

## Short Report on IEN Acoustical Department activities

C. Guglielmono

August 2002

### **Overview of the metrology organisations in Italy**

The national measurement system in Italy is under the responsibility of three primary metrology institutes, IMGC, ENEA and IEN.

IEN in particular is responsible for electrical quantities, time, photometry and acoustics.

The organisation for the accreditation of calibration laboratories in Italy, SIT, is similarly a co-operation of the three metrology institutes.

At present (July 2002) eight calibration laboratories in Italy hold one or more accreditation in sound in air calibrations. Two more laboratories are in the process of accreditation.

IMGC is the source of traceability for accelerations.

No national traceability is available in Italy for ultrasound and underwater acoustics, however IEN is setting up a standard for ultrasonic power.

### **National standards of acoustical pressure and calibrations**

IEN is responsible for national standards of acoustical pressure. The laboratory standards microphones LS1 and LS2 are calibrated according to IEC standard 61094 part 2 by the primary method of pressure reciprocity. The electrical transfer function is measured by means of synchronous FFT analysis, and traceability to volt unit is realised by calibration of the FFT analyser in the amplitude and frequency range of interest by comparison to a digital multimeter traceable to national standard of volt. The electro-mechanical parameters of the microphones are indirectly measured by performing calibration with plane wave couplers of different lengths and minimising the difference of the sensitivities. Some of the couplers have been realised in co-operation with OFMET (now METAS). The relevant number of calibration laboratories needing traceability in Italy is the main source of the demand of primary calibrations of laboratory standard microphones. Actually the number of primary calibrations of microphones is about 25 per year. The interval between calibrations of primary standard of accredited laboratories is one year. Many more calibrations are performed on IEN laboratory standard microphones.

Starting from 2002, all electro-acoustic parameters of customer's microphones under calibration are individually determined. This will allow gain of experience on the measurement technique on a larger number of individual microphones than the limited number of LS1 and LS2 of IEN. In addition it will be useful to investigate the cause of sensitivity drift of customer's microphones, that are often treated more roughly than in primary laboratories.

Other calibration for accredited laboratories are mainly those of multi frequency, multi level acoustical calibrators.

Given the rather large number of calibration laboratories in Italy, verifications of SLM at IEN are reduced to a minimum.

Planned improvements in the apparatus for primary calibrations are the control of pressure in the vessel containing the microphones under calibration, and the measurement of temperature directly on the coupler. The control of pressure is of particular significance because Turin is at about 250 m above sea level.

A new calculation program is under development to speed up the re-calculation of sensitivities during parameters optimisation.

Another reason for realising a new program is to be able to incorporate improvements of IEC 61094 part 2 now under revision.

A research activity on free field calibration of microphones by comparison has been started in 2002. In particular the use of signal processing to remove the effect of residual reflections of the anechoic chamber and the study of the effect of the finite dimensions of the sound source are the subjects that will be investigated.

### **Measurement of ultrasonic power**

There is an increasing demand of calibrations of medical diagnostic and therapy devices in Italy. Unfortunately no national traceability is available. For this reason IEN began at the end of 2001 an activity concerning the realisation of a force balance for the measurement of ultrasonic power.

The first balance, aimed at calibrations at therapy level, is already working and its characteristics are under study. The uncertainty budget is being calculated. In parallel a standard transducer, with in-built rectifier, has been made. It is now in the phase of the determination of the stability characteristics. It will be used for inter-laboratory comparisons with other NMIs, for the validation of the force balances. Another force balance is under development and will be used for the realisation of the standard for ultrasonic power at levels in the tens of mW range.

### **Measurement of the speed of sound in gases and liquids**

An experimental apparatus for precision measurement of speed of sound in gases based on a spherical resonator technique has been built and tested during the last few years, achieving an overall accuracy in the measurement of  $5 \times 10^{-6}$ . It has been successfully applied to the determination of several properties (density, perfect-gas heat capacities, virial coefficients) of some new HFC refrigerants as R125 and R227ea. At present, a project in the primary thermometry field has been started in cooperation with IMGC, aimed to lower the measurement uncertainty in determining the relative thermodynamic temperatures (ratios between a temperature  $T_x$  and the temperature of the triple point of water,  $T_x/273.16$  K).

Measurement capabilities are being extended to speed of sound in liquids at high pressures, so having the possibility to determine with high accuracy heat capacities in liquid phase and isentropic compressibilities. The determination of speed of sound is based on the evaluation of the delay undergone by ultrasonic waves of frequency near to 3 MHz to propagate over a known distance inside a small cylindrical cell, inserted in a high pressures vessel, within a thermostatic bath for temperature control. As a first test of the experimental apparatus, some measurements in pure water have been performed as a function of temperature in the range 278K- 350K and pressure up to 60 MPa..

### **Participation in international organisations in metrology and in**

The acoustic department of IEN participates in the activities EUROMET TC AUV, IEC TC29 in particular in WG5 on measurement microphones.

IEN participated in EUROMET AUV.A-K1 regional key comparison. The results of this regional key comparison however are not enough to supplement CCAUV key comparisons, because many laboratories did not submit LS2 data, or were not ready to participate when the project was started. In order to provide the technical basis of equivalence new regional comparisons are needed, in our opinion.

Too many laboratories from the EUROMET region expressed an interest to take part in the planned CCAUV key comparison CCAUV.A-K3, concerning pressure reciprocity calibration of

LS2P microphones. For this reason IEN proposed in the EUROMET TC AUV contact person meeting in Warsaw to start a EUROMET comparison on the same subject. If agreed, the comparison will follow the CCAUV.A-K3 key comparison protocol and will provide traceability to all European NMIs not able to find a place in the CCAUV comparison. IEN proposes to be the pilot laboratory for this regional comparison.

### Recent publications from the IEN

R. Spagnolo (Editor), *Manuale di acustica applicata*, Utet Libreria, marzo 2001, Torino, contributing authors (VN):

G. Benedetto, R. Spagnolo: *Fondamenti di acustica* (RN1).

G. Benedetto, D. Camerino, F. Merluzzi, R. Spagnolo: *Percezione uditiva ed effetti del rumore* (RN2).

E. Carletti, A. Chiattella, C. Guglielmone, A. Pavoni Belli: *Strumentazione e tecniche di misura* (RN3).

G. Brambilla, F. Duretto, M. Garai, M. Masoero, A. Pavoni Belli, G. Righini, C. Varaldi: *Rumore nell'ambiente esterno* (RN4).

P. Bisio, A. Chiattella, R. Guariniello, F. Merluzzi, G. Miccoli, A. Peretti: *Rumore e vibrazioni negli ambienti di lavoro* (RN5).

G. Benedetto, E. Brosio, P. Brosio, A. Chiattella, M. Fringuellino, P. Oliaro, A. Pavoni Belli, F. Scamoni, R. Spagnolo: *Acustica dei materiali e dei sistemi edilizi* (RN6).

A. Astolfi, S. Cingolani, M. Filippi, M. Garai, C. Guglielmone, C. Ianniello, A. Pavoni Belli, R. Pisani, G. Righini, R. Spagnolo: *Acustica architettonica* (RN7).

M. Grigiane, G. Scalabrin, G. Benedetto, R.M. Gavioso, R. Spagnolo: *A direct reduction procedure for gas densities determination of R143a from acoustic measurements*, High Temperatures-High Pressures, vol. 33, pp. 447-454, 2001(RI1).

G. Benedetto, R. M. Gavioso, R. Spagnolo, M. Grigiane, G. Scalabrin: *A vapor phase Helmholtz equation for HFC 227ea from speed of sound measurements*, Intern. Journal of Thermophysics, vol. 22, pp. 1073-1088, 2001 (RI2).

R. M. Gavioso: *Determination of the universal gas constant R and other metrological applications of speed of sound measurements*, CXLVI Course of the Intern. School of Physics Enrico Fermi on "Recent Advances in Metrology and Fundamental Constants", Varenna, Società Italiana di Fisica, pp. 195-215, IOS Press Amsterdam 2001 (CI1).

G. Benedetto, L. Brunetti, R. M. Gavioso, R. Spagnolo, P. Marcarino, A. Merlone, A. Tiziani: *Acoustic apparatus for thermodynamic measurements from 234 to 400 K*, Proc. of the 8<sup>th</sup> Intern. Symposium on Temperature and Thermal Measurements in Industry and Science – TEMPMEKO 2001, Berlin (Germany), June 2001 (ci1).

G. Benedetto, R. M. Gavioso, S. Lago, D. Madonna Ripa, R. Spagnolo: *Pulse-echo technique for speed of sound measurements in high-pressure liquids*, Proc. of the 17<sup>th</sup> Intern. Congress on Acoustics, Rome, September 2001 (ci2).

G. Benedetto, L. Brunetti, R. M. Gavioso, R. Spagnolo, P. Marcarino, A. Merlone, A. Tiziani: *Acoustic measurements of the thermodynamic temperature between  $T = 230$  K and  $T = 400$  K*, Proc. of the 17<sup>th</sup> Intern. Congress on Acoustics, Rome, September 2001 (ci3).

S. Lago, D. Madonna Ripa, R. Spagnolo, A. Troia: *Evidence for liquid phase reactions during single bubble cavitation*, Proc. of 17<sup>th</sup> Intern. Congress on Acoustics, Rome, September 2001 (ci4).

C. Guglielmo, A. Agostino, E. Dragone: *Free Field Comparison Calibration at IEN*. IEN Technical Report no. 633, September 2001.

A. Agostino, C. Guglielmo : *Recenti sviluppi nella realizzazione del campione primario italiano di pressione acustica*, Proc. Of 29th National Congress of Associazione Italiana di Acustica, Ferrara, 12-14 June 2002, pp. 613-618

C. Musacchio, E. Dragone, C. Guglielmo, R. Spagnolo: *Bilancia a forza di radiazione per la misura della potenza ultrasonora*, Proc. Of 29th National Congress of Associazione Italiana di Acustica, Ferrara, 12-14 June 2002, pp. 627-633