrations: in the last years IMGC has issued an average of 800 calibration certificates/year. Of the issued certificates, about 36 % were for SIT calibration centres, already accredited or applying for accreditation.

7) ACCREDITATION OF CALIBRATION LABORATORIES

The accreditation of calibration laboratories is made within the SIT (Italian Calibration Service). The unified central secretariat of the SIT is directly managed by the three Italian Metrology Institutes (the central secretariat was formed at the end of 1997 by IMGC-CNR, IEN, and INMRI-ENEA. The head of SIT-IMGC has responsibility for the accreditation of centres in mechanical and thermal metrology and of the coordination of the SIT Central Secretariat which manages and coordinates all accreditation

activities. The SIT calibration laboratories accredited by IMGC are 85 out of a total of about 142.

8) STAFF

At the beginning of 2003, the permanent staff of the Institute was of 84 people. Considering the temporary positions, the total number of staff is 91..

9) ORGANISATION OF SCIENTIFIC EVENTS

The staff of IMGC has participated with significant contributions in many conferences, seminars and exhibitions in the last two years. Among the exhibitions is to be mentioned the Universal EXPO in Hannover and the Italian exhibition in Japan, where IMGC presented the new prototype of the inertial balance. It has also organised, cooperating with other Institutes, several national and international workshops, courses and conferences ,and the usual open-door days for about 650 students.

10) EDUCATIONAL ACTIVITIES

During the last few years, the Institute increased its educational activity, introducing both internal courses and others held at national academic institutions. Of particular interest is a new training course for "Production Metrologists", the increased number of Ph.D.s in Metrology, training courses for assessors, various courses in cooperation with Universities, Polytechnic Schools and national metrology and quality associations (ANGQ, SINAL, EMIT-LAS, .).

More detailed information about activities, research projects, services and contact points, together with annual reports (in Italian and English), are available at the Institute web site: <http://www.imgc.cnr.it>