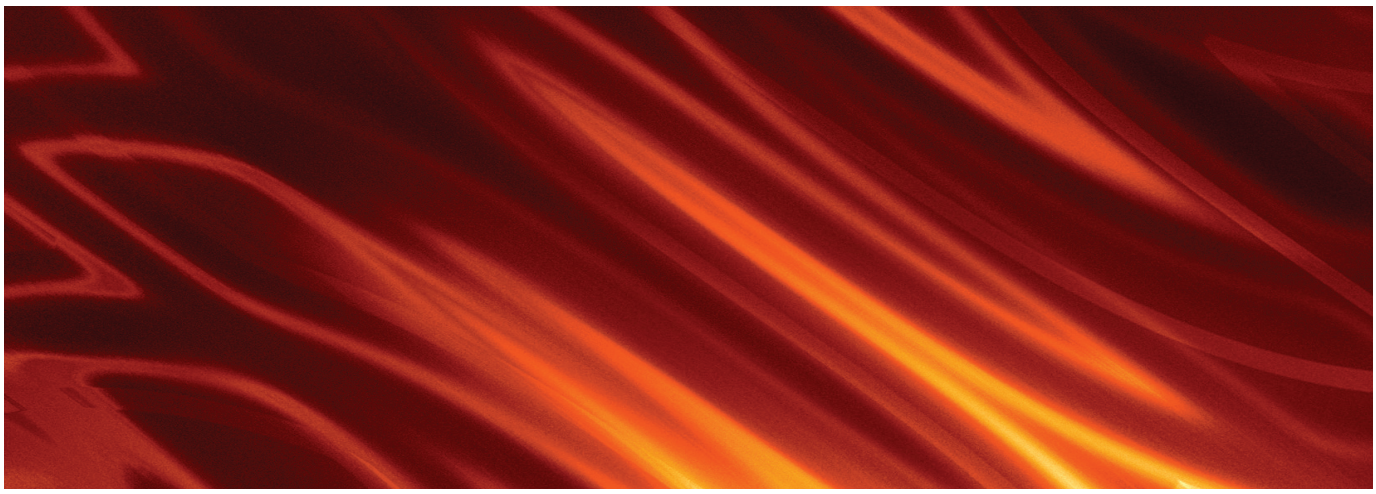


A Conversation with Czech Metrology Institute

Introduction

The Czech Metrology Institute (CMI) provides services in three major metrology areas:

1. *Fundamental Metrology: This includes research & development in metrology, including maintenance and development of national standards.*
2. *Dissemination of Units—Industrial Metrology: Mainly top level any atypical calibrations of standards and measuring instruments both in the Czech Republic and abroad.*
3. *Legal Metrology: Regulated measurements, including type approvals of legal metrology instruments, initial and periodic verification of measuring instruments, metrological supervision, and conformity assessment in metrology*

In 1977, Dr. Klenovsky's first, and in fact last, engagement was with the Brno Laboratory Base of the Federal Office for Standards and Measurement where he gradually worked in laboratories that specialized in various fields of metrology. In 1991 he was appointed Deputy Director of the State Metrology Inspectorate, a legal metrology body in the former Czechoslovak Federation. Since 1993, he has been General Director of the newly established Czech Metrology Institute, which is the national metrology institute of the Czech Republic.

As a United Nations Industrial Development Organization (UNIDO) expert in metrology, he has been fielded on several missions to developing countries, including Ethiopia, Uganda, and Pakistan. In the 1990's he managed a number of EU-sponsored foreign aid projects aimed at metrology in the Czech Republic. Dr. Klenovsky is currently representing the Czech Republic in a variety of international metrology organisations, including the Meter Convention, International Organization of Legal Metrology (OIML), European Association of National Metrology Institutes (EURAMET), European Cooperation in Legal Metrology (WELMEC), and the International Organization for Standardization Committee on Conformity Assessment Working Group 25 (ISO CASCO WG 25). He is a holder of the European Organization for Quality (EOQ) certificate of quality manager.

Dr. Pavel Klenovsky, General Director, CMI.

Q. NCSLI is very pleased to interview you for its metrology journal NCSLI **Measure**. What were the circumstances of the Czech Metrology Institute's (CMI's) foundation?

A. CMI was founded on January 1, 1993 as a result of the split of the Czechoslovak Federation in 1992 into the Czech Republic and the Slovak Republic. In the preceding years, a new federal national metrology institute had been built in the Slovak capital Bratislava—it had been the site of the federal Czechoslovak Metrology Institute since the inception of the federation in 1969. During the split, property was divided between both parties, using the principle of its current physical location—what was physically on the soil of the Czech Republic was Czech and what was on the soil of the Slovak Republic was Slovak. Consequently, nearly all the federal national standards were located and remained in Slovakia, while CMI was put together from various bits and pieces of Government metrology laboratories located in the Czech Republic. As a result, CMI was therefore nearly lacking of the necessary metrology infrastructure, including buildings, laboratories, measuring instrumentation, etc. On the other hand, instrumentation from the old socialist times was of limited usefulness, so that, in hindsight, building-up the institute from scratch was more an asset than a liability.

New CMI metrology building at RI Prague.

Anechoic chamber used for electromagnetic compatibility (EMC) testing.

Location of the eleven CMI facilities in the Czech Republic.

Q. Since you have been the General Director of CMI for over seventeen years, you have seen steady growth in the Czech national metrology institute (NMI). What are some of the accomplishments that have been obtained in CMI's calibration services?

A. As mentioned above, we started, so to speak, on a green meadow, but under constant pressure from our industry to offer all the necessary metrological services in practically every field of measurement. Particularly challenging for CMI, and having a great impact on our industry, were the following metrology fields: low mass flow, vacuum, radiometry—photometry, 3D contact/optical measurements, quantum electrical standards, high voltage/current measurements, vibration, nanometrology standards, and ionizing radiation.

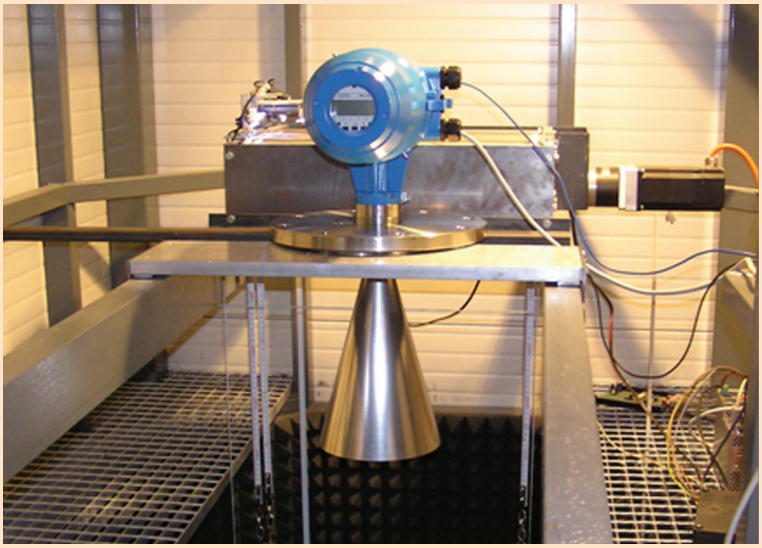
Q. What has been an overall strategy you have been using in developing the institute?

A. Especially in this time of globalization, the strategy for how to develop and set up a national metrology institute (NMI) is a tricky task. Unlike most existing NMIs, our approach to metrological activities is to view them as more or less business activities than anything else. We believe that there is a niche market of services in metrology for which an NMI is best suited and it will be most effective if the internal mode of operation is favorable for that approach. We achieved this business approach in 2002 by a change in legislation: since that time we have operated without any limitations typical for Government bodies (staff or salary caps) and, as a result, our dependence on the Government budget has fallen to under 18 % of our total operating budget. As a matter of course, nothing goes without issues. For example, there is some overlap with private calibration laboratories so that a sharp eye on public financing and competition rules needs to be kept by the CMI management. On the other hand, to manage a multi-site, multi-task and multi-source financed institute is quite a challenge.

Q. What is the target vision of the institute?

A. At a minimum, our vision is to develop CMI into a regional center of multifaceted metrological services at the highest levels of metrological traceability with a maximum thrust in research and development (R/D) in metrology, especially in the European context of participating in the projects of the European Research Area (ERA) in EURAMET, under the program EMRP—European Metrology Research Program.

Q. The Czech Republic metrology network managed by CMI is currently composed of eleven branch laboratories. Can you briefly describe the system of laboratories that make up CMI, highlighting their special roles in supporting standards



Radar level gauge being calibrated in the Laboratory of Flow and Heat.

Primary vacuum standard based on conical piston technology.

and calibration for Czech Republic's manufacturing and technology industries?

A. The 11 laboratories are uniformly distributed across the country and could be roughly called verification offices/branches (officially they are called Regional Inspectorates). The background is that CMI is the only body in the CR authorized by law to verify legally controlled measuring instruments that are important for the general public; for verification of the other regulated instruments, private bodies are authorized. To a various extent, some fundamental and industrial metrology activities are attached to all of the laboratories, with the most metrology activities carried out by RI Prague and Brno. There are three special CMI laboratories, all of which are located in Prague: (1) Inspectorate for Ionizing Radiation deals with all the metrology aspects of ionizing radiation, (2) TESTCOM is active in electromagnetic compatibility (EMC) testing and telecommunication activities and (3) the Laboratory of Fundamental Metrology maintains and disseminates national standards in length, acoustics, vibration, hardness, radiometry/photometry, high voltage/current measurements, and force/moment of force.

Q. As a signatory of the International Committee for Weights and Measures Mutual Recognition Arrangement (CIPM MRA) under the Bureau International des Poids et Mesures (BIPM), CMI is heavily involved in supporting the Key Comparisons Database (KCDB). Can you summarize the status of the calibration services of CMI that are currently listed in Appendix C of the CIPM MRA and CMI's future plans for the recognition of additional calibration services under the MRA?

A. The current position in the number of CMCs in the KCDB database of CIPM MRA: There are a total of 471 CMCs for the CR which represents a rank of 6th in Europe, after the four biggest EU countries and the Netherlands.

Q. Training in the area of metrology is an important responsibility of any national metrology institute and is very much supported by NCSLI. Over the past several years, CMI has developed training courses for industry, as well as their own staff. Can you summarize some of the current training programs in metrology that are offered to industry and plans for the future in this area?

A. Apart from ad-hoc training courses in individual fields of calibration, we currently offer a training course on general metrology aimed at company metrologists. The course covers the principles of a national measurement systems, terms in metrology—International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM), principles of legal metrology, quality systems and metrology, SI units, basics of uncertainty calculation, and administration of metrology in a company. In a longer period, more extensive training courses, called School of …….. Metrology, are organized in individual fields, such as flow, pressure, and temperature. Recently, a special training course on the uncertainty of measurement, with practical examples from individual fields, has been launched; the course is basically a "humanized" version of the "Guide to the Expression of Uncertainty in Measurement" (GUM) with extensive explanations and derivations of formulas. In response to demand from the automobile industry, a special course on the quality tool Measurement Systems Analysis, 4th Edition (MSA 4) is being prepared; it should be launched in the 1st half of 2011.

Q. CMI has had a long and important relationship in the area of metrology research and development with many Czech institutions, including the Academy of Science, Institute of Radio Engineering and Electronics (now Institute of Photonics and Electronics); Institute of Physics; Czech Technical University; Charles University; Palacky University; Agriculture University; and Institute of Chemical Technology. Can you highlight some of the collaboration efforts between CMI and these institutions over the past few years?

CMI national standard of plane angle.

A. Since CMI is a small national metrology institute, collaboration in research and development with academia is a typical method to implement work projects, especially in recent years. In addition, these collaborations are not limited to Czech institutions only. It is not very easy to select just a few example projects, but definitely one of the most successful collaborations is a long-term cooperation with the Charles University Prague in the field of vacuum metrology. Since 1997, this collaboration has including the development of a continual expansion primary vacuum standard and two primary leak standards. Currently, together we are finishing a completely new primary ultra-high vacuum standard covering the range up to 10^{-10} Pa (10^{-12} mbar). By the way, the Charles University is the oldest university in the middle of Europe, as it was founded in 1348.

Other examples of very successful collaborations are with the Masaryk University Brno and the Academy of Sciences in the field of nanometrology, with the Czech Technical University in the fields of ionizing radiation metrology and electrical quantities, and with the Institute of Photonics and Electronics in time and frequency metrology.

Q. CMI has been in the process of developing new quantum metrology standards, including the development of quantum Hall systems for resistance measurements and Josephson systems for dc voltage calibrations. Can you discuss the application of these new quantum systems and highlight progress on their development and support of CMI's calibration services ?

A. CMI purchased its first Josephson Voltage System (JVS) in 2002 which was a commercial system based on a cryocooler (closed cycle refrigerator—CCR). This is because the operation of a liquid helium system is cumbersome and expensive. The cooling was based on a mechanical Gifford-MacMahon type cryosystem which caused notable electromagnetic noise and mechanical vibrations. The system was periodically used to calibrate a bank of Zener standards which served as the national DC Voltage standard. In 2008 CMI found that the manufacturer of the system was not developing it any further. Since the cooling power was insufficient to maintain a low temperature of the chip, CMI was forced to replace the cryocooler. In collaboration with Supracon, Germany, the cryocooler was replaced with a new pulse-tube type system. The substantially lower electromagnetic and mechanical noise also improved stability of the original chip and thus the calibration of Zeners could be performed faster and with lower uncertainties.

Today, our system is a unique merger of the Hypress and Supracon systems. One of the benefits of a cryocooler based system is that it is easily transportable and can thus be used for intercomparisons of JVSs. Present work on the JVS is aimed at a higher automation using Clark Hamilton's NISTVolt software together with banks of Zener standards connected by a scanner to the JVS.

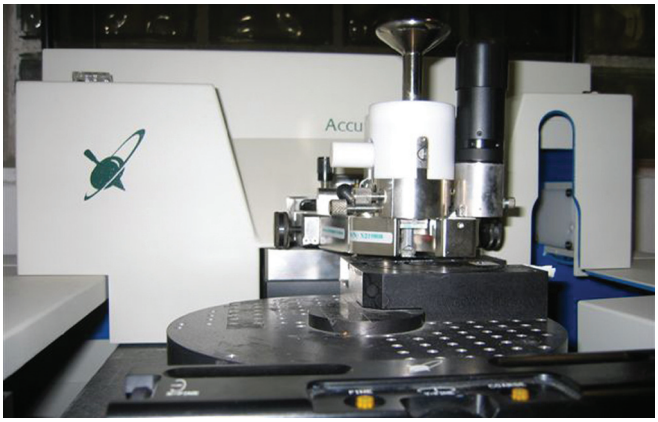
As to the quantum Hall resistance (QHR) standard, CMI procured a commercial system in 1999 but its operation was constantly hindered, especially by problems with electronics of the cryogenic current comparator (CCC). In 2003 we finished troubleshooting the system and put it into operation with some limitations: direct comparison of the 100 Ohm-resistor with the quantum structure yielded a two times higher uncertainty than the specification, which was 0.01 ppm. Up until 2005, the QHR system was fully in operation including the CCC, but the best achieved uncertainty was only 0.04 ppm. At that time it was the only commercially manufactured QHR system in operation worldwide. Since its operation started to deteriorate, it has been replaced by an MI 6010 Q resistance ratio bridge working at room temperature with a little bit higher uncertainties. Finally, we have teamed up with the Technical University Prague to develop a new electronics and control software for the CCC with the aim to complete the work in 2011.

Generally, primary electrical standards are quite expensive to procure and to operate, as you could see from the discussion above, with relatively few practical applications other than for traceability. Thus it is no wonder that some NMIs are considering to close them.

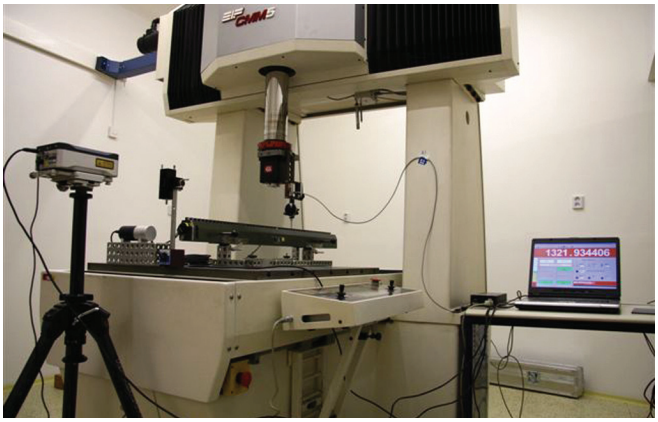
Q. The accreditation system in Czech Republic is operated by the Czech Accreditation Institute (CAI). Can you outline the relationship between CMI and CAI in the area of the accreditation of calibration laboratories? In addition, how many calibration laboratories are currently accredited by CAI to the *ISO/IEC 17025* standard?

A. In my opinion, the current cooperation between CMI and CAI can be used as a positive example of a partnership between a national metrology institute and an accreditation body, where the NMI is well positioned to play a crucial role in all the technical activities associated with accreditation by providing technical experts, harmonized technical procedures, intercomparisons, etc. On the one hand, representatives of CMI are members of the CAI Accreditation Board and of the Technical Committee for calibration laboratories of CAI; on the other hand representatives of CAI are members of the Metrology Board of the Czech Office for Standards, Metrology and Testing and of the Scientific Committee of CMI. Periodic working meetings of the CMI and CAI management are now established as well.

Probably the most visible part of our cooperation in support of the 107 accredited calibration laboratories is a use of CMI experts as technical assessors in the accreditation of calibration



Atomic Force Microscope (AFM) that supports measurements in the Nanometrology Laboratory.



CMI Laboratory of Technical Length: Touch-probe CMM5-SIP.

laboratories based on a contract between CMI and CAI (they are involved here as CMI employees, not as private persons). The high number of accredited calibration laboratories is a result of the fact that the CR is a highly industrialized EU member state and, by way of comparison, it represents the highest density of calibration laboratories in the whole of EU. It has to be pointed out here that our cooperation with accreditation bodies in not limited to the Czech Republic only—long term cooperation has been operating with SA (Slovenska Akreditacija) Slovenia and SNAS (Slovak National Accreditation Service) Slovakia as well.

Q. Considerable effort has been spent improving length measurements using interferometric techniques, as well as the development of procedures for the calibration of coordinate measuring machines (CMMs). Can you provide more information about these developments and how they have impacted your calibration services and support of Czech industry?

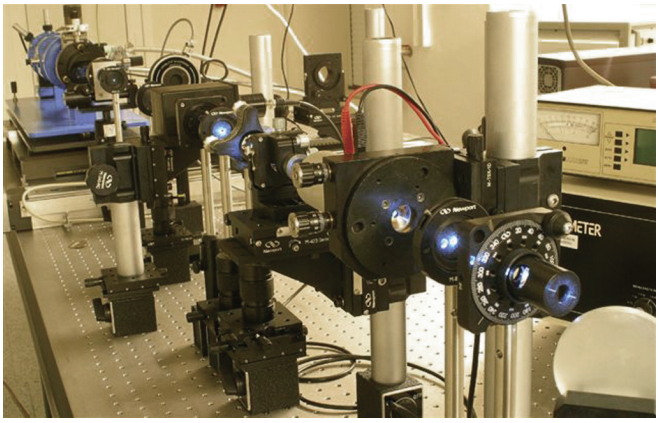
A. Length measurement is traditionally quite a strong field in CMI. First, it has to be pointed out that CMI has always developed and manufactured its primary lasers by itself. Developments are now in process towards improving the precision, range and speed of our length calibrations. European NMIs decided to strengthen their research cooperation by organizing the European Metrology Research Program (EMRP) and CMI is taking part in four ongoing joint research projects in the field of length and will also be participating in several others that are in preparation.

For example, long range measurements with classical EDM (electronic distance meter) are currently provided by the National Standard of Long Distances operated by the Czech Geodetical Institute. However, a new calibration method using femtosecond frequency comb is being developed within EMRP program Long Distance, aiming to improve precision to 0.1 ppm and resolution to far below 1 µm. The broad spectra of a femtosecond comb can also be simultaneously used to obtain more information in addition to distance through precision spectroscopy.

In the field of nanometrology, we have recently improved the uncertainty of interference fringe interpolation down to 10 picometres using a dual wavelength interferometer developed within another EMRP project NANOTRACE. Thus we are able to measure macroscopic (millimeter) lengths with an uncertainty of one tenth of the atomic lattice parameter. With such a precision - and in nanometrology generally - a careful definition of the measurand is important; without it the different techniques could give different results. Comparison of various approaches to measurement with 1 nm uncertainty is a task of EMRP project Nanoparticles. A measurement of large 3D objects and the calibration of Coordinate Measuring Machines (CMMs) with traditional and new techniques are dealt with by EMRP project NIMTech.

One should be aware that it can take a long time before a newly developed measurement technique is officially recognized and can be made fully available to customers. As an example, the CIPM MRA requires the organization, performing and evaluation of international comparisons which take typically three years. Thus NMIs need to stay well ahead of actual requirements from industry. For example, improved methods for the calibration of step gauges, using a combination of an interferometer and a CMM resulting in an expanded uncertainty of 300 nm, or the calibration of precision line-scales with a combination of an interferometer and a CCD microscope resulting in a 30 nm uncertainty, both were developed five years ago, but are only now being recognized and published in the KCDB database. This is because both calibrations belong to key measurement services in length and have to be underpinned by key comparisons.

As to 3D measurements, CMMs have a long tradition in CMI—the precise CMM5-SIP was commissioned already in 1996. This CMM is still the most accurate touch-probe machine of its category in the CR. Our laboratory of technical length at LPM has participated in a number of international intercomparisons (EA, EURAMET) including key comparisons. Based on these and other results, we have been offered partnership in a number of EU research projects, including Mestral, Easytrac, MTCheck, Evigem, Nano CMM, and NIMTech). Recently we have procured two new CMMs, one for RI Brno that will be used for the calibration of sieves and the other for LPM that is a high precision multisensor CMM Werth with a touch-probe, an optical system and a miniature optical fiber. All these CMMs are used daily to calibrate various artifacts and complex parts for our industry,



The Cryogenic Radiometer that is the CMI national standard of total radiation power.

especially the automotive sector, including Škoda, Volkswagen, etc. Annually, over 200 Czech and about 30 English calibration certificates are issued.

Research in metrology is another major field of application. Just this year, we made measurements of two unique artifacts: the first one is a miniature silicon artifact manufactured by the Physikalisch-Technische Bundesanstalt (PTB) for the calibration of CMMs to measure nano- and micro-parts. The other one is a brand new free form shaped artifact developed by the National Physical Laboratory (NPL) for the calibration of general complex shapes.

Q. Are there some other new or exciting metrology or measurement activities at CMI that you would like to communicate to the members of NCSLI?

A. We are constantly being surprised by leaps in various manufacturing technologies which generate urgent demand for metrological solutions. This also includes the extension of ranges of various quantities and improvements in uncertainties in the area of traditional physical metrology fields such as vacuum, flow, magnetism, temperature, photometry, etc. We are being approached by those companies to address these needs.

Recently, despite the economic crisis, we have had to extend our laboratory space considerably in our branch laboratories in Prague and Brno (the investment subsidy from the Government was only 30 % of all the costs). Furthermore, it is amazing to watch how, due to ever increasing prices of energy, fuel and water in recent years, the public at large is more and more interested in metrology, thereby forcing us to intensify our public relations activities.

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