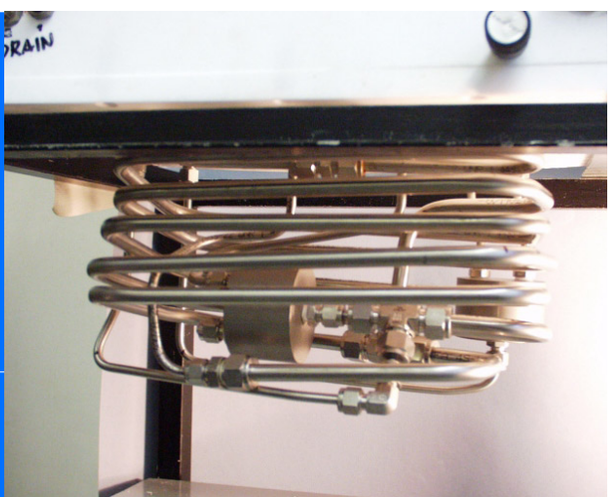
MIKES

FINNISH NATIONAL STANDARDS LABORATORIES

2003

Annual Report



www.mikes.fi

Contents

Centre for Metrology and Accreditation
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Editorial board: Jaana Järvinen, Martti Heinonen, Antti Lassila,
Risto Rajala and Ling Wang(Layout)
Helsinki 2004

Preface

In Finland MIKES successfully continued its work as the metrology research institute during the year 2003. Frequently daily work was interrupted by a building project meeting. However, in circumstances like these, scientists take this as an opportunity to contribute to one's future. Good working premises were in everybody's mind to accomplish better service and better metrology. The ongoing project has turned out to be an unusually demanding one, both for constructors and scientists. As a consequence the time schedule fell behind the original schedule: the moving date is now at midsummer 2005. The new location is on the Otaniemi science campus, about 10 km from Helsinki. All the present activities of MIKES will be gathered in these new metrology premises. As a consequence a slightly more centralised organisation of metrology in Finland will result. Local speciality is also taken care of: a traditional Finnish sauna is on the top floor.

International cooperation developed both scientifically and in comparisons. Among the new EU-funded tasks began the EuropeAid for Estonia in the field of metrology. Another field of cooperation was the NMERA project; which is a Nordic satellite to the original MERA (Metrology European Research Area). The Nordic satellite is an ongoing project aiming at enhanced cooperation among Nordic countries including all the three Baltic neighbours.

An intensive collaboration period finished with the Advisory Commission for Metrology when it ended its 3-year period at the end of 2003. Commission is an important stakeholder for MIKES with its over 200 experts from different fields. Among other things, Commission suggested and arranged several seminars, participated in developing 5-year plans to all the metrology fields and made metrology strategy for Finland. A new commission was designated in 2004 and began its work. One of the challenges is to continue the metrology in chemistry.

The need to put MIKES on the map has continued in several ways; the target groups being the general public and stakeholders. Several lectures at universities have been given and seminars have been arranged. MIKES also took part in two exhibitions in the Finnish science centre Heureka. The first was a weekend happening on father's day. The second one is a part in an exhibition planned to travel around the world until 2008 in science centres: Easy life - Automation at your service.

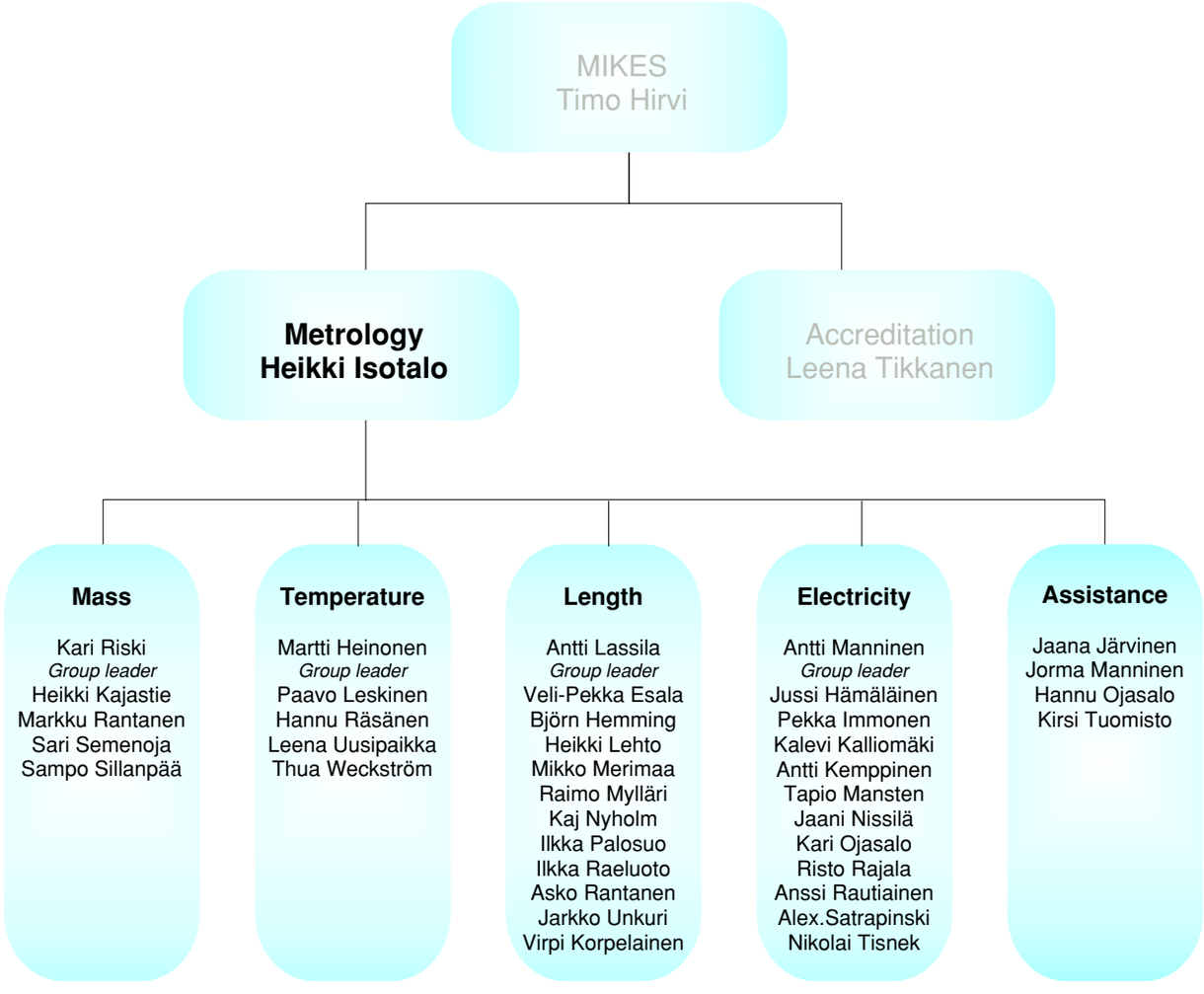
This annual report summarises the activities of the Finnish National Standards Laboratories and Contract Laboratories in 2003. I hope you will find this information useful.

Helsinki March 2004

Heikki Isotalo
Head of Metrology

Mission of MIKES Metrology

In Finland the Centre for Metrology and Accreditation (MIKES) is responsible for the implementation and development of the national measurement standards systems. MIKES also participates actively in international co-operation and ensures that Finnish metrology is up to international requirements.

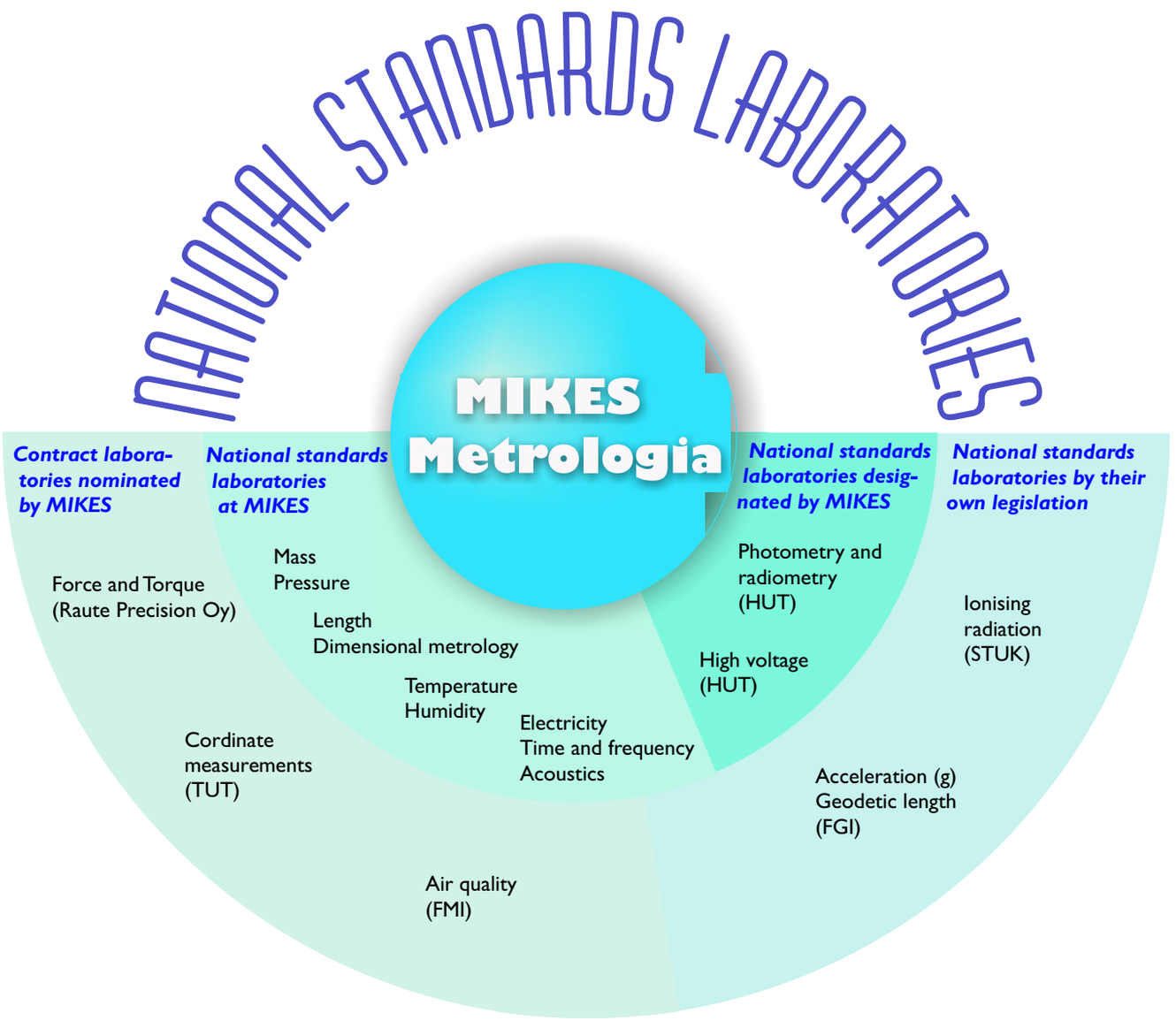


Today Finland has a slightly decentralised organisation of its national standards laboratories. MIKES itself acts as the National Metrology Institute (NMI) of Finland, designating the National Standards Laboratories and financing the maintenance, research and development of the national measurement standards. Some of the activities are delegated to Contract Laboratories. International co-operation is also channelled through MIKES. The personnel of the department of metrology is divided into four metrology groups mass, temperature, length, electricity supported by assisting activities.

MIKES METROLOGY

International Co-operation	MIKES participates in European and international research programmes and in scientific and technical activities promoted by European and international bodies in metrology, such as EUROMET, CGPM/CIPM/BIPM, EA, OIML, NORDTEST etc.
Training	MIKES organises various training courses and seminars in several sub-fields of metrology. In addition experts from MIKES give lectures in courses and seminars.
Research	Research on the realisation methods of SI units, measurement standards and methods is carried out in various research projects often in co-operation with other research institutes and universities. In these projects several young scientists are carrying out their practical training.
Consultancy	MIKES Metrology works together with industry and various institutes. This type of national co-operation in the field of metrology is increasing in Finland.
Realisation of SI-Unit	The national standards for mass, length, temperature, pressure, electrical quantities, time, frequency, humidity, acoustics and dimensional quantities are maintained and developed at MIKES to fulfil the needs of consumers and the society in Finland. The duties of the national standards laboratories for photometry and radiometry, high voltage, length in geodesy, acceleration of free fall and ionising radiation have been delegated to other institutes outside MIKES. In addition the traceability, international relations and expert services in the field of force, torque, coordinate measurements and air quality measurements have been organised through Contract Laboratories.
Calibrations	The laboratories of MIKES Metrology offer a calibration service to establish the traceability of reference standards at the accredited laboratories. The calibration service is also offered directly to end-users, mostly when the scope of accredited laboratories is not sufficient for the customer.

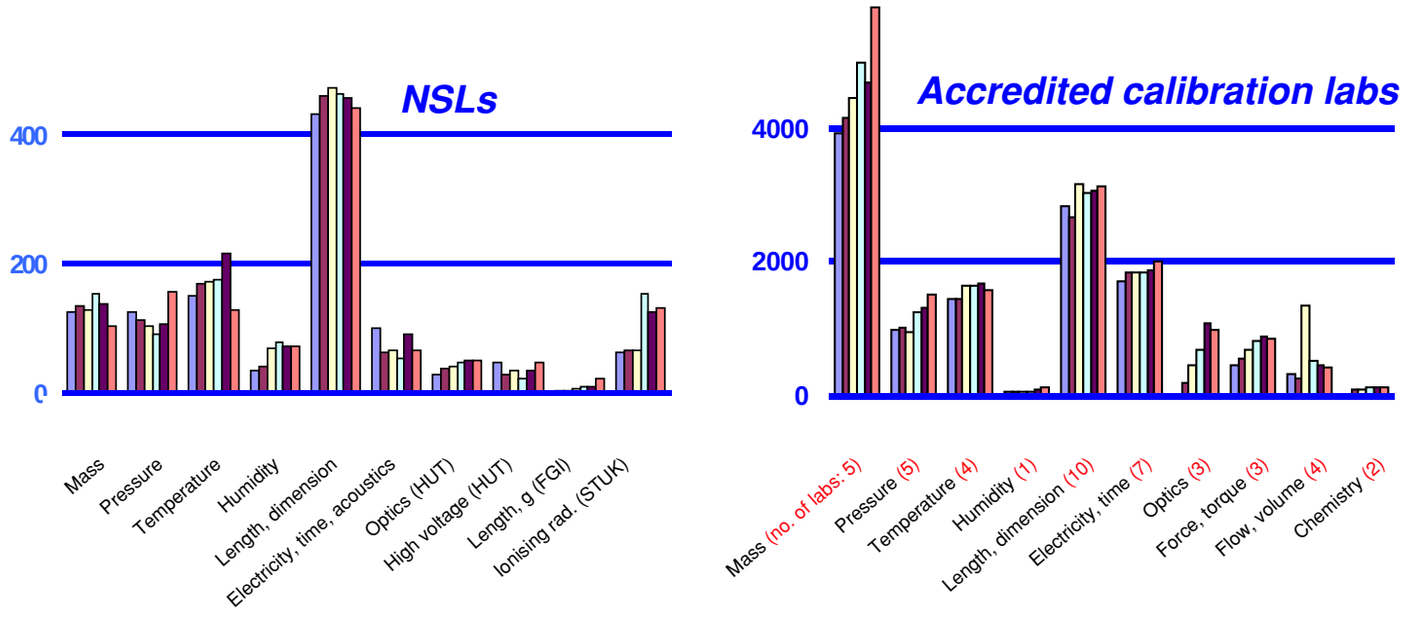
Within MIKES, the Metrology Department is responsible for tasks relating to the maintenance and supervision of the national measurement standards system. Below is the organisation of the National Standards Laboratories in Finland.



MIKES = Centre for Metrology and Accreditation, HUT = Helsinki University of Technology, TUT = Tampere University of Technology, FMI = Finnish Meteorological Institute, FGI = Finnish Geodetic Institute, Raute = Raute Precision Oy, STUK = Radiation and Nuclear Safety Authority

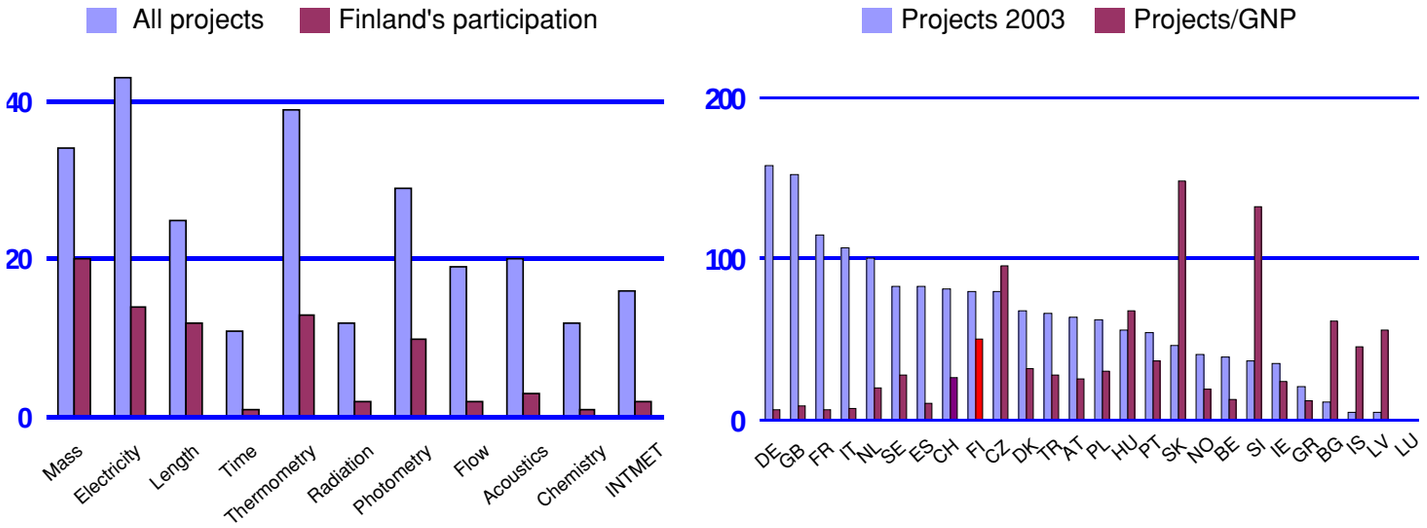
2003 in numbers

Number of calibration certificates 1998-2003

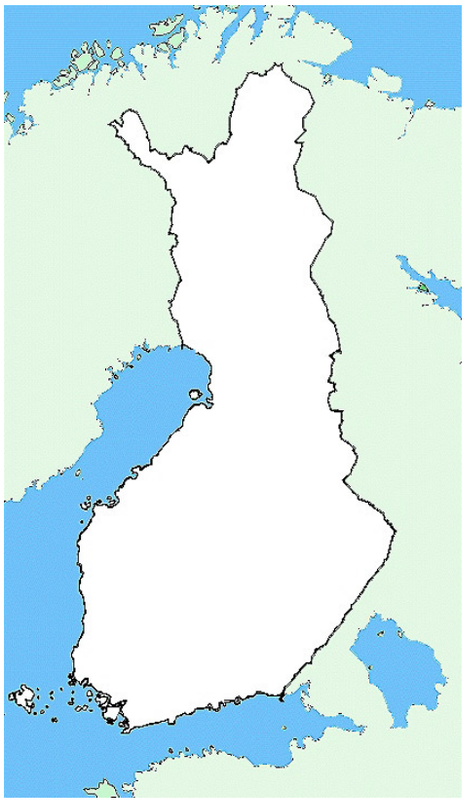


The volume of the calibration service in Finnish NSLs was roughly the same as the previous years. In the future Nordic and European (EUROMET) co-operation will update standards to a higher level for the future needs of industry. Attempts in this direction are e.g. EUROMET initiated MERA (Metrology Research Area) projects. In accredited calibration laboratories the volume of calibrations is tenfold compared to the NSLs. Number of calibration laboratories increased in *length and dimensional metrology* and in *flow and volume*. Decrease in number of calibration laboratories was in *mass* and *electricity and time*.

Participation in EUROMET subject fields
Agreed and proposed projects



Facts about Finland



5.2 million inhabitants
338 000 km^2
188 000 lakes
Currency: euro
Gross national procuct 143 10^9 euro
Official languages: Finnish and Swedish

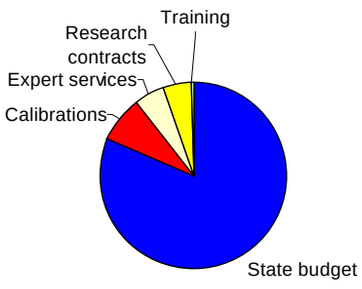
Monthly temperatures in Helsinki and in metrology laboratory (°C)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Mean in Helsinki*	-8.6	-5.1	-1.2	2.4	9.1	13.2	20.7	16.8	12.1	4.4	3.7	0.2
Max	3.4	5.4	9.7	18.7	22.8	22.9	29.6	27.7	21.0	13.1	8.4	5.6
Min	-27.0	-20.9	-15.6	-8.6	-1.4	5.6	13.4	8.1	1.4	-10.6	-4.9	-16.9
Mean in MIKES mass laboratory**	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Max	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
Min	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8	19.8

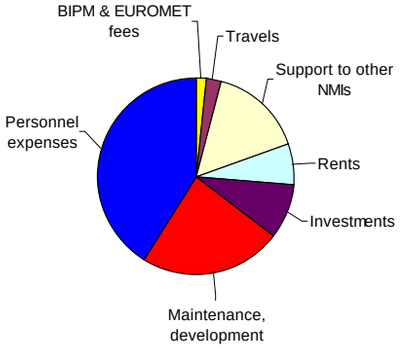
* Source: Finnish Meteorological Institute ** Measurement uncertainty (k=2) 0.02 °C

Facts about MIKES Metrology

Proceeds 3,7 M€



Costs 3,7 M€



Reports of the National Standards Laboratories

Mass

PERSONNEL AND ORGANISATION OF LABORATORIES

MIKES	**Raute Precision Oy (Raute)** Mass and Force Laboratory Contract Laboratory of MIKES	**Finnish Geodetic Institute (FGI)** National Standard Laboratory Acceleration of free fall
Kari Riski *Group Leader* **Mass Laboratory** Kari Riski — Laboratory Head Heikki Kajastie — Research Scientist Sampo Sillanpää — Research Scientist **Pressure Laboratory** Markku Rantanen — Senior Research Scientist, Laboratory Head Sari Semenoja — Research Scientist **Flow Laboratory** Martti Heinonen — Senior Research Scientist, Laboratory Head Sampo Sillanpää — Research Scientist	*Aimo Pusa* *Head of Laboratory* Mikko Mäntylä — Supervisor	*Prof. Markku Poutanen* *Head of Department of Geodesy and Geodynamics* Jaakko Mäkinen — Laboratory Head Hannu Ruotsalainen — Research Scientist Mirjam Bilker — Research Scientist Heikki Virtanen — Research Scientist

In Finnish national standard laboratory scheme realisation and maintenance of the units and development of mass, pressure, density and gas flow is in the responsibility of MIKES. The mass group of MIKES has three laboratories: mass laboratory, pressure laboratory and flow laboratory. The units of mass, pressure, solid density, liquid density and gas flow are realised by these laboratories.

MIKES has a contract with Raute Precision Oy nominating its Mass and Force Laboratory to take care of needs of force and torque metrology. The measurement standards of MIKES-RAUTE include standard force and torque machines.

The operation of Finnish Geodetic Institute is based on legislation. Finnish Geodetic Institute has the status of National Standard Laboratory with responsibility for the measurement of acceleration of free fall. In this field, the measurement standards of FGI are absolute gravimeters.

The MIKES mass group laboratories, MIKES-RAUTE and FGI gave about 550 calibration certificates for accredited calibration laboratories, research institutes and industry during 2003.

Cryogenic calorimeter (MIKES)

A cryogenic calorimeter for the measurement of energy losses in superconductors has been built. Test measurements have been performed. Preliminary test results show that the calorimeter works as planned. The principle of operation of the calorimeter is the following. The upper part of the calorimeter consists of a superconducting coil, a superconducting plate, a heater and a thermometer. The lower part consists of a heat link to liquid helium and a heater and a thermometer. The upper and the lower parts are connected via a weak thermal link which is made from a stainless steel tube. The temperature difference between the upper and lower part is kept constant. Any losses in the coil or in the plate are compensated by reducing the heating power of the upper part. The sensitivity of the calorimeter is about 1 nW.

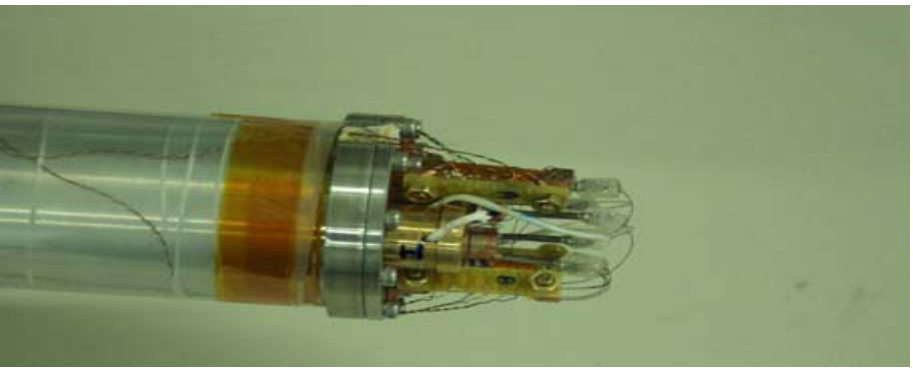


Figure M1. Lower part of calorimeter.

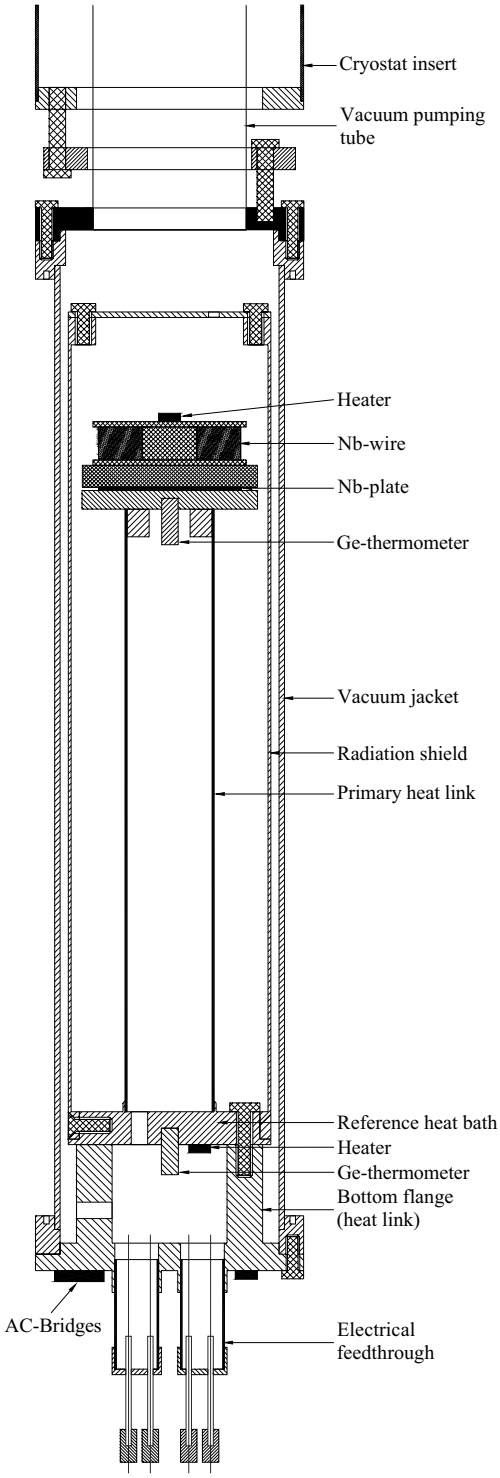


Figure M2. Construction of the cryogenic calorimeter.

New 20 kNm reference torque machine (RAUTE)

At the end of the year a new reference torque standard machine has been finished. The capacity of the machine is 20 kNm. The instrument is under testing.

Figure M3. The new 20 kNm reference torque machine.

New absolute gravimeter (FGI)

The new absolute gravimeter FG5 (s/n 221), ordered in 2002, was delivered to the FGI in March 2003. It gives more than 50% reduction in uncertainty compared with the previous standard at the FGI, the JILAg absolute gravimeters. The FG5-221 took part in the International Intercomparison of Absolute Gravimeters organized by the European Center for Geodynamics and Seismology (ECGS, Luxembourg) in November. Altogether 15 absolute gravimeters of 4 different models participated. The FG5-221 was used to measure 3 sites in Azores, 3 in mainland Portugal, and 2 in Spain, in cooperation with 4 international partners. Seven of the eight sites had previously been occupied by the JILAg-5 of the FGI. Observed gravity changes at Azores sites were reversed since the previous measurement and may be due to hydrology rather than volcanic or tectonic phenomena.

Nordic absolute gravity project (FGI)

The "Nordic Absolute Gravity Project" started with FGI involvement in the design and in the measurements. This is a major international project of repeated absolute gravity measurements in the Nordic countries, with annual measurements at approximately 20 sites over the next 5 years.

Figure M4. The FG5-221 of the FGI, here photographed at the International Comparison of Absolute Gravimeters in Luxembourg with another FG5 in the background. On the left (from top to bottom) the dropping chamber, the interferometer and the super spring. On the right the blue electronics rack.

RESEARCH PROJECTS

Realisation of the kilogram (MIKES)

The purpose of the project is to determine mass in terms of other quantities (length, time, current, voltage) by using the superconducting magnetic levitation method. In the method the electrical energy of a superconducting coil is (partly) converted to the mechanical energy of a levitating body. In this process no energy losses are allowed. To measure energy losses in superconductors a cryogenic calorimeter has been built. The calorimeter is operated at 4 K. Measurements with different superconductor materials at varying magnetic fields are under way. The optics for the interferometer of the levitation system have been finished. The project has been made in co-operation with VNIIM (Russia) and VTT Information Technology.

Measurement of temperature gradients in water for solid density calibrations (MIKES)

Temperature gradients were measured in two different hydrostatic density calibration instruments.

Figure M5. Rectangular Silicon prism for testing density measurement instruments.

Figure M6. Weight handler for a commerical absolute pressure balance.

Density gradients and the convection forces were measured with two rectangular silicon prisms. The results show that under stable environmental conditions the temperature gradients are small and no significant convection flows occur.

Weight exchanger for an absolute pressure balance (MIKES)

A low-cost weight exchanger system was developed for a commercial absolute pressure balance. The system consisting of eight chained 250 gram weights covers the pressure range 850 hPa 1050 hPa and saves a lot of time in barometer calibrations. The vertical position of each weight combination is controlled by a step motor. Some minor improvements in the system will be made in 2004.

A density calibration system for liquid samples (MIKES)

The purpose of the project is to construct an equipment for the measurement of the density of a liquid sample using hydrostatic weighing method. The density reference is a Si sphere. When completed the project, density determinations will be carried out at a relative uncertainty level better than 10^{-5} in the temperature range +10 °C to +40 °C. The equipment is under construction. It will be finished and tested in 2004.

A calibration system for gas flow meters (MIKES)

A new calibration facility for small gas flow meters was developed for the range 20 ml/min to 30 l/min (nitrogen). A primary standard based on dynamic weighing (DWS) was tested and compared with the METAS volumetric flow standard. The relative uncertainty (k=2) of 0.3 % to 0.4 % estimated for the DWS was in good agreement with the comparison results. A calibrator based on laminar flow elements is used in the calibration service started in September 2003.

Vacuum calibration system (MIKES)

The chamber used for vacuum calibrations was equipped with a heating system and a residual gas analyser.

The Nordic absolute gravity project (FGI)

The project aims at producing a time series of absolute gravity measurements (1/year) at about 20 Nordic sites over the next 5 years, i.e. approximately the lifetime of the GRACE gravity satellite. The purpose is to compare terrestrially observed variation in gravity with the variation detected by the satellite, primarily caused by postglacial rebound (PGR). The project is thus geodynamical in motivation, but the time series will also constitute an unprecedented dataset of reference values for metrological purposes. Absolute gravity observations will be made by FGI, by the Institut für Erdmessung (IfE, University of Hanover), and by the Department of Mathematical Sciences and Technology of the Agricultural University of Norway. Other participants are the Danish Survey and Cadastre (KMS, Copenhagen), the Norwegian Mapping Authority (Hönefoss), and Lantmäteriet (Gävle). In 2003 the Bundesamt für Kartographie und Geodäsie (BKG, Frankfurt) participated, too. FGI measured 4 sites. The project is coordinated by the Working Group for Geodynamics of the Nordic Geodetic Commission (NKG), as a part of the Nordic Geodetic and Geodynamic Observation System (NGGOS) of the NKG.

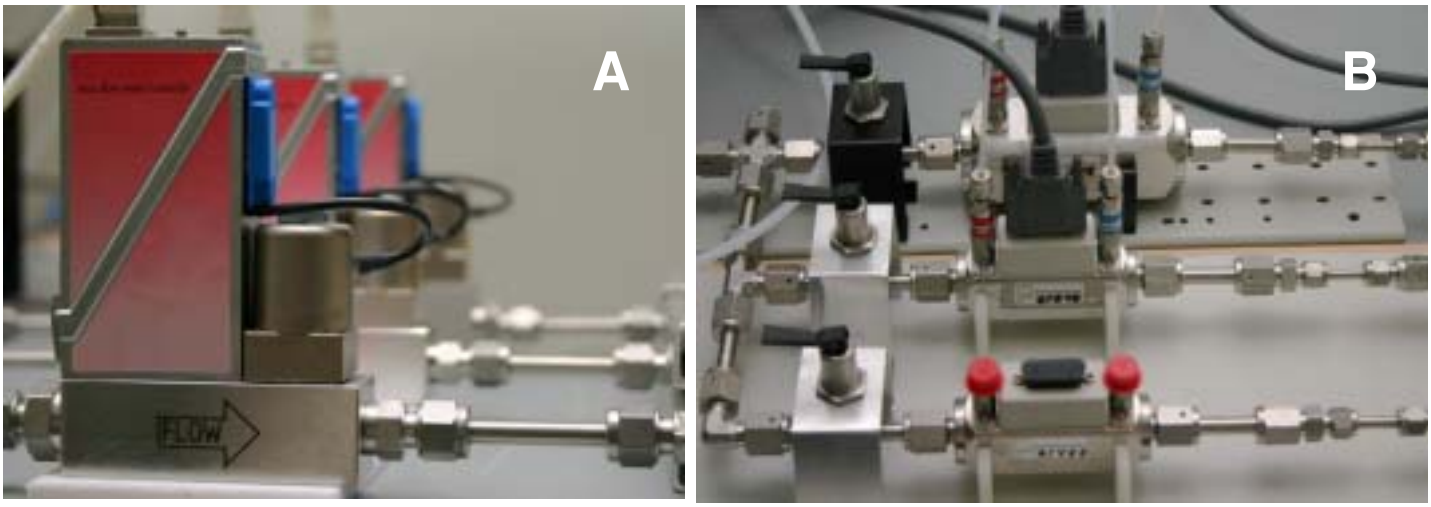


Figure M7. Improved flow control (A) and measuring (B) unit of the gas flow calibration system.

Nordic land uplift gravity line (FGI)

The relative measurements along the latitude 63°N through Finland, Sweden and Norway were repeated in August-September. This was the eighth time the line was measured in its entirety after inception in 1966-67. Over the years the measurements have produced the first empirical estimate, anywhere, of gravity change due to PGR. The measurements in 2003 agreed with this estimate of -2.0 nms^{-2} per 1 mm of uplift which so far has the uncertainty of 0.6 nms^{-2} (k=2). The project will be continued in order to further narrow down the uncertainty, which could lead to important conclusions about the rheological properties of the Earth. In 2003 absolute gravity stations were established at the main sites of the Line. In the future the measurements can thus be carried out using absolute gravimeters and the observational part of the project merged with the Nordic Absolute Gravity Project. In 2003 the absolute and relative measurements were performed in parallel and agreed well. Since 1966 more than 10 institutions from Nordic, European, and other countries have participated in the relative work. In 2003 it was performed by FGI, KMS, and Lantmäteriet, while the Norwegian Mapping Authority provided instrumentation support. While the purpose of the project is geodynamical, its results are also important for the metrology of the acceleration of free fall in the PGR area.

Dynamics of the Azores triple junction (FGI)

The measurements in Portugal and Spain (see highlights) sort under various projects. The measurements at three sites in Azores (P. Delgada, Horta, Flores) were made in order to investigate the *Dynamics of the Azores Triple Junction* and form the continuation of observations performed by the FGI and partners in 1992, 1994, and 1997 under various project banners. They were performed in cooperation with the Astronomical Observatory of the University of Porto and the Department of Geomatics of the University of Lisbon. Gravity increase observed in Horta and Flores in 1997 now reverted and may have depended on hydrological rather than volcanic or tectonic phenomena.

European sea level service research infrastructure (FGI)

The measurements at three sites (Porto, Mértola, Cascais) in mainland Portugal were performed in cooperation with the Portuguese Geographic Institute (IGP). Porto and Mértola had previously been observed by the FGI in 1994, and were now re-measured in order to monitor the stability of these fundamental stations of the Portuguese gravity reference network. Preliminary results indicate insignificant gravity change. The measurement at the Cascais tide gauge starts a time series to control its stability and supports the *European Sea Level Service* (ESEAS), in particular its initial project ESEAS-RI (*European Sea Level Service Research Infrastructure*). Finally, the measurements at two stable sites (Madrid Facultad, Valle de los Caídos) in and near Madrid in cooperation with the Institute of Astronomy and Geodesy of the Complutense University of Madrid constitute a reference for the work in the Azores. They also strengthen the calibration line Madrid-Valle de los Caídos, where Spanish relative gravimeters are calibrated since the first measurement by FGI in 1992. In this work as in the previous ones, the metrological and geodynamical aspects are inseparable.

Global geodynamics project (FGI)

The superconducting gravimeter GWR T020 at Metsähovi participates in the *Global Geodynamics Project* (GGP), along with 19 other SGs distributed worldwide. The SGs record the variation in the gravity field of the Earth with high accuracy, and additional monitoring with absolute gravimeters permits the determination of trend-like phenomena, too. Data is collected at the International Center of Earth Tides (ICET) in Brussels and put to various uses by the GGP participants and others. In 2003 the data from European SGs including Metsähovi was applied to determine seasonal variation in gravity on the European scale. An unexpectedly good correlation with gravity variation observed with the gravity satellite CHAMP was found.

Modelling of the influence of atmospheric masses and Baltic Sea level on gravity (FGI)

Using the single SG record at Metsähovi, FGI pursued further the *Modelling of the Influence of Atmospheric Masses and Baltic Sea Level on Gravity*, in cooperation with the Finnish Meteorological Institute and the Finnish Institute of Marine Research. The influence of the local hydrology on gravity is investigated in the three-year project *Modelling and Monitoring Local Hydrological Effects in Gravity*, financed by the Academy of Finland. The lead scientist is Prof. Markku Peltoniemi (Department of Rock Engineering, Helsinki University of Technology), and other cooperation partners are the Finnish Environment Institute and the Geological Survey of Finland. In 2003 a large number of ground penetrating radar (GPR) profiles were collected in order to determine sediment thickness and bedrock fractures. They are currently being interpreted.

COMPARISONS & PUBLICATIONS

COMPARISONS

MIKES

EUROMET Project no. 445: "Comparison of mass standards in multiples and sub-multiples of the kilogram". Regional key comparison. Participants: most EUROMET members. Measurement at MIKES in January and February 2003.

EUROMET Project no. 510: "Comparison of mass standards of the kilogram (stainless steel)", Regional key comparison. Participants: BE, CH, CZ, DE, DK, ES, FI, FR, GB, HU, IE, IS, IT, NL, NO, PT, SI, TR. Preliminary results available. Results of MIKES comparable with other countries. E_n values below 0.5.

Figure. M8. A view from the International Comparison of Absolute Gravimeters in Luxembourg. Behind the FG5-221 of the FGI, the FG5-209 of METAS and the IMGC-2 of IMGC can be discerned. Twelve more gravimeters are mounted in the laboratory that was built in the gallery of former gypsum mine. Each gravimeter occupied three different sites during the comparison.

EUROMET Project no. 509: "Intercomparison of Pt-Ir kilogram standards". Participants: BE, CH, CZ, DE, DK, ES, FI, FR, GB, HU, IT, NO, PL, SE, SI, SK. Preliminary results available. Results of MIKES comparable with other countries. E_n values below 0.5.

Gas flow comparison: Bilateral comparison of the primary low gas flow standards between MIKES (FI) and METAS (CH) (MIKES, flow). E_n values below 0.6. The report will be published in 2004.

EUROMET Project no. 702: "Comparison of calibrations of high resolution hydrometers for liquid density determinations". Participants: IT, DE, HU, PT, FR, FI, AT, PL, SK, TR, RU. Due to the problems with transfer standards the already started project will be re-planned.

EUROMET Project no. 627: "Comparison of density determination of liquid samples", Participants: DE, FI, FR, HU, IT, NO, PL, ZA. Draft A2 of the report was prepared and accepted by the participants.

EUROMET Project no. 442: Key comparison for absolute pressure range from 0.1 Pa to 1000 Pa. Measurements performed in 1999.

EUROMET Project no. 439. Key comparison in the range 80 kPa to 7 MPa. Measurements in 2000. Only draft reports of these comparisons have come out by the end of 2003. All the MIKES results were within the claimed uncertainties according to the preliminary data.

EUROMET Project no. 650: Bilateral comparison between MIKES and BNM-LNE in the pressure ranges from 0 to 13 kPa (gauge mode) and from 0,1 Pa to 13 kPa (absolute mode).The measurements were completed in 2003 and the results were presented in the IMEKO TC16 conference (J.-C. Legras, P. Otal; M. Rantanen and S. Semenoja, Bilateral Inter-Laboratory Comparison between BNM-LNE and MIKES in the Pressure Ranges 0 to 13 kPa Gauge and 0.1 Pa to 13 kPa Absolute, in Proc. of International Symposium on Pressure and Vacuum, IMEKO TC16, Beijing, China, Sept. 22 24, 2003, pp. 79-83.)

Digital piston manometer (FPG) comparison. A bilateral comparison between MIKES and CMI (Czech Metrology Institute) was carried out. Two similar instruments were compared at MIKES in August 2003. The report will come out in 2004.

RAUTE

CCM.F-K1.a and K1.b. CCM key comparison piloted by MIKES-RAUTE. Report is in preparation, acceptance during the meeting in March 2004.

EUROMET Project no. 535, Intercomparison of force standards at 5kN and 10 kN. Regional key comparison piloted by MIKES-RAUTE. Report is in preparation. Two bilateral comparisons connected to this project are carried out during the year 2004.

EUROMET Project no. 461, Comparison of 500 kg mass standard weight. Pilot is Czech metrological institute. Preliminary results were good. (This capacity of the weights are connected to the determination of masses for force standard machines.

FGI

Intercomparison of absolute gravimeters.
With the FG5-221, FGI took part in the International Intercomparison of Absolute Gravimeters organized by the European Center for Geodynamics and Seismology (ECGS, Luxembourg) in the Walferdange Underground Laboratory for Geodynamics in Luxembourg, November 3-7. Other participants were Observatoire Royal de Belgique (ORB), MCT-Observatório Nacional (Brazil), Research Institute of Geodesy, Topography and Cartography (Czech Republic), Ecole et Observatoire des Science de la Terre / Institut de Physique du Globe de Strasbourg (EOST/IPGS), BKG (Frankfurt), IfE (Hanover), ECGS (Luxembourg), METAS (Switzerland), Proudman Oceanographic Laboratory (POL, UK) who all brought FG5 gravimeters; U.S. Geological Survey (USGS) who brought an A10; Instituto Geográfico Nacional (IGN, Spain) who brought both an FG5 and an A10; BEV (Austria) who brought the JILAg-6; and IMGC (Italy) who brought an IMGC-2. Altogether 15 absolute gravimeters of 4 different models participated. The IMGC-2 was the only instrument that applies the symmetrical rise-and-fall principle, and moreover the only one which is unrelated to Micro-g Solutions, Inc. (Erie, Colorado). The FG5 and A10 are manufactured by the Micro-g, and the JILAg is the immediate predecessor of the FG5.See Fig. M8.

The Nordic Absolute Gravity Project.
Project contains numerous comparisons between the participating gravimeters to ascertain that they produce consistent results. The first bilateral comparison was performed between the FG5-221 of the FGI and the FG5-220 of the IfE in August. Parallel measurements were performed on two piers in Metsähovi and at two sites in Vaasa. The maximum discrepancy was 34 nms-2.

National intercomparisons for accredited calibration laboratories

Mass comparison: 5 kg laboratory balance
Participants were four accredited laboratories. The measurements were made at MIKES. All E_n values were less than 1. Report.

Pressure comparison
Four laboratories from Finland and one from Sweden participated in a comparison of gauge pressures Report.

Pressure comparison
A bilateral comparison in the vacuum range was arranged with the accredited laboratory of Oy Beamex Ab. Report.

Pressure comparison
A bilateral comparison with the accredited pressure laboratory of Vaisala Oyj in absolute pressure range from 100 kPa to 2100 kPa. The report will come out in 2004.

PUBLICATIONS

Articles in International Journals

MIKES
M. Heinonen, S. Sillanpää, *The effect of density gradients on hydrometers*, Meas. Sci. Technol. 14 (2003) 625 - 628.

FGI
H.Virtanen and J. Mäkinen, *The effect of the Baltic Sea level on gravity at the Metsähovi station*, J. Geodynamics 35 (2003) 553 - 566.

Conference Presentations

MIKES
S. Sillanpää, M. Heinonen, *The MIKES measuring system for gas mass flow*, in Proceedings of 11th FLOMEKO Conf., IMEKO TC9, Groningen, The Netherlands, Gasunie 2003.

S. Semenoja and M. Rantanen, *Force-Balanced Piston Gauge and Spinning Rotor Gauge the new measurement standards of MIKES*, European Vacuum Congress, Berlin, Germany, 23-26 June 2003 (poster).

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M. Amalvict, J. Hinderer, J. Mäkinen, S. Rosat and Y Rogister: *Long term and seasonal gravity changes at the Strasbourg station and their relation to crustal deformation and hydrology.* XXIII General Assembly of the IUGG (IUGG2003), Sapporo, June 30 to July 11, 2003.

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J. Neumeyer, P. Schwintzer, H. Barthelmes, O. Dierks, Y. Imanishi, C. Kroner, B. Meurers, H.-P. Sun and H. Virtanen, *Comparison between Superconducting Gravimeter and CHAMP Satellite Gravity Measurements*, in Geophysical Research Abstracts, Vol 5., EGS-AGU-EUG Joint Assembly, Nice, France, April 6-11, 2003, p. 06704.

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Kari Riski, *Basic formulas for mass calibration*, MIKES Publication J2/2003, 15 p.

Kari Riski, *Mass comparison: 5 kg laboratory balance*, MIKES Publication J5/2003, 17 p.

M. Rantanen, *Intercomparison in gauge pressure range 0 ... 60 MPa*, MIKES Publication J3/2003, 18 p.

M. Rantanen and S. Semenoja: *Comparison in absolute pressure range 0.02 hPa ... 10 hPa between MIKES and Beamex*, MIKES Publication J6/2003, 14 p.

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Electricity, Time & Acoustics

PERSONNEL AND ORGANISATION OF LABORATORIES

MIKES		**HUT/HVI** Helsinki University of Technology / High Voltage Institute National Standards Laboratory designated by MIKES	
Antti Manninen *Senior Research Scientist, Group* Leader		*Jari Hällström* *Senior Research Scientist, Group Leader*	
Jussi Hämäläinen	Research Scientist	Esa-Pekka Suomalainen	Senior Research Scientist
Pekka Immonen	Research Scientist	Marja-Leena Pykälä	Quality Manager
Kalevi Kalliomäki	Senior Research Scientist, Head of Time and Frequency Lab.	Jukka Piiroinen	Research Scientist
Antti Kemppinen	Trainee (26 May -)	Juri Chekurov	Research Scientist
Tapio Mansten	Senior Research Scientist		
Mikko Moisio	Trainee (2 June -12 September)		
Jaani Nissilä	Research Scientist		
Kari Ojasalo	Research Scientist		
Risto Rajala	Research Engineer		
Anssi Rautiainen	Research Engineer (Permanent position: VTT Inf.Tech.)		
Alexandre Satrapinski	Senior Research Scientist		
Nikolai Tisnek	Research Scientist		

The Electricity Group of MIKES includes the National Standards Laboratories of electrical quantities (DC voltage, DC current, AC voltage, AC current, resistance, capacitance, electric power), time and frequency, and acoustics (sound pressure). The group is located in the Otaniemi campus area in Espoo, and it is staffed permanently by 10 metrologists. In addition to MIKES, there is another National Standards Laboratory in the field of electricity in Finland: High Voltage Institute of the Helsinki University of Technology (HUT/HVI), which is responsible for national standards of DC and AC voltage and current, capacitance and inductance at high voltages (> 1 kV) and currents (>1 kA), and of impulse voltage, impulse current, and impulse charge.

National Standards Laboratories are responsible for realisation and maintenance of the units, and they perform active research and development in metrology. The units are disseminated by calibrating standards and devices for accredited calibration laboratories and other customers who need traceable calibrations at the highest level of accuracy. In 2003, the number of calibration certificates was 64 at the Electricity Group of MIKES and 47 at HUT/HVI.

In the beginning of 2003, the Electricity Group of MIKES moved into new office premises hired from the Helsinki University of Technology. The offices are located in the same building as the earlier ones and the laboratory rooms, in the Otaniemi campus area in Espoo. In addition to the office rooms, the premises also contain two laboratory rooms and a meeting room. The Electricity Group will stay in these premises until the new MIKES building will be ready in Spring 2005.

New hydrogen masers (MIKES)

The equipment of time and frequency laboratory of MIKES strengthened considerably during the year 2003. First, a passive hydrogen maser CH1-76 was received in February, together with a 5 & 10 MHz phase comparator to utilise the excellent short term stability of the maser. With them, the short term stability of any customer oscillator can be measured.

Figure E1. Kalevi Kalliomäki (left) and Tapio Mansten with the new active hydrogen maser CH1-75A.

In principle the short term stability of the measurement system is 10 fs (sd) but the stability of the reference, the passive hydrogen maser, limits it to 1 ps. In December MIKES received an active Hydrogen Maser CH1-75A, which should improve the stability of our reference even further, by at least one decade.

NTP service fully operational (MIKES)

The NTP service of Finland, which was developed between 2000 and 2002, has been in full production use in 2003. The service has about two dozen organisations as users and can easily accept new customers. The work in 2003 has concentrated on developing the quality and surveillance systems of the service. The service has two servers with atomic clocks and two with GPS as reference. The servers are connected to internet via two independent routes.

Final results of key comparison of DC voltage ratios (MIKES)

Draft B of the final report of key comparison EUROMET.EM-K8 (Comparison of DC voltage ratios up to 1000 V) appeared in April 2003, and the results were approved for equivalence in the BIPM key comparison database in December 2003. In this comparison, a Datron 4902S voltage divider was used as a travelling standard, whose 100 V / 10 V and 1000 V / 10 V voltage ratios were measured in 20

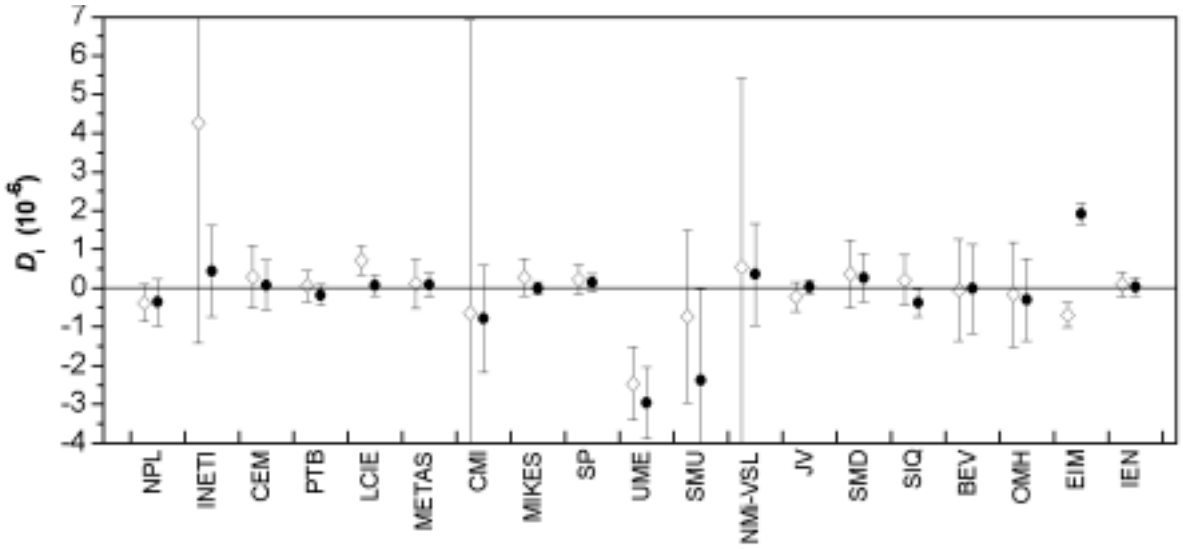

Figure E2. Results of key comparison EUROMET.EM-K8: degrees of equivalence with respect to the comparison reference value for ratios 1000 V / 10 V (open diamonds) and 100 V / 10 V (solid circles) [G. Marullo-Reedtz et al., *submitted to CPEM 2004*].

European laboratories. Measurements in MIKES were made in November 1999, and the results were among the best ones of all participants (see Fig. E2): MIKES result deviated from the key comparison reference value (KCRV) by $0.28 \cdot 10^{-6}$ (with 95% uncertainty $0.48 \cdot 10^{-6}$) at ratio 1000 V / 10 V, and by $-0.01 \cdot 10^{-6}$ (with uncertainty $0.16 \cdot 10^{-6}$) at ratio 100 V / 10 V. At optional ratios 10 V / 0.1 V and 10 V / 1 V the results of MIKES were even better compared to other participants.

Resistance comparisons EUROMET.EM-K10 and EUROMET.EM-S18 (MIKES)

MIKES has continued its activity in the field of resistance comparisons. As the only Scandinavian participant of the ongoing CCEM key comparison on 100 Ω standard resistor, CCEM-K10, MIKES has acted as a "subpilot" of the Scandinavian loop of the corresponding EUROMET key comparison EUROMET.EM-K10, whose pilot is PTB: two temperature and pressure stabilised standard resistors of MIKES were circulated by car and measured at MIKES, SP, JV, DFM, PTB, and VNIIM. The measurements in MIKES have been made in April and July/August, 2003, against QHR. In parallel with EUROMET.EM-K10, a supplementary comparison EUROMET.EM-S18 on 1 Ω and 10 kΩ resistance standards was arranged between Nordic countries. The measurements in MIKES were made in July/August 2003. Results of these comparison are not available yet.

Impulse voltage comparisons (HUT/HVI)

HUT/HVI has been the pilot of the impulse voltage comparison EUROMET.EM-S12 with 26 participating laboratories. The comparison is of lightning impulse voltages, from 50 mV to 1000 V and from 80 kV to 400 kV, and of switching impulse voltages from 50 mV to 300 V. This project has been going on since 1999. The measurements were finished by October 2002, and the analysis of the results was completed during 2003 by HUT/HVI. Draft A is under preparation. The reference measuring system prepared by HUT/HVI showed excellent performance, and HUT/HVI comparison results were among the best ones. The project has been a technical success, and feedback from the participants has been very positive. This project has been partly funded by the Standards, Measurement and Testing Programme of the Commission of the European Communities (Contract number EU-SMT4-CT98-2270). Motivated by the first results of EUROMET.EM-S12, HUT/HVI coordinated another trilateral comparison (EUROMET project no. 748) with PTB and NML (Australia). This comparison is of lightning and switching impulse voltages from 50 mV to 300 V. The measurements were completed in autumn 2002. Analysis of the results is going on, and draft A is expected in spring 2004.

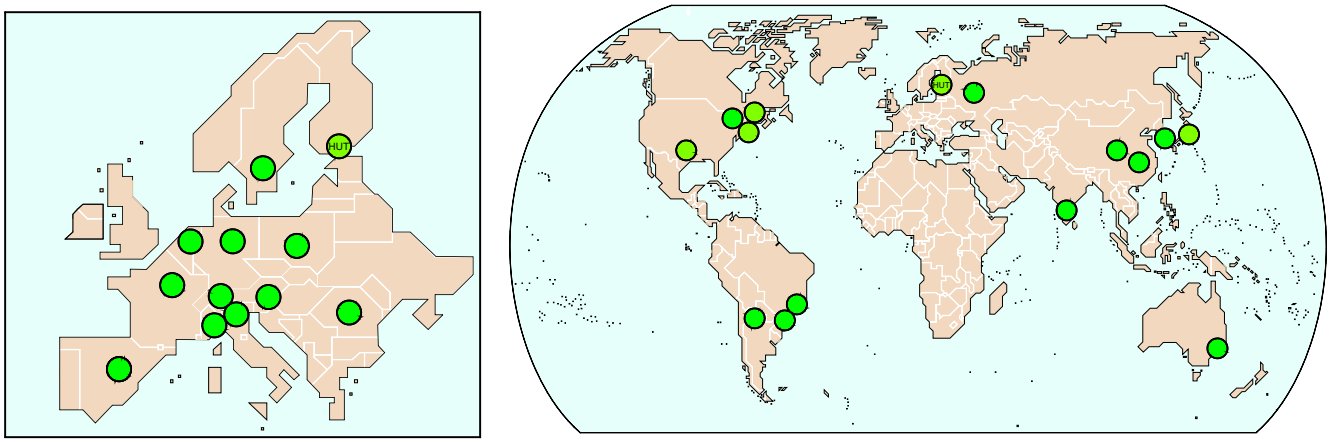

Figure E3. The impulse voltage comparison coordinated by HUT/HVI was participated by laboratories from all over the world.

RESEARCH PROJECTS

AC Josephson voltage standard (MIKES)

The collaboration between MIKES and VTT Information Technology to realize a 1 V quantum AC

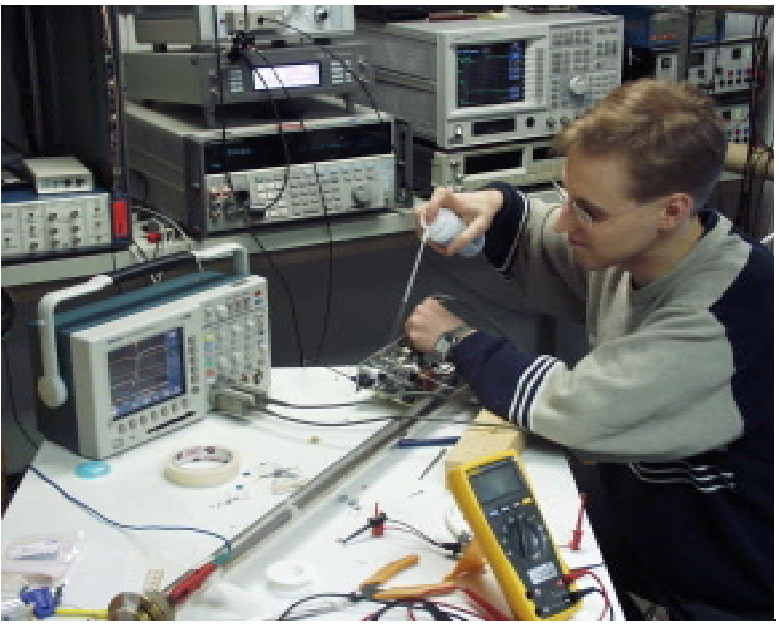

Figure E4. Antti Kemppinen working for his M.Sc. Thesis and fiercely trying to save the bias current source from overheating in the midst of the development of a new quantum AC voltage standard. The trace on the oscilloscope shows one achievement of the project so far: switching of polarity in less than 20 ns.

voltage standard at 1 kHz has continued. The standard is based on novel externally shunted Josephson junction arrays (JJA) designed and fabricated by VTT. The idea is to generate a 1 kHz square-wave voltage whose amplitude is of fundamental accuracy depending only on fundamental constants and the atomic clock frequency. The main frequency component of this waveform is then used to control the amplitude of a stable sinusoid voltage source. Critical of the performance of the standard is the speed and noiselessness of the bias and measurement electronics directly connected to the JJA. In 2003, we have improved the bias current source and the buffer amplifier such that we believe to be quite close of achieving a 1 ppm accuracy at 0.5 V level in the near future. For example, the spectral power in the square wave was measured to be correct within the accuracy of a good-quality true-RMS AC voltage meter (HP3458A). The next generation of the setup is under test in the turn of 2003 - 2004. VTT designed and fabricated new Josephson arrays in 2003. Chips containing two identical 1 V arrays could be most helpful in e.g. impedance metrology. New 10 V arrays would probably raise great international interest as DC voltage standards instead of conventional hysteretic JJAs. The first tests of these chips were performed at the end of 2003 and are being continued in the beginning of 2004.

EMMA - electromechanical microcomponents for precision applications (MIKES)

MIKES participates in the European Union funded EMMA project, which started in September 2001. Other partners are VTT Information Technology (coordinator), VTI Technologies, NMi-VSL, PTB, Fluke PM, and University of Twente. In this project, stable DC and AC/DC references, microwave power sensors and precision inertial sensors based on microelectromechanical components (MEMS) are developed. During 2003, MIKES has mainly studied the long-term stability of the so-called pull-in voltage, which will be the basis of stable DC references. Results of Fig. E5 show that the existing MEMS components, which are not designed for metrological applications, are not stable enough due to electrostatic charging effects. The first set of components specially designed for the DC voltage

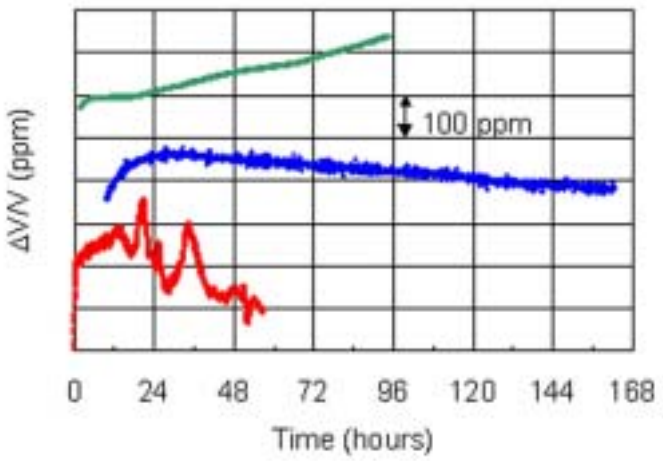

Figure E5. Stability of pull-in voltage in some MEMS components. In these samples, which are not specially designed for the DC reference application, electrostatic charging effects cause a drift which is much larger than the goal of 1ppm/year. These results have been utilised in the design of new components which are expected to have a much better performance.

reference application were manufactured by VTT in the end of 2003 and are under tests at MIKES. The first high frequency power sensors were also fabricated in 2003 by both VTT and University of Twente. MIKES tested the first sensors of the University of Twente in the end of 2003 using S-parameter measurements.

Impedance metrology development (MIKES)

Development of a system to link capacitance with quantum Hall resistance has been going on since the year 2000. Main components of the link - the standard combining 100 kΩ resistors and 1 nF capacitors, and ac 10:1 coaxial resistance bridge - have been constructed during 2003. The characterisation of the standards and ac bridge is in progress. A bootstrap transformer has been constructed partly in collaboration with PTB.

Development of AC/DC current traceability set-up (MIKES)

Current stepup using the new ac current shunts of MIKES is in progress. A new Guildline trans-conductance amplifier was purchased in 2003.

UTC time and GPS common view comparisons (MIKES)

The GPS common view system and especially the corresponding software is under development. The goal is to add our four atomic clocks to the UTC system maintained by BIPM. A geodetic GPS receiver Legacy-E and a special choke ring antenna were bought for international UTC time comparisons.

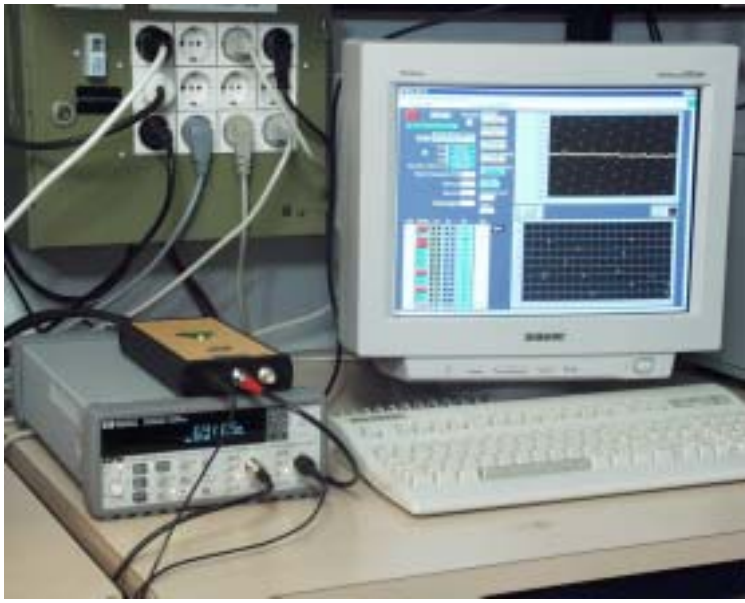

Figure E6. The new geodetic GPS receiver collecting data using the self-developed software.

The receiver has 40 channels for GPS and GLONASS satellites. It will be part of the Stationary geodetic measurement line of southern Finland, too.

The programming of the BIPM UTC comparison

Figure E7. A variable guard ring capacitor (left) was used to calibrate the absolute losses of a 100 pF reference capacitor (right). Calibration was performed at power frequency (50 Hz), voltage was some hundreds of volts.

procedure is well under way and should be completed during the first quarter of 2004.

25 MHz standard frequency transmitter and receiver (MIKES)

Due to digitalisation of TV broadcast, the quality of standard frequency based on stabilised line and frame frequencies of TV has been decreased by two decades compared to old analog TV transmissions. The new 25 MHz standard frequency transmitter compensates for the TV method in the capital area.

Determination of the absolute loss factor of capacitance (HUT/HVI)

In this project a method developed in SP (Sweden) was implemented to determine the absolute loss factor of capacitance. A guard-ring capacitor with variable capacitance and fixed losses was used to characterise the losses in the other arm of the bridge. These measurements also gave information about the linearity of the loss factor scale of the bridge.

Numerical integration of Rogowski coil signal (HUT/HVI)

The signal from the Rogowski coils used for measurement of alternating currents is a derivative of the applied current. A computer algorithm was developed for integration of this signal to get rid of the frequency dependence of the current-to-voltage conversion factor. It appeared that this task is demanding, the main problems that arouse during the project are low-frequency noise and dc-offset of the signal. Both of these get amplified during the integration process. A working solution was reached, but the algorithm development will continue.

Software for impulse voltage calibration (HUT/HVI).

Porting of the impulse voltage calibration software for the new transient digitiser was completed. The functionality of the old version was preserved. Fully automatic impulse calibration of the digitizer, as well as analysis of high voltage calibrations, are again possible.

COMPARISONS & PUBLICATIONS

COMPARISONS

International comparisons

MIKES

EUROMET.EM-K8 (EUROMET project no. 449), Comparison of DC voltage ratios up to 1000 V. Key comparison linked with CCEM-K8. Participants: BEV, BNM-LCIE, CEM, CMI, DFM, EIM, IEN (pilot), INETI, JV, METAS, MIKES, NMi-VSL, NPL, OMH, PTB, SIQ, SMD, SMU, SP, UME. See highlights for more details.

EUROMET.EM-K9 (EUROMET project no. 557), Calibration of high voltage thermal converters. Key comparison to be linked with CCEM-K9. Participants: AREPA, BEV, BNM-LNE (pilot), CEM, CMI, EIM, GUM, IEN, INETI, JV, METAS, MIKES, NMi-VSL, NPL, OMH, PTB, SP, UME. Measurements in MIKES have been made in May, 2000. Draft A of the final report was circulated in June, 2003. MIKES had some problems with 500 V and 1000 V measurements, particularly at highest frequencies: at 50 kHz and 100 kHz, the MIKES results deviated from the comparison reference value by as much as 20 µV/V to 40 µV/V.

EUROMET.EM-K10 (EUROMET project no. 636), 100 standard resistor. Key comparison to be linked with CCEM-K10. Participants: BEV, BFMMP, BIPM, BNM-LNE, CEM, CMI, CSIR-NML, DFM, EIM, GUM, IEN, INETI. JV, LNMC, METAS, MIKES, MINECO, NMi-VSL, NML(IE), NPL, OMH, PTB (pilot), SASM, SIQ, SP, UME, VMT, VNIIM. See highlights for more details.

EUROMET.EM-S18 (EUROMET project no. 710), Comparison of resistance standards. Supplementary comparison. Participants: DFM, JV (pilot for 1 Ohm), MIKES, SP (pilot for 10 kOhm). See highlights for more details.

HUT/HVI

EUROMET.EM-S12 (EUROMET project no. 488), Impulse voltages. Supplementary comparison. 26 participating laboratories, including National Standards Laboratories from five EUROMET countries (FI, FR, DE, ES, SE), and from Australia (NML), Russia (VNIIMS), and China (WHVRI). Pilot HUT/HVI. See highlights for more details.

EUROMET.EM-S14 (EUROMET project no. 495), Measurement of divider ratios at high voltages. Supplementary comparison. Participants: BNM-LCIE, HUT, IEN, METAS, NMi-VSL, NPL (pilot), PTB, SP. The comparison is of direct voltage ratio, ratios ranging from 100000/100 V/V to 100000/1 V/V, and input voltages ranging from 1 kV to 100 kV. The measurements at HUT/HVI were carried out in 2000. Draft B became available during 2003. HVI uncertainties ranged from 20 ppm to 40 pmm, depending on the applied voltage. E_n values ranged from -0.4 to 0.4. HVI uncertainties were in the middle class of this comparison.

EUROMET.EM-S16 (EUROMET project no. 599), AC voltage ratio standards. Supplementary comparison. Participants: BEV, CMI (pilot), GUM, HUT, LCOE, METAS, OMH, SMU. The comparison is of alternating voltage ratio, ratios ranging from 5000/100 V/V to 22000/100 V/V, and input voltages ranging from 2 kV to 26 kV. HUT/HVI measurements were carried out in 2001. HUT/HVI uncertainty for phase displacement was 40 µrad and ranged from 40 ppm to 80 ppm for ratio error. Draft A became available in 2003. For HUT/HVI, the E_n values were well below unity and the uncertainties were in the middle class of the comparison.

EUROMET project no. 748, Impulse voltages. Trilateral comparison piloted by HUT/HVI. Other participants are PTB and NML (Australia). See highlights for more details.

EUROMET project no. 759, Capacitance and inductance. Bilateral comparison between HUT/HVI (pilot) and SP. The comparison is of capacitance (50 µF) and its tan, and of inductance (4 mH) and its quality factor. Last measurements were performed in autumn 2003, and draft A is under preparation.

PUBLICATIONS

Articles in International Journals

MIKES

P. Helistö, J. Nissilä, K. Ojasalo, J.S. Penttilä, and H. Seppä, *AC Voltage Standard Based on a Programmable SIS Array*, IEEE Trans. Instr. Meas. 52 (2003) 533 - 537.

R. Behr et al., *Analysis of Different Measurement Setups for a Programmable Josephson Voltage Standard*, IEEE Trans. Instr. Meas. 52 (2003) 524 - 528.

A. Satrapinski and Y.P. Semenov, *Application of Combined Standard of Resistance and Capacitance for Quadrature Bridge*, MAPAN - Journal of Metrology Society of India 18 (2003) 129 - 132.

A. Satrapinski, *Possible Application of a Cryogenic Current Comparator Bridge for the Measurement of Capacitance Standards*, MAPAN - Journal of Metrology Society of India 18 (2003) 133 - 136.

HUT/HVI

J. Hällström, Y. Chekurov, and M. Aro, *Calculable Impulse Voltage Calibrator for Calibration of Impulse Digitizers*, IEEE Trans. Instr. Meas. 52 (2003) 400 - 403.

Conference Presentations

MIKES

J. Nissilä, K. Ojasalo, J. Hassel, J. Penttilä, A. Manninen, P. Helistö, and H. Seppä, *AC Voltage Standard Based on a Nonhysteretic Josephson Junction Array*, Proceedings of the XXXVII Annual Conf. of the Finnish Phys. Soc., Helsinki, Finland, 20 - 22 March, 2003, p. 221. Poster presented by J. Nissilä.

P. Helistö, J. Hassel, H. Seppä, J. Nissilä, K. Ojasalo, and L. Grönberg, *Development of a Josephson Voltage Standard for AC Applications*, Abstracts of the 6th European Conference on Applied Superconductivity (EUCAS 2003), Naples, Italy, 14 - 18 September, 2003, p. 15. Talk given by P. Helistö.

HUT/HVI

E.-P. Suomalainen and V.-M. Niiranen, *Accurate AC current measuring system up to 300 A,* Nordic Insulation Symposium 2003, NORD-IS 03, Tampere, Finland, 11 - 13 June, 2003, pp. 333 - 340.

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J. Hällström, M. Aro, M.-L. Pykälä et al, *Progress of worldwide comparison of LI measuring systems round 2*, Procedings of 13th International Symposium on High Voltage Engineering, ISH 2003, Delft, the Netherlands, 25-29 August, 2003, 4 p.

E.-P. Suomalainen, J. Hällström, and J. Piiroinen, *Capacitive divider as field probe for voltage linearity measurement of AC dividers*, Proceedings of 13th International Symposium on High Voltage Engineering, ISH 2003, Delft, the Netherlands, 25-29 August, 2003, 4 p.

E.- P. Suomalainen and M. Aro, *Accurate current measuring system based on Rogowski coil,* Proceedings of 13th International Symposium on High Voltage Engineering, ISH 2003, Delft, the Netherlands, 25- 29 August, 2003, 4 p.

Other Publications

HUT/HVI

J. Piiroinen, *Comparison of ESD Reference Measuring Systems at HUT and PTB*. Helsinki University of Technology, High Voltage Institute, Report TKK-SJT-56, 2003, 13 p.

M.-L. Pykälä, J. Hällström, and M. Aro, *Traceability and Mutual Recognizability of Impulse Voltage Measurements Round three*, Helsinki University of Technology, High Voltage Institute, Report TKK-SJT-58, 2003, 155 p.

M.-L. Pykälä, J. Hällström, and M. Aro, *Traceability and recognizability of impulse voltage measurements Round four*, Helsinki University of Technology, High Voltage Institute, TKK-SJT-59, 2003, 150 p.

Y. Chekurov and J. Hällström, *Resistive attenuators for high accuracy measurements of LI voltages in the range 0,5 kV-1,5 kV*, Helsinki University of Technology, High Voltage Institute, Report TKK-SJT-64, 2003, 34 p.

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Photometry and radiometry

PERSONNEL AND ORGANISATION OF LABORATORIES

HUT / MRI
Helsinki University of Technology / Metrology Research Institute
National standards Laboratory designated by MIKES

Prof. Erkki Ikonen
Head of the National Standards Laboratory

Jouni Envall	Research Scientist
Jari Hovila	Research Scientist
Tomasz Jankowski	Research Scientist (Till June 30)
Petri Kärhä	Senior Research Scientist, Quality Manager
Hanne Ludvigsen	Academy research fellow
Farshid Manoocheri	Senior Research Scientist, Head of calibration service
Mikko Merimaa	Senior Research Scientist
Maria Mustonen	Research assistant (From June 1)
Saulius Nevas	Research Scientist
Tapio Niemi	Senior Research Scientist (Leave of absence from July 30)
Juha Nieminen	Research assistant
Mart Noorma	Research Scientist
Soile Saloranta	Coordinator
Jesse Tuominen	Research Scientist
Antti Lamminpää	Research Scientist

HIGHLIGHTS OF PHOTOMETRY AND RADIOMETRY

The effects of correlations in the HUT spectral irradiance realisation were analysed. The obtained results support the earlier uncertainty calculations. The work gives new knowledge on the propagation of uncertainties in interpolation of spectral data. Highlights also include work on oblique angle thin film measurements. In this project the transmittance measurement facilities at HUT have been applied to obtain knowledge of optical properties of materials. HUT completed a one-year Nordic project on high fibre optic power measurements. Considering the relatively small amount of resources invested, a lot of results were obtained. Finland, Sweden and Denmark all now have facilities for calibrating high fibre optic power levels. The intercomparison arranged demonstrated very satisfactory agreement. In 2003 HUT participated in numerous bilateral intercomparisons.

RESEARCH PROJECTS

Development of absolute scale of spectral diffuse reflectance

An absolute measurement facility has been characterized and the uncertainty budget of measurements has been determined. The facility is going to be used to establish an absolute scale of spectral diffuse reflectance in the wavelength range 360 - 820 nm at HUT.

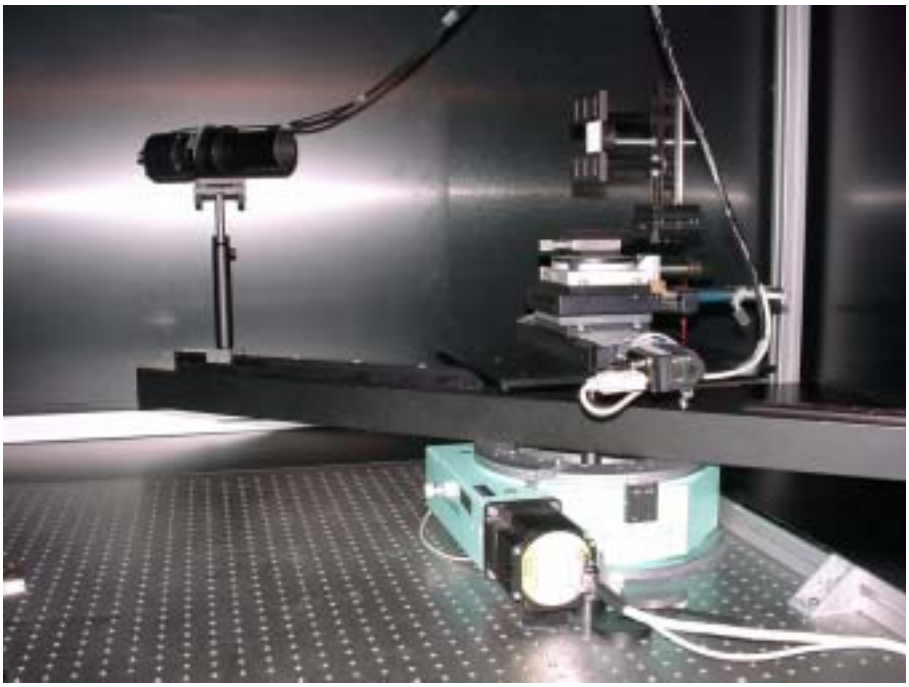

Figure P1. In 2003 HUT completed a development project on absolute measurement method for diffuse reflectance.

Extension of the wavelength ranges of spectral irradiance and radiance

In this project the wavelength ranges of the spectral irradiance and radiance scales are extended to cover from 200 nm to 2.5 m. In 2003, a trap detector with GaAsP photodiodes was built and characterised to be used in the UV region. All additional filters needed for the wavelength region 250 nm - 2.5 m were purchased and characterised. In the IR region, a pyroelectric radiometer was used as the detective element. Preliminary lamp measurements carried out were encouraging.

Intense UV radiation facility for calibration of radiometers

In the project we developed a calibration facility for spectral irradiance responsivities of UV meters. The setup consists of a single grating monochromator, a 450-W Xe light source, and apertured reference photodiodes. In 2003, the reference photodiodes were characterised and test measurements were performed on a commercial UVA meter. The results were compared with the earlier spectroradiometric calibration method of the laboratory. A good agreement of the methods was demonstrated. The results were published in the diploma work of Jouni Envall. The setup was further compared with the facilities of NIST. This activity is described with more details in the intercomparison section.

Determination of radiation temperature using filter radiometers

In this collaboration project of HUT and the MIKES Temperature Laboratory, a new approach to measuring the radiation temperature of a black body radiator is tested. Spectral irradiance of the high precision black body radiator is measured through the limiting set of two apertures in near-IR wavelength region. In 2003 the work was focused on measuring the silver fixed point cell. The agreement of the new method with ITS-90 was of the order of 0.02 K with an uncertainty of 0.15 K.

Calibration facility for color displays and colorimeters

The aim of this project is to build a calibration facility for colour displays. The calibration facility is intended for measuring the relative spectral radiance of color displays with an expanded uncertainty of better than 0.7% (k=2). The facility will include a measurement setup around a characterised spectroradiometer, a translation stage, a standard light source, and a characterised color display. In 2003, experiments have been performed using the existing spectroradiometer of the laboratory for which imaging input optics were purchased.

High power fibre optic calibration

In this collaboration project between HUT, SP and DFM, methods for calibrating fibre optic power meters with optical powers in the range 1 200 mW were developed and compared. The whole project was completed in 2003. The HUT setup consists of and integrating sphere detector and a 1550-nm laser coupled to an erbium-doped fibre amplifier, EDFA. The obtainable uncertainty is of the order of 1.5 %. The independent setups of the three laboratories were compared. The agreement of the measurements was well within the uncertainties of the laboratories (of the order of 1 %).

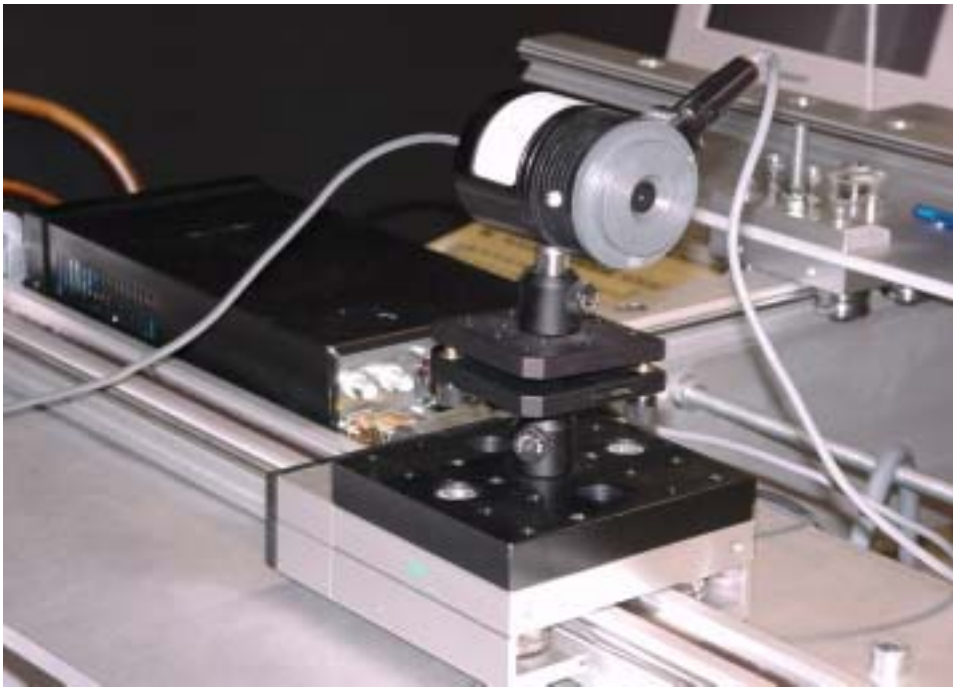

Figure P2. Filter radiometers have an important role in modern radiometry and photometry. HUT is one of the leading experts in this demanding field.

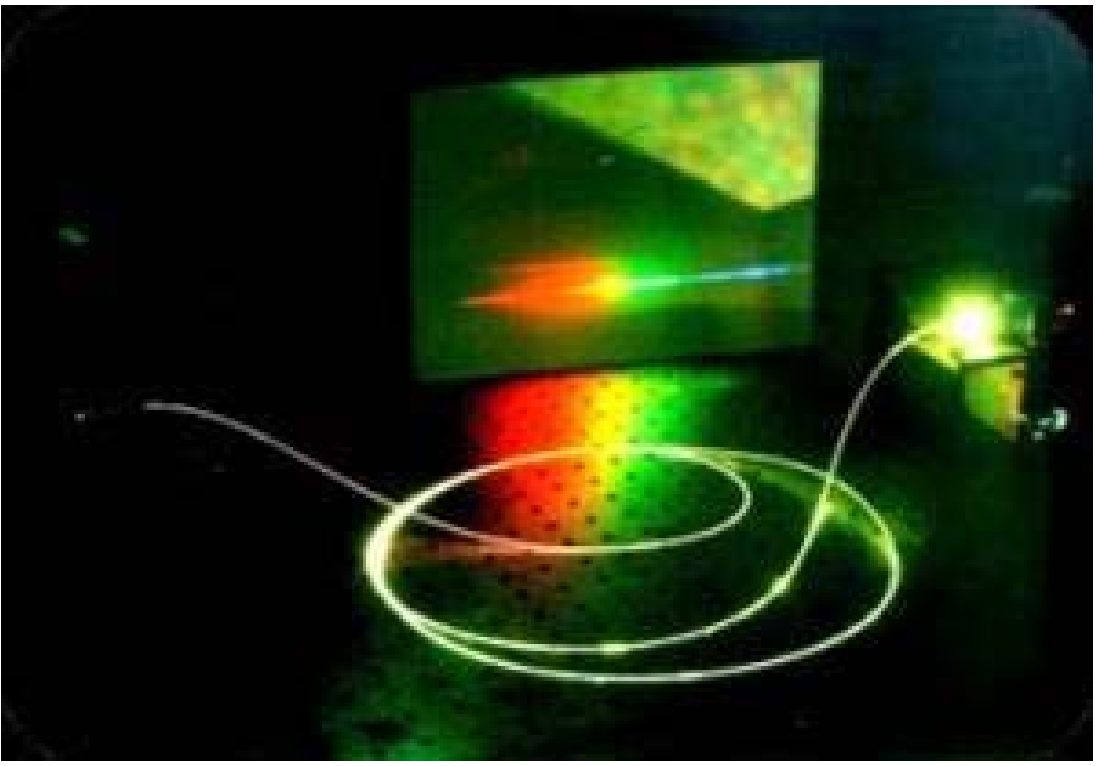

Figure P3. Supercontinuum in an optical fibre. Short pulses of infrared radiation transform in the fibre to light with continuous spectrum.

COMPARISONS & PUBLICATIONS

COMPARISONS

International comparisons

CCPR-K1.a International comparison of spectral irradiance in the wavelength region 250 - 2500 nm
In 2003 the coordinator, NPL, made final measurements on the HUT lamps and the lamps were returned to HUT. Draft A is expected in spring 2004.

CCPR-K2.a International comparison of spectral responsivity in the wavelength region 900 - 1600 nm
Draft A has been circulated to participants in spring 2003.

CCPR-K2.b International comparison of spectral responsivity in the visible region
Draft A was circulated to participants in 2002. The contents of Draft A has been discussed in 2003 and Draft B is expected in 2004.

CCPR-K5 International comparison of spectral diffuse reflectance in the wavelength region 360 - 830 nm
The key comparison piloted by NIST is on diffuse reflectance measurements of Spectralon and tile samples in the wavelength region from 360 nm to 820 nm. In 2003 HUT completed their first set of measurements.

Improving the accuracy of ultraviolet radiation measurement
In this project funded by the SMT-programme of the EU, novel filter radiometer techniques developed by HUT were used to compare various ultraviolet calibration facilities in Finland (HUT), France (BNM), and UK (NPL). In 2003, the results were published in Metrologia.

Bilateral comparison of ultraviolet filter radiometers with BNM-INM
In this project, HUT and BNM-INM characterise spectral irradiance responsivities of ultraviolet filter radiometers and the results are compared. In 2003, HUT carried out the the first set of measurements and the filter radiometer was shipped to France.

Bilateral comparison of ultraviolet filter radiometers with NIST
In this project, HUT and NIST characterise spectral irradiance responsivities of ultraviolet filter radiometers and the results are compared. In 2003, B. Carol Johnson of NIST visited HUT and all comparison measurements were completed. The results are in good agreement in the 365 nm wavelength region but deviate in the 250 nm region. The reasons for the deviation are known, and studies are being carried out to calculate the corrections needed.

Bilateral comparison of aperture area and luminous responsivity measurements with KRISS
In 2003, HUT did its measurements. The artefacts were transported to Korea.

Bilateral comparison of luminous intensity with SP
The luminous intensity scales of HUT and SP were compared in 2003. The results indicate good agreemens.

Multilateral comparison of wavelength scales with NIST
The comparison was piloted by NIST and NPL in the wavelength region of 220-1700 nm. A dilute acidic holmium oxide solution and a solid wavelength calibration filter were used as samples. In 2003 HUT carried out its measurements. The preliminary results for the Holmium oxide have been analysed by NIST. HUT results indicate good agreement with the consensus average. The work for analysing the rest of the measurements and for a draft manuscript for a scientific publication is proceeding.

EUROMET Project no. 666 Intercomparison of Chromatic Dispersion Reference Fibres
The aim of this project is to perform an intercomparison of chromatic dispersion measurements on the most commonly used types of reference fibres (standard, dispersion shifted and non zero dispersion shifted). In 2003, the HUT measurements were completed.

Trilateral comparison of high fibre optic power calibrations with SP and DFM
In this one-year project funded by NORDTEST, HUT, SP and DFM developed calibration facilities for fibre optic power in the range 1 - 200 mW. An intercomparion was arranged at HUT in 2003. The preliminary results indicate good agreement (~1%) of the new realisations. This value is well within uncertainties of the measurements.

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Length

PERSONNEL AND ORGANISATION OF LABORATORIES

MIKES

Antti Lassila
Group Leader

Length Laboratory

Antti Lassila	Head of Laboratory
Kaj Nyholm	Senior Research Scientist
Mikko Merimaa	Senior Research Scientist
Virpi Korpelainen	Research Scientist
Jarkko Unkuri	Research Scientist

Dimensional metrology Laboratory

Veli-Pekka Esala	Head of Laboratory
Heikki Lehto	Senior Research Scientist
Björn Hemming	Senior Research Scientist
Ilkka Palosuo	Research Scientist
Raimo Mylläri	Research Assistant
Ilkka Raeluoto	Research Assistant
Asko Rantanen	Research Assistant

Tampere University of Technology TUT
Institute of Production Engineering,
CMM Contract Laboratory of MIKES

Prof. Heikki Tikka
Head of Laboratory

Paul H. Andersson	Substitute of K003
Tero Ristonen	Laboratory Manager
Timo Antila	Laboratory Engineer

Finnish Geodetic Institute (FGI)
National Standards Laboratory
geodetic measurements

Prof. Markku Poutanen
Head of Department of Geodesy and Geodynamics

Jorma Jokela	Head of Laboratory
Mikko Takalo	Senior Research Scientist, Deputy Laboratory Head
Joel Ahola	Research Scientist
Pasi Häkli	Research Scientist
Paavo Rouhiainen	Research Scientist

In Finnish national standards laboratory scheme, realisation and maintenance of the units of length and development of length metrology are responsibilities of MIKES and Finnish Geodetic Institute (FGI). The MIKES length group has two laboratories: length and dimensional metrology. The length group realises units for length, flatness, straightness, roundness, cylindricity, surface roughness, and angle, and carries out research, development projects and training on its field. In addition, MIKES has a contract with Tampere University of Technology (TUT) nominating its Institute of Production Engineering to take care of needs of co-ordinate measuring machine (CMM) metrology.

Operation of Finnish Geodetic Institute (FGI) is based on its own legislation. FGI operates as a National Standard Laboratory for geodetic length measurements. Measurement standards of FGI in geodetic measurements include quartz meters, Väisälä interferometer geodetic baselines, precision tacheometers and other high precision electronic distance measurement instruments, laser interferometers, and comparators for levelling rods. FGI maintains traceability for geodetic measurements and performs high precision measurements and calibrations for various geodetic applications.

The laboratories of the MIKES length group, TUT, and FGI, made around 500 calibration certificates for approximately 200 different customers in accredited laboratories, research institutes, and industry, during 2003. The total number of calibrated measurement standards and devices was more than 2000.

HIGHLIGHTS OF LENGTH METROLOGY

Acoustic method for determination of the refractive index of air (MIKES)

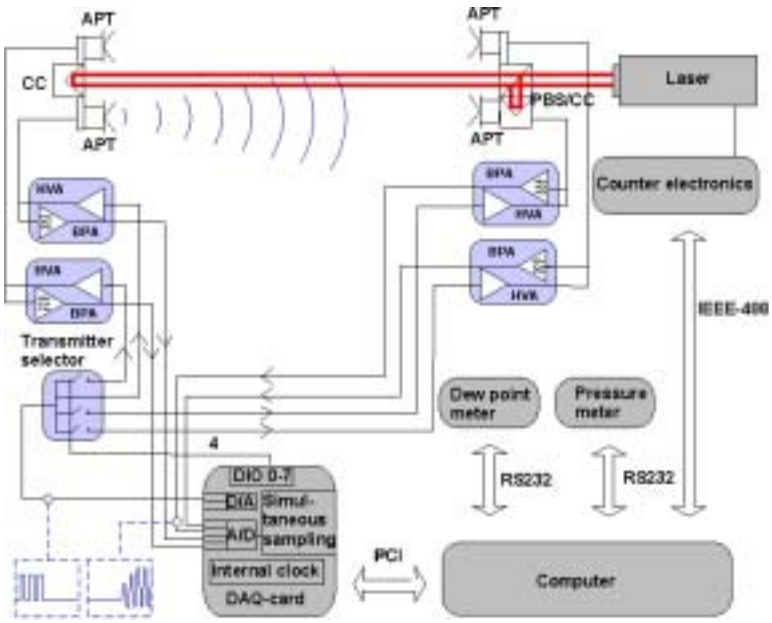

Figure L1. Experimental set-up at MIKES.

Excellent results were achieved in a research project focused to develop an acoustic method for determination of effective refractive index of air along beam path of laser interferometer. The project was carried out in co-operation with AcWaCo Ltd, and it was partly funded by Finnish Technology Agency (TEKES).

The accuracy requirements of position measurements are increasing in both laboratory and production applications. In laser interferometric position measurements, the environmental conditions affect the results due to the effect on refractive index of air. For that reason, air pressure, temperature and humidity have to be measured accurately. Especially near or inside of production equipment, temporal and spatial temperature variations may be large, which makes measurement of actual air temperature difficult with traditional methods. The studied method together with two-colour interferometry is a strong candidate for a future method to improve accuracy of laser interferometric displacement measurements in air.

The effectiveness of the acoustic method is based on the fact that the speed of sound is about two thousand times more sensitive to temperature variations than the refractive index of air. The speed of sound can be measured simultaneously with the laser interferometric measurement and over the same path utilising ultrasonic piezo transducers fixed to the optical components of the interferometer, see Fig. L1.

With equations developed at MIKES during the project, the effective air temperature and refractive index of air can be calculated from the measured speed of sound (f = 50 kHz), pressure, humidity, and CO_2 concentration. The standard uncertainty of the set-up is estimated to be 25 mK in temperature and 2.6×10^{-8} in the refractive index.

EUROMET project no. 744 was started to further study possibilities of the method. During the project, a comparison of the acoustic method and PTB's nanometer comparator a vacuum interferometer will be carried out.

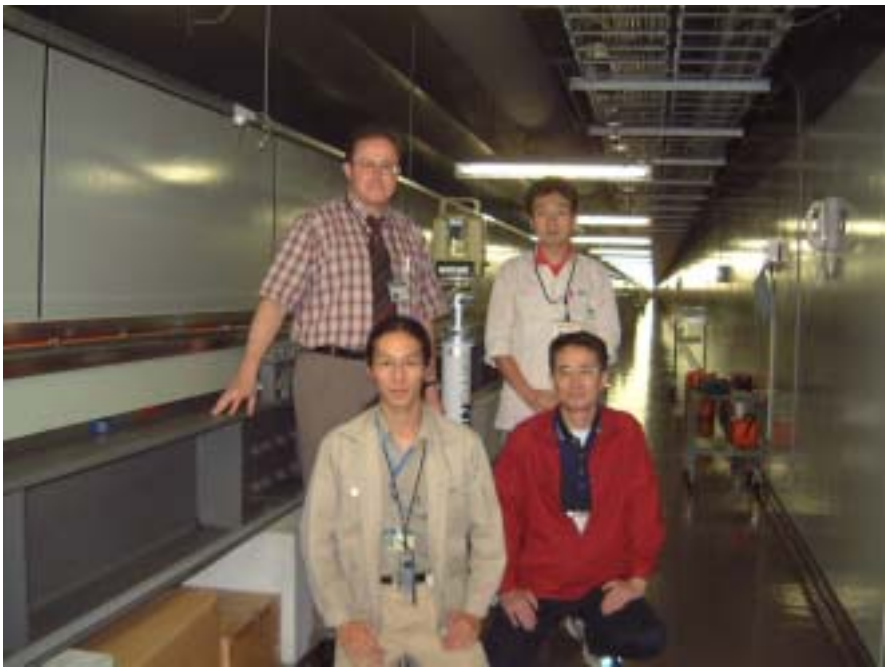

Figure L2. J. Jokela, S. Telada, A. Watanabe and T. Niwa performed a comparison of EDM instruments in the 310-m baseline tunnel of NMIJ/AIST in Tsukuba, Japan.

Finnish-Japanese comparison of EDM instruments (FGI)

A bilateral comparison of EDM instruments was performed in the 310-m optical tunnel of the National Metrology Institute of Japan / National Institute of Advanced Industrial Science and Technology in Tsukuba (see Fig. L2). Two instruments from the FGI and one from the NMIJ/AIST were used. A 96-m laser interferometric baseline was used to study scale corrections, and an adjacent 7-point baseline was used for additive constant. Comparisons connected with new measurements with the Väisälä interference comparator at the Nummela Standard Baseline are planned for 2004-2005.The results of the successful comparison are somewhat open to various interpretations, and to take full advantage of the work, it will be complemented by measurements in Nummela.

Excellent results in CCL-nano3, line scale comparison (MIKES)

Results of CCL-nano3 line scale comparison were reported and published by the pilot laboratory PTB (DE). The comparison was originally initiated as pilot study but it was decided later by CCL-WGDM to promote it to CCL supplementary comparison of MRA. The purpose of the pilot study was to investigate how accurately it is possible to measure line distances. Participants were NIST (USA), METAS (CH), CMS/ITRI (TW), NIM (CH), KRISS (KR), MIKES (FI), SP (SE), IMGC (IT), VNIIM (RU), MNIJ (JP), LNE (FR), and PTB (DE). The subject of comparison was calibration of several high quality line scales up to 280 mm on quartz and Zerodur substrates. The results of MIKES were excellent showing length-dependent and length-independent deviations of only 10 nm/m and 5 nm, respectively, from the reference values. See Fig. L3 showing results for task 1B: calibration of every 5 mm line of a 280 mm on the Zerodur scale.

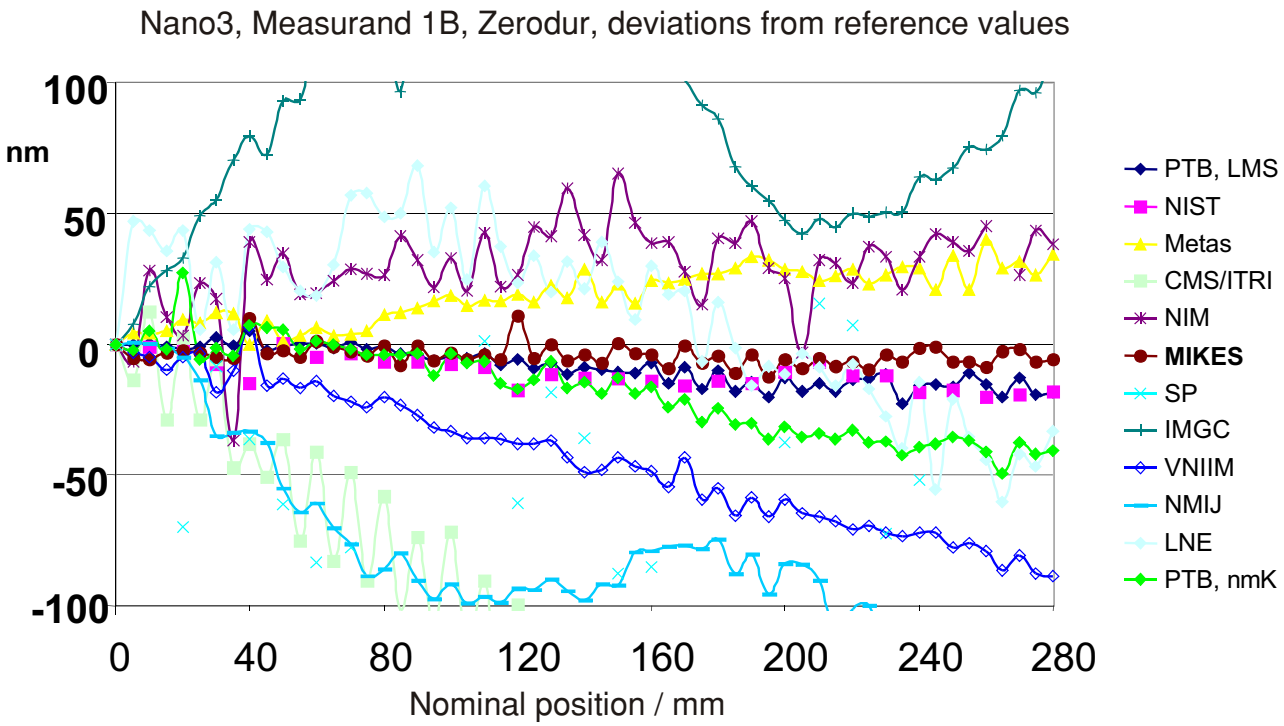

Figure L3. Results of task 1B from CCL/nano3 comparison.

Optical frequency comb (MIKES)

The objective of the research project is to build a frequency comb extending over a full optical octave. The comb will improve the accuracy of optical frequency measurements and of the practical realisation of the metre. In addition to absolute determination of optical frequencies of stabilised lasers, the comb will be used for spectroscopical studies of optical transitions that are interesting for metrological applications.

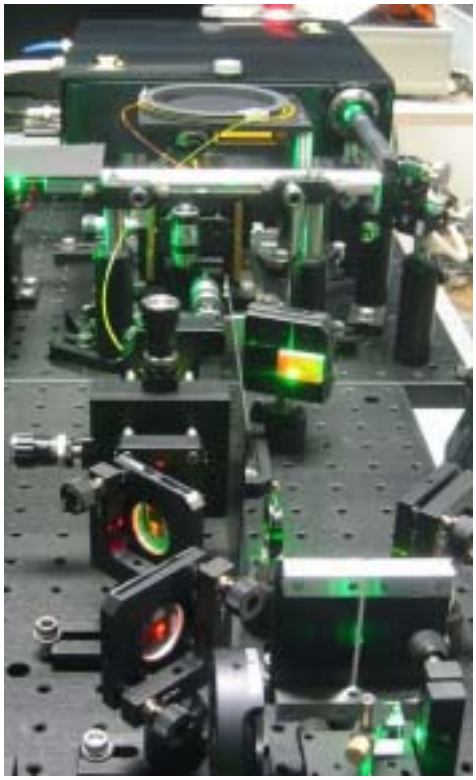

Figure L4. Optical frequency comb at MIKES.

A commercial Kerr-lens mode-locked femtosecond Ti:S laser and a photonic crystal fibre are used to generate the frequency comb (see Fig. L4). The stabilisation scheme of the comb utilises the good short term stability of our iodine-stabilised Nd:YAG laser and the good long term stability of a caesium atomic clock. The comb will be phase-locked at two wavelengths (532 nm and 1064 nm) to the Nd:YAG-laser, which serves as a low phase-noise flywheel. The repetition rate and the carrier-offset frequency of the comb are then determined and referenced to a caesium atomic clock (the primary time and frequency standard).

In the first experiments, a frequency comb covering a wavelength range from 500 nm to 1300 nm was successfully generated and the comb phase-locked to the iodine-stabilised Nd:YAG laser at 532 nm with good S/N ratio. However, when good beat-signal between the comb and the Nd:YAG laser at green was obtained, the output from the fibre was too low at 1064 nm for phase-locking, and vice versa. Therefore, a new photonic crystal fibre was acquired and the set-up changed to also allow self-referencing for the determination of the carrier-offset frequency. At the end of the year 2003 a hydrogen maser was installed at the MIKES time and frequency laboratory. The maser will act as a very stable microwave oscillator, which is required when self-referencing technique is used. During 2004, the frequency comb will be characterised and the first absolute frequency measurements carried out.

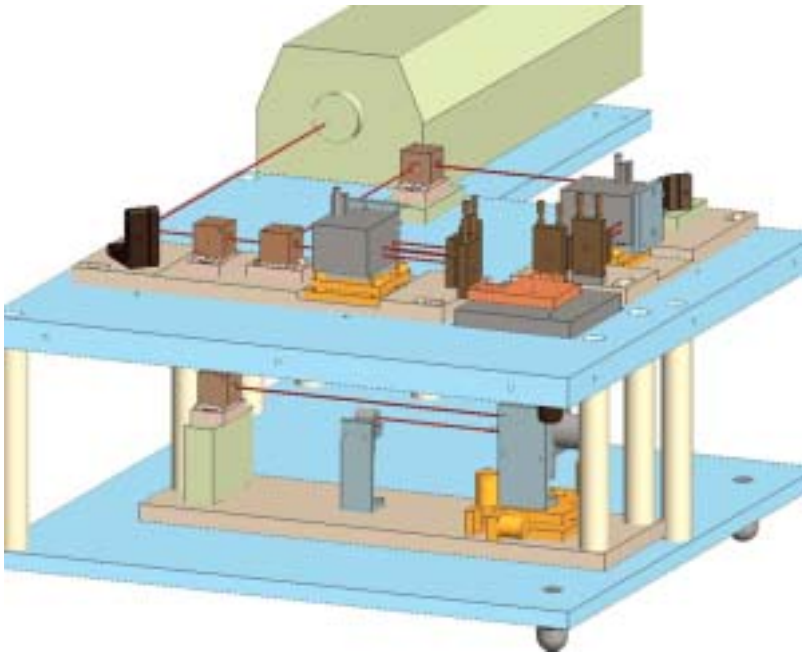

Figure L5. The 3 axes interferometer of the AFM.

Nanometrology (MIKES)

In order to realise traceable length scale on nanometer region and to offer related calibration and measurement services, MIKES has a project to engineer a metrological AFM (Atomic Force Microscope) In the designed AFM, the non-linearities of the 3D scanner of the microscope are eliminated by direct interferometric online measurement of the movements. The design of the constructed interferometer is shown in Fig. L5. A sample will be placed on a piezoelectric xyz mirror-stage under the AFM cantilever. In order to minimise the cross talk and angular errors of the movement, the stage is constructed from two separate piezo stages. Xy-movements are made by one flexure guided piezo stage and z-movement with separate piezo movement. The 3-axes interferometer is constructed around the scanner following Abbe's principle to measure accurately the position where the tip interacts with sample surface. Death path errors are eliminated form x and y axes by utilising differential optics and from z axis by online calculations. Periodic non-linearity of the laser interferometers is eliminated by a self-calibration method with combined capacitive sensors. Sub-nanometer linearity is reached with this method. The frame of the device is constructed of Invar and SuperInvar metal alloys in order to minimise effects of thermal expansion. In future, the AFM head will be combined with scanner and the interferometer.

Development of calibration facility for thermal expansion coefficient (MIKES)

For high precision length calibrations, the accurate and traceable value of the linear thermal expansion coefficient (LTEC) of material measurement standards is needed. During this project, a device for interferometric determination of the LTEC of gauge blocks has been constructed. Minimum temperature gradients in a gauge block with 500 mm maximum length and relatively fast operation were basis of the design.

For controlled temperature change, the artefacts are placed inside a separate vacuum chamber with an isothermal radiation cavity, where the laser beam of the interferometer can be directed. Two radiation shields form a nearly uniform temperature around the gauge block and protect it from heat radiation from the chamber walls. Changing the temperature of a base plate with two peltier elements sets the temperature. The other side of the peltier element is attached to a water-cooled aluminium plate. During year 2003 fine tuning and test measurements with the device were carried out. Based on preliminary uncertainty analysis, LTEC can be measured with an expanded uncertainty of 0.04×10^{-6} 1/K (k=2) for 100 mm gauge blocks.

2D optics (MIKES)

The aim of this project is to develop instrument for calibration of optical 2-dimensional standards. Such standards are useful e.g. for calibration of measuring systems with camera and modern vision based CMMs. Technical aims for the calibration instrument are: measuring range of 150 x 150 mm^2 and calibration uncertainty of 100 nm (k=2).

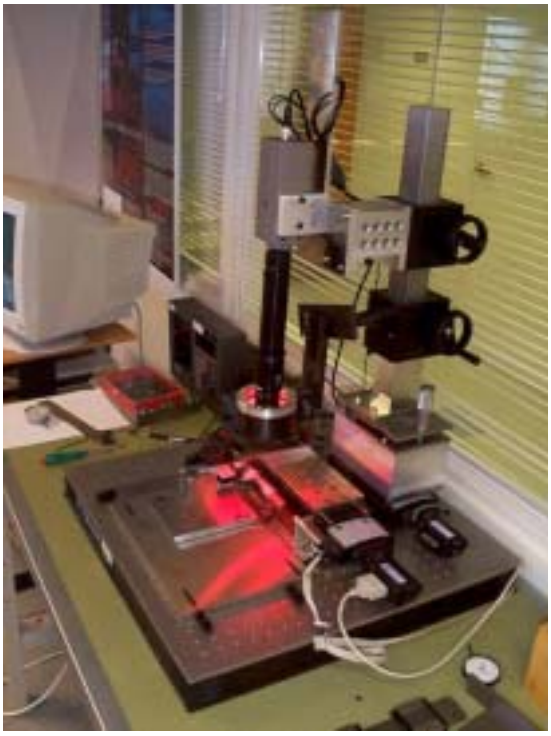

Figure L6. Setup for automatic calibration of micrometers.

The mechanics of the equipment consists of XY-table with air bearings, plane-mirror interferometer system for position measurement, and machine vision based detection system (see Fig. L6). Refractive index of air is determined with environmental sensors (temperature, pressure, and humidity) and updated Edlén formula. The final testing of the system is underway.

Automatic calibration of micrometers (MIKES)

In this project a machine vision based automatic calibration device of micrometers was developed (see Fig. L6). The accuracy of automatic calibration was found to be better than that of manual calibration. In addition, automation makes it possible to take more readings along the scale, and it gives therefore much more information about properties of the micrometer.

Although some mechanical problems still remain in the equipment, the main conclusion is that the presented new approach has the potential to produce ten times more calibration points at an uncertainty which is only 10 % compared to the uncertainty of a manual calibration.

Traceability of angle measurements (MIKES)

The aim of this project is to develop our accuracy and procedure for calibration of polygons, angle gauge blocks, angle optics of laser-interferometers,

Figure L7. Calibration of a polygon with autocollimator and rotary table.

autocollimators, theodolites, and several other angle measuring instruments (see Fig. L7). During year 2003 we have made new procedures for calibration of our vertical and horizontal rotary tables, designed new fixing for the collimator during calibration of theodolites, and acquired a new collimator. The collimator has four targets at different optical distances. This feature can be used to study influence of focusing with optical measuring instruments.

Step gauge interferometer (MIKES)

The aim of this project was to develop an accurate and practical device for calibration of step gauges. Step gauges are important length standards, which are useful for example in calibration of co-ordinate measuring machines. Technical aims for the calibration instrument are measuring range up to 2 m and uncertainty in calibrations ± 0,5 µm/m (k=2).

Development work and modernisation of the old step-gauge calibration set-up has been made, and the measurement time for step gauges has been much reduced. Also the accuracy and usability of the system have been improved.

Research and development (FGI)

Planning of new working premises at the Nummela Standard Baseline was started. The construction works will be completed in summer 2004, preparatory to the next interference measurements with the Väisälä interference comparator.

Capability in angle and length measurements was improved by purchasing a new advanced robotic total station. Calibration of precise levelling instruments and systems has been continuous. Programs for automated vertical calibration of levelling rods and instrumentation for system calibration of digital levelling have been improved. Field tests have been performed at the Metsähovi test field.

Interferometric traceability of CMM (TUT)

A new project is running on the reference CMM, SIP CMM 5 at TUT. The purpose of the project is to implement direct interferometric measurement of the

displacement of the stylus of the CMM. This is done in order to improve stability, repeatability and accuracy of displacement measurements of the stylus. Fig. L8 shows the set-up. The wavelength of the laser interferometer is sensitive to refractive index of air. In order to compensate better the changes of the index, a new device "Acoustic wavelength compensator" using patented method by AcWaCo Ltd will be coupled to the interferometer in the beginning of the year 2004.

Intercomparison of video co-ordinate measuring machines in Finland 2002 (TUT)

A MIKES-funded development project "Intercomparison of Video Co-ordinate Measuring Machines in Finland 2002" was finished and reported. During the project, two new transfer standards suitable to test performance of visual CMMs were developed. One of the standards has etched rings on a flat glass substrate. Another transfer standard is a prismatic hole plate with assembled coloured bushes. Bushes of three different colours and surface finish were used in order to study their effect to measurement results. One conclusion of the comparison is that uncertainty values given by manufacturers of the visual CMMs are two small to apply for actual measurements.

Easytrac (TUT)

EC project called Easytrac was finished in February 28, 2003. The Institute of Production engineering participated in the project. The technical report of the project GRD1, 1999-10626, was published by the Spanish co-ordinator Unimetric Ltd.

CMM- ball plate calibration (TUT)

The calibration methods of ball plates in combination with CMM were studied for the first time at TUT. There are two different reversal methods to calibrate hole or ball plates. One is the well known PKAL by PTB, and the other one developed by Prof. Tikka at TUT. During the project, both methods were used for CMM calibration. Also the uncertainties for CMMs were determined by both PTB's and Prof. Tikka's methods.

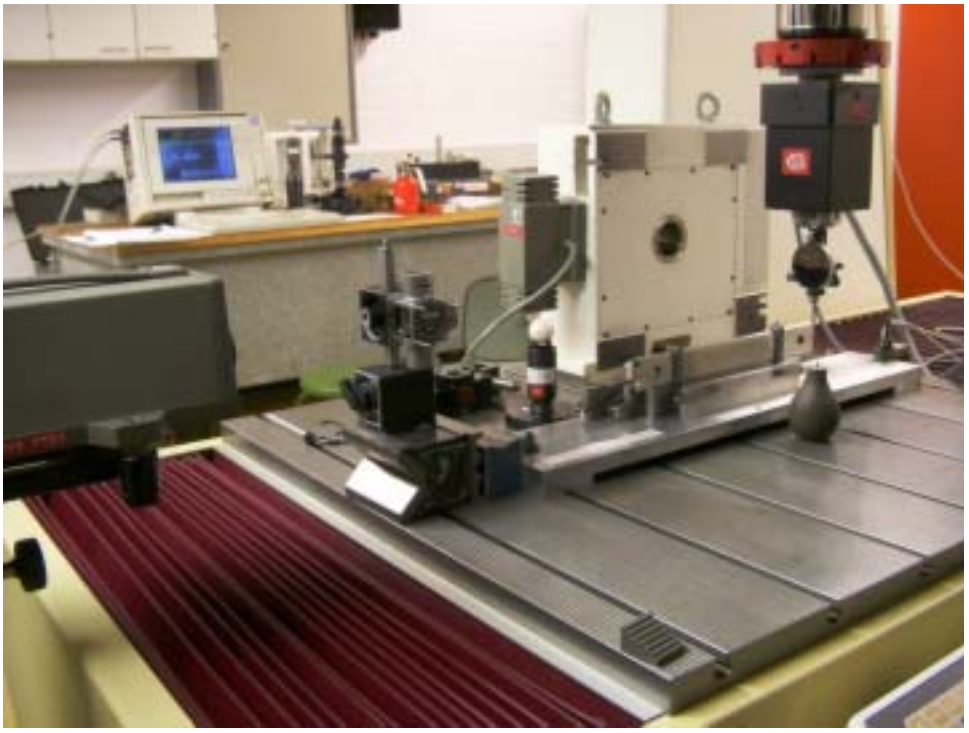

Figure L8. The realisation of direct Laser-interferometeric displacement measurement of the stylus of CMM.

COMPARISONS & PUBLICATIONS

COMPARISONS

MIKES

CCL-nano3
See highlights earlier.

BIPM.L10
Length laboratory participated in a measurement campaign on absolute frequency determination of iodine-stabilised He-Ne lasers at 633 nm held at BIPM, France, in November 2003. The absolute frequency of the portable MRI3 laser of MIKES locked on the *f* - component of the R(127) 115 transition of $^{127}I_2$ was determined by using BIPM's frequency comb. The measured frequency agrees well with the CIPM value. In Finland, the frequency value was then transferred by beat-measurements to MRI1 and MRI2, the two stationary iodine-stabilised red He-Ne lasers of MIKES. The report is in the making.

Euromet project No. 600
The supplementary comparison of MRA, Euromet project No. 600, "Intercomparison of Measurements on Surface Roughness Standards", was arranged by the Technical University of Denmark together with Physikalisch-Technische Bundesanstalt. The participating countries were AT, CH, CZ, DE, DK, ES, FI, IT, LT, NL, PL, PT, SE, SK, TR and GB. The circulation of the standards began in July 2001 and ended in May 2003. Draft B was received in October 2003. A considerable amount of the results in the whole comparison (nine institutes of 15) did not fulfil the criterion En<1. For MIKES, En<1 for all the results, and the comparison indicated that calculation of reduced uncertainties is feasible.

Euromet project No. 667
Length laboratory participated EUROMET project No. 677, "Comparison of a steel tape measure", which is still running. Measurements at MIKES were made on May 2003. Other participants are METAS (CH), BEV (AT), CEM (ES), CMI (CZ), GUM (PL), IMGC (IT), JV (NO), LNMC (LV), MIRS (SI), NML CSIRO (AU), NCM (BG), OMH (HU), PTB (DE), SMD (BE), SP (SE), UME (TR), VMT/VMC (LT).

National intercomparisons for accredited calibration laboratories

MIKES

Comparison D6
The interlaboratory comparison D6 for Finnish accredited laboratories was arranged by dimensional metrology laboratory of MIKES between March and August 2003. The measurands of the comparison were roundness deviation and diameter of a plug gauge. Participants were four accredited laboratories and two other laboratories. Final report of the comparison was published in MIKES Publication series.

FGI

Finnish-Japanese comparison of EDM instruments
See highlights earlier.

PUBLICATIONS

Articles in International Journals

MIKES

S. Picard, L. Robertsson, L.-S. Ma, K. Nyholm, M. Merimaa, T. E. Ahola, P. Balling, P. Kren, and J.-P. Wallerand, *Comparison of $^{127}I_2$-stabilized frequency-doubled Nd:YAG lasers at the Bureau International des Poids et Mesures*, Appl. Opt. 42 (2003) 1019-1028.

S. Picard, L. Robertsson, L.-S. Ma, Y. Millerioux, P. Juncar, J.-P. Wallerand, P. Balling, P. Kren, K. Nyholm, M. Merimaa, T. E. Ahola, and F.-L. Hong, *Results from international comparisons at the BIPM providing a world wide reference network of $^{127}I_2$-stabilized frequency-doubled Nd:YAG lasers*, IEEE Trans. Instrum. Meas. 52 (2003) 236-239.

K. Nyholm, T. Ahola, M. Merimaa, and A. Lassila, Frequency stabilization of a diode-pumped Nd:YAG laser at 532 nm to iodine by using third-harmonic technique, IEEE Trans. Instrum. Meas. 52 (2003) 284-287.

L.-S. Ma, S. Picard, M. Zucco, J.-M. Chartier, L. Robertsson, P. Balling, P. Kren, J. Qian, Z. Liu, Ch. Shi, M. V. Alonso, G. Xu, S. L. Tan, K. Nyholm, J. Henningsen, J. Hald, and R. Windeler, *First absolute frequency measurements of the R(12) 260 and R(106) 280 transitions in $^{127}I_2$ at 543 nm*, submitted for publication in IEEE Trans. Instrum. Meas.

Conference Presentations

MIKES

A. Lassila, J. Jokela, M. Poutanen, and Xu Jie*, Absolute calibration of quartz bars of Väisälä interferometer by white light gauge block interferometer*, in Proc. XVII IMEKO World Congress, June 22-27, 2003, Dubrovnik, Croatia, 1886-1890.

J. Unkuri, J. Manninen, and A. Lassila, *Accurate linear thermal expansion coefficient determination by interferometry*, in Proc. XVII IMEKO World Congress, June 22-27, 2003, Dubrovnik, Croatia, 221-224.

A. Lassila and V. Korpelainen, *An acoustic method for determination of the effective temperature and refractive index of air*, in Proc. SPIE, 5190, 2003, pp 316-326.

V. Korpelainen, B. Hemming, H. Lehto, and A. Lassila, *A new acoustic method for determination of the effective air temperature for length interferometers*, in Proc. Euspen International Topical Conference, Aachen, Germany, 2003, 431-434.

K. Nyholm and M. Merimaa, *Optical frequency comb generator for metrology*, Proceedings of the XXXVII Annual Conference of the

Finnish Physical Society, March 20-22, 2003, Helsinki, Finland, Helsinki University, Report Series in Physics HU-P-265, p. 383.

M. Merimaa, V. Ahtee, M. Vainio, and K. Nyholm, *Development of a frequency comb generator for precision optical frequency measurements*, Northern Optics 2003, June 16-18, 2003, Espoo, Finland, Helsinki University of Technology, Publications in Engineering Physics, TKK-F-A822, p. 82.

V. Korpelainen and A. Lassila, *A new acoustic method for the determination of the refracticve index of air*, Northern Optics 2003, June 16-18, 2003, Espoo, Finland, Helsinki Univ. of Technology, Publications in Engineering Physics, TKK-F-A822, p 68.

Björn Hemming, Ilkka Palosuo, and Antti Lassila, *Design of a calibration machine for optical two-dimensional length standards*, Northern Optics 2003, June 16-18, 2003, Espoo, Finland, Helsinki University of Technology, Publications in Engineering Physics, TKK-F-A822, p. 94.

FGI

A. Lassila, J. Jokela, M. Poutanen, and Xu Jie, *Absolute calibration of quarz bars of Väisälä interferometer by white light gauge block interferometer,* in Proc. XVII IMEKO World Congress, June 22-27, 2003, Dubrovnik, Croatia, p. 1886-1890.

P. Lehmuskoski, P. Rouhiainen, V. Saaranen, and M. Takalo, *On stability of the Metsähovi test field for levelling instruments,* Meeting of the NKG Working Group for Height Determination, April 1, 2003, Copenhagen, Denmark.

M. Ollikainen, J. Mäkinen, J. Jokela, and R. Chen, *National Report of Finland,* Symposium of the IAG Subcommission for the European Reference Frame (EUREF), June 4-6, 2003, Toledo, Spain, 8 p. submitted to proceedings.

M. Takalo, *On application of the system calibration results,* Meeting of the NKG Working Group for Height Determination, April 1, 2003, Copenhagen, Denmark.

M. Takalo and P. Rouhiainen, *On the system calibration comparator of the Finnish Geodetic Institute,* Poster, IUGG2003, June 30 July 11, 2003, Sapporo, Japan.

M. Takalo and P. Rouhiainen, *On use of FGI system calibration comparator,* Poster, Working Week and 125th Anniversary of Fédération Internationale des Géomètres, April 13-17, 2003, Paris, France.

MIKES Publications

V-P. Esala, *Pituuden vertailumittaus D6*, MIKES Publication J3/2004, 12 p.

Other Publications

MIKES - TUT

V-P. Esala, H. Lehto, and H. Tikka, *Konepajatekniset mittaukset ja kalibroinnit,* Tekninen tiedotus 3 - 2003 Teknologiateollisuus (2003) 75 p.

FGI

J. Jokela, *Maailman tarkimmat perusviivat,* in M. Poutanen (Ed.): Maan muoto, p. 102-117. URSA.

J. Jokela, J. Mäkinen, and M. Takalo, *Metrology and standardization*, in M. Poutanen, J. Jokela and M. Ollikainen (Eds.): Geodetic Operations in Finland 2000-2003, p. 17-20. Finnish Geodetic Institute.

P. Lehmuskoski, P. Rouhiainen, V. Saaranen, M. Takalo and H. Virtanen, *Metsähovin vaaitustestikentän ensimmäiset kaksi vuotta liikkuvatko kalliokiintopisteet?,* Maanmittaus, Vol. 78, No. 1-2, p. 57-69.

Thermometry

PERSONNEL AND ORGANISATION OF LABORATORIES

MIKES

Martti Heinonen
Head of Humidity Laboratory, Group Leader

Thua Weckström	Senior Research Scientist, Head of Thermometry Laboratory
Leena Uusipaikka	Research Scientist
Hannu Räsänen	Research Assistant
Riikka Viskari	Trainee (19.5. - 24.8.2003)
Paavo Leskinen	Trainee (10.11.2003 -)

The MIKES Thermometry Group carries out research and provides measurement service in the field of temperature and humidity measurements. The Group has been organized in two national standards laboratories.The laboratories realise units for temperature, dew-point temperature and relative humidity and carry out research on measurement standards and calibration methods. The expert service for customers provided by the Group covers training, co-operative development projects and consultation. The Group issued about 200 calibration certificates for customers at accredited laboratories, research institutes and industry during 2003.

HIGHLIGHTS OF THERMOMETRY

Comparing ITS-90 to filter radiometry

In this project the Thermometry Laboratory and the HUT Metrology Research Institute have been comparing the International Temperature Scale of 1990 (ITS-90) to filter radiometer techniques, where the temperature is determined from the measured irradiance at known distance. The HUT filter radiometer consists of a silicon trap detector, a precision aperture and a bandpass filter. The construction allows changing of the bandpass filters during the measurements without changing the alignment of the filter radiometer. The trap detector, the aperture and the filters were all characterised separately. In 2003, a fixed-point temperature was measured with the filter radiometer. The copper point at 1084.62 °C was chosen in order to get a good signal from the filter radiometer. The aperture of the fixed-point cell was 10 mm.

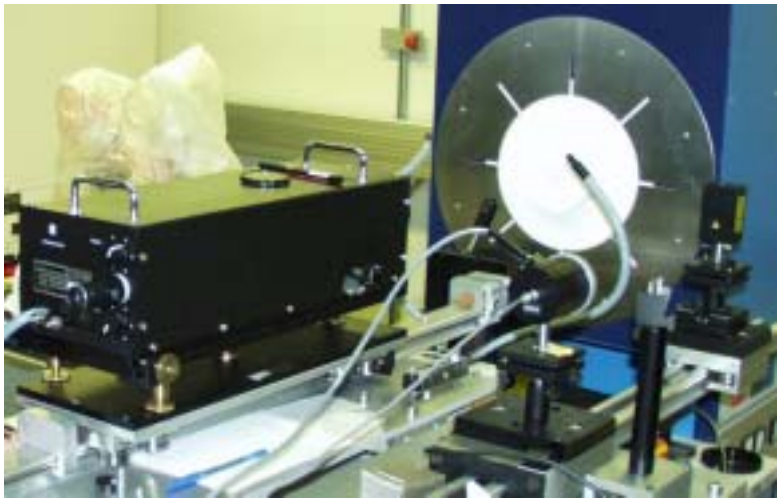

Figure T1. The pyrometer of MIKES and the HUT filter radiometer.

The standard uncertainty includes the calibration uncertainty of filter radiometer, the uncertainty corresponding to the measurement set-up, the uncertainty in the photocurrent measurements and the uncertainty in the fixed-point realisation.

Comparison measurements at different temperatures will be carried out after the updating the pyrometer of the Temperature Laboratory.

Results:

Filter	Effective Wavelength (nm)	FWHM (nm)	Measured Temperature (°C)	Deviation from ITS-90 (°C)	Expanded Uncertainty (°C) (*K*=2)
900D	901	10	1084.40	-0.17	0.36
800C	800	13	1084.67	0.10	0.34
700	698	22	1084.73	0.17	0.48
V(λ)	594	112	1084.72	0.15	0.38

Active role in EUROMET co-operation

The laboratories participated actively in the international co-operation: A significant effort was focused in the work of the EUROMET Humidity Expert Group (EUROMET Project no. 720) and the

Figure T2. Transfer standards of the CCT-K6.

EUROMET Key Comparison (EUROMET Project no. 621). Both projects are coordinated by the Humidity Laboratory. At the inter-regional level, the Humidity Laboratory has been participating in the CCT-K6 Key Comparison and assisting the CCT Working Group 8 in processing the CMC humidity entries. Measurements of various EUROMET comparison projects were carried out at the both laboratories.

Fruitful co-operation with partners

Co-operative projects with the Finnish Meteorological Institute (FMI) and Orion Pharma Ltd show that the partnership with MIKES produces results that are relevant both at scientific and industrial level. In the project with FMI, the Humidity Laboratory developed an equipment for humidity tests at temperatures down to -67 °C. A capacitive humidity sensor unit (Fig. T3 a) designed by the FMI for measuring conditions in Mars were successfully tested in the temperature range from -67 °C to 0 °C. The relative humidity of the air in the chamber (fig T3 b) was between 7%rh and 80 %rh. According to the test results, the relative humidity of the air in the chamber can be determined with an expanded uncertainty smaller than ±3 %rh in the whole temperature range. The capacitive polymer sensors were found linear and faster than the test system. The results will be reported in the Tempmeko 2004 Conference.

In the development project with the Orion Pharma, a portable relative humidity calibrator was designed and constructed (Fig. T4) to be used in the Orion Pharma factories. The operation of the calibrator is based on controlled mixing of dry and wet air. As a results of the project, the time needed for calibrations at the factories reduced significantly.

Figure T4. The humidity control unit of the calibrator constructed for Orion Pharma.

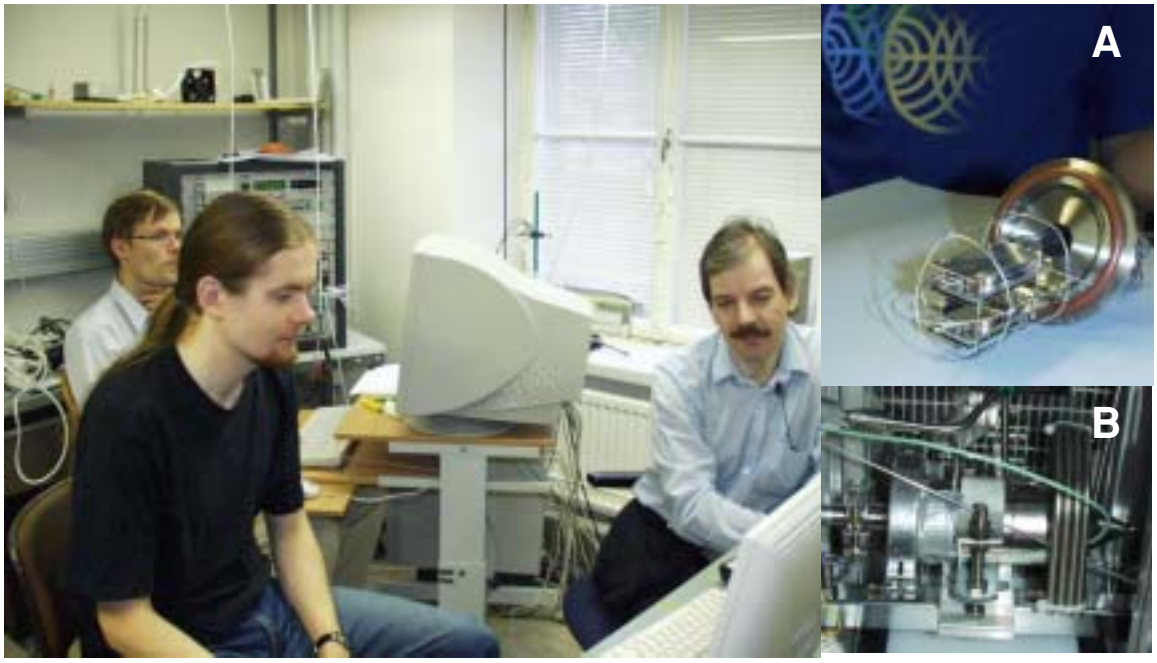

Figure T3. A humidity sensor unit (A) was tested by scientists from MIKES and FMI using a test chamber (B) in temperature down to -67°C.

RESEARCH PROJECTS

Developing a new measurement standard for a cryogenic temperature range

In 2003 MIKES began the project " Metrological CBT - A Thermometer Based on Coulomb Blockade" together with the Low Temperature Laboratory of HUT (LTL/HUT). The principle of CBT was invented in 1994

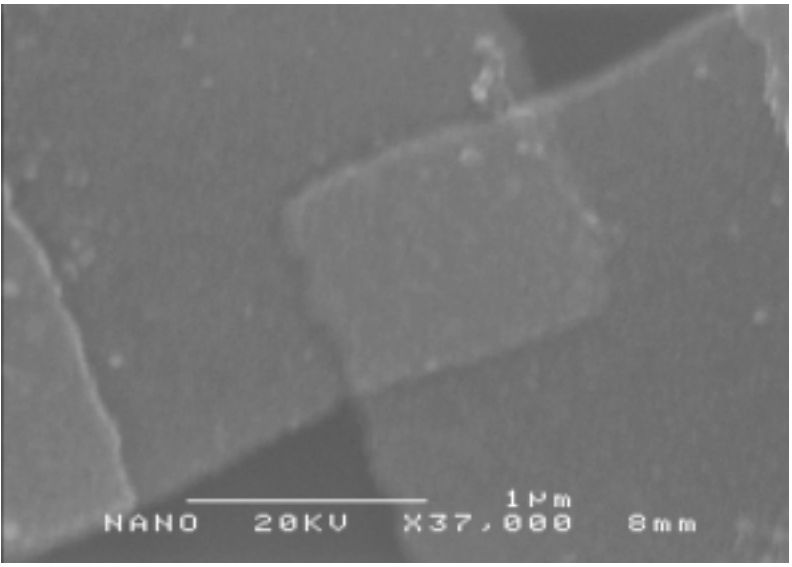

Figure T5. The operation of the CBT is based on the current limiting effect of the charging energy created by individual electrons in a series of tunnel junctions. The above is a scanning electron microscope image of a tunnel junction.

and it is applied in commercial thermometers covering the range 20 mK - 30 K. In this project the research is focused in the suitability of a CBT as a scale defining instrument for the range 20 mK - 1K. For this range there is only a provisional temperature scale that is defined using a helium melting curve thermometer, which is rather difficult to use. The strengths of the CBT are its primary nature and ease of use.

In 2003 a new type of CBT sensor was designed. The new design is meant to improve the performance of the sensor around the low temperature limit. The sensors were manufactured using electron beam lithography and tested in a cryostat at the LTL.

Developing calibration facilities for infrared thermometers

The Thermometry Laboratory is improving its calibration facilities for infrared thermometers. In 2003, a new reference instrument was tested at the temperature range between -40 °C and 300 °C. The instrument is a high-temperature infrared thermometer (Heitronics Transfer Radiation Pyrometer TRT II) working between -50 °C and 1000 °C. It has two detectors with wavelengths of 8 μm -14 μm and 3,9 μm. It will be used as a reference when calibrating infrared thermometers at temperatures below the range of the IKE LP2.

Comparison methods for humidity standards

New methods to compare humidity standards are developed to improve the comparison uncertainty: 1) A new saturator-based humidity comparator; 2) improved procedures to use of chilled mirror and capacitive hygrometers as transfer standards. In 2003, both the saturator and sensor head unit of the comparator were re-designed and constructed. Parameters affecting frost formation on a cool mirror surface were studied using a microscope, constant temperature mirror with variable sample volume enclosure and a dew-point generator. Various hygrometers were tested, and the results show that reliability of comparison results can be improved by a careful procedure planning. This project continues in 2004.

Extending the dew-point temperature range

Tests for the MDFG dew-point generator in the ranges

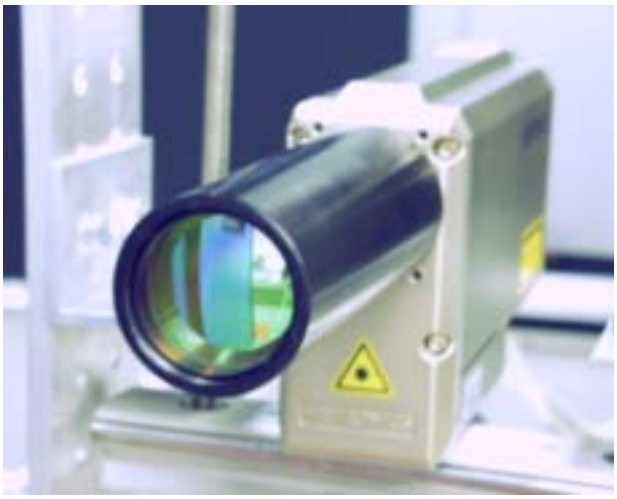

Figure T6. The new infrared thermometer of the Thermometry Laboratory.

-80 °C to -60 °C and +77 °C to +83 °C were completed successfully. After full validation of the generator in the high range, the dew-point temperature range of the MIKES calibration service was extended to +83 °C. In the low range, measurements in the EUROMET project no. 715 were carried out to validate the performance of the generator by comparing it with other European national standards. The expanded uncertainty of the realised dew-point temperature is 0.04 °C to 0.06 °C in the range above -60 °C. In the lower range, the uncertainty is 0.15 °C to 0.20 °C.

A new low dew-point temperature generator (EUROMET Project no. 737)

In this co-operative project with the Swedish National Testing and Research Institute (SP), a new dew-point generator is designed, constructed and validated at SP. Also, a comparison with the dew-point standards at MIKES will be carried out. The generator will cover the dew-point temperature range from -50 °C to +20 °C. In 2003, the saturator system was designed and constructed.

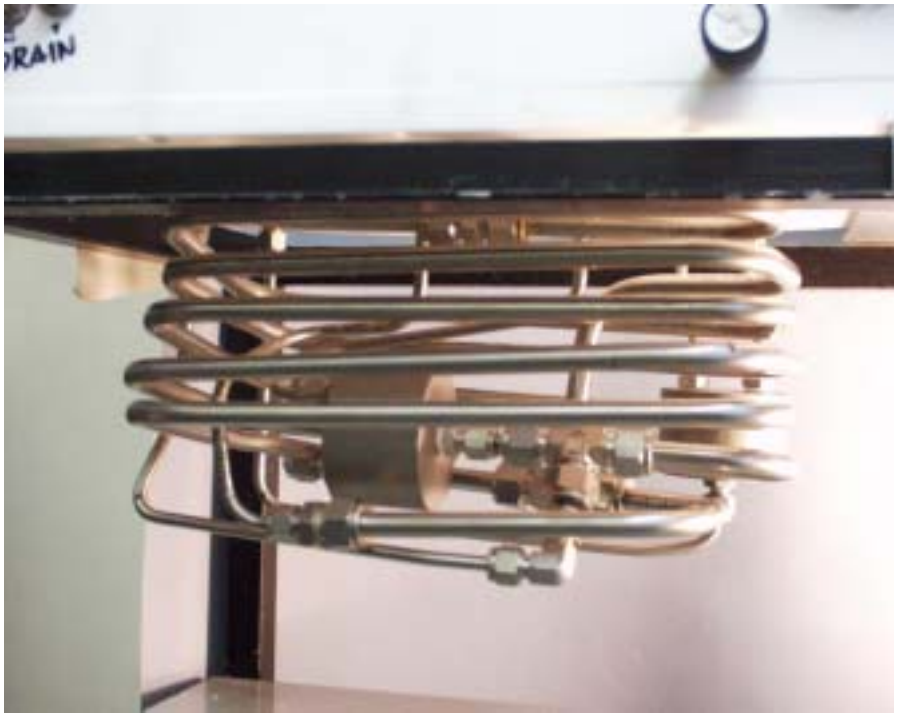

Figure T7. The high range saturator of the MDFG generator.

COMPARISONS & PUBLICATIONS

COMPARISONS

International comparisons

EUROMET Project No 391 (Thermometry)
Intercomparison of the freezing point of Indium, participants: BEV, BNM-INM, CEM, MIKES, CMI, DTI, SM/MD, IMGC, IPQ, JV, NMi, NML, NPL, METAS, OMH, PTB, SMIS, SMU, SP and UME. C. Rauta, E. Renaot, G. Bonnier, *A European Interlaboratory Comparison of Indium Freezing Points* in AIP Conference Proceedings 684 of the Eighth International Temperature Symposium Temperature, Its measurement and control in science and industry Vol. 7 p.897-902, good agreement within 0,2 mK.

EUROMET Project No 412 (Thermometry)
Intercomparison of local realizations of the ITS-90 above the silver point, participants: PTB,CEM,BNM-LNE, MIKES, NPL, OMH, IMGC, NMi, IPQ, SP, SMU, UME and CSIR, measurements completed, no report.

EUROMET Project No 502 (Thermometry)
Intercomparison of Argon triple point cells, participants: BNM-INM, CEM, MIKES, GUM, IMGC, IPQ, JV, NMi, NPL, METAS, PTB, SMIS, SP and UME, results will be presented at Tempmeko2004.

EUROMET Project No 549 (Thermometry)
Comparison of water triple point cells, participants: BEV, BNM-INM, MIKES, CMI, GUM, EIM, JV, LS, OMH, NML, SMIS, SMD, SMU, SP and UME, preliminary report indicates good agreement with 2 cells (-0.06 mK and 0.04 mK) and 0.20 mK for the third one.

EUROMET Project No 552 (Thermometry)
Comparison of the realization of the ITS-90 over range 83.805 K to 692.677 K, participants: BEV, BNM-INM, CEM, MIKES, CMI, DTI, GUM, EIM, IMGC, IPQ, JV, LS, METAS, NMi, NML, NPL, PTB, SMIS, SMD, SMU, SP and UME, not finished.

EUROMET Project No 635 (Thermometry)
Comparison of the Reference Surface Temperature apparatus at NMIs by comparison of Transfer Surface Temperature. Standards, temperature range 50 °C - 300 ºC, participants: PTB, OMH, BNM-LNE, MIKES, NMi, CEM, JV, SMIS-FE-LMK, UME, CISR-NML and SP. The results of MIKES were poor because the MIKES equipment was not suitable for the comparison method; the equipment needs to be improved, the calibration method has been improved.

CCT-K6 Key comparison of humidity standards (Humidity)
The technical protocol was approved by CCT WG8 in June 2003. NPL (UK), NMIJ (JP) and NMi (NL) carried out their measurements. The other partners are in the order of the comparison scheme: MIKES (FI), IMGC (IT), INTA (ES), NIST (USA), SPRING (Singapore), NRCCRM (China), VNIIM (RU).

EUROMET Project No 621 (Humidity)
Key comparison in humidity (dew-point temperature). MIKES as the coordinating institute - prepared the technical protocol that was agreed by the partners from 23 countries (AT, CH, CZ, DE, DK, ES, FI, FR ,GB ,GR, HR, HU, IE, IT, NL, NO, PL, PT, RU, SE, SI, SK, TR, ZA) and approved by CCT WG8. The comparison will be realised in three parallel loops piloted by MIKES, NMi and METAS. MBW Calibration Ltd delivered the first of six chilled mirror hygrometers that will be used as the transfer standards.

EUROMET Project No 715 (Humidity)
Investigation on frost point temperature scales and comparison of standards. To study the performance of the low frost-point generators, a comparison between IMGC (IT), CETIAT (FR), VNIIM (RU) and MIKES was initiated. IMGC provided the transfer standard hygrometer and is the pilot laboratory. In 2003, measurements were completed at all participating institutes except at VNIIM.

EUROMET Project No 717 (Humidity)
Comparison in dew-point temperature (high range). A dew-point comparison in the range +20 °C to +80 °C was agreed by 16 laboratories from the following countries: AT, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PL, SI, SK, TR. The project is coordinated and piloted by PTB.

International (EA or other) intercomparisons for accredited calibration laboratories

The final report of the M-02TdC001: "Comparison of dew-point temperature calibrations" was published in the MIKES Publication series.

National intercomparisons

The final report of the M-02RHC001: "Comparison of relative humidity calibrations" was completed.

MIKES arranged a comparison for humidity calibration laboratories (M-03RHC001). All the measurements were performed in 2003. The report will be completed in 2004.

Bilateral comparison with K008, liquid-in-glass thermometers in the range from -30 °C to +30 °C.

Bilateral comparison with K025, liquid-in-glass thermometers in the range from -40 °C to 25 °C.

Bilateral comparison with K023, infrared thermometer in the range from 0 °C to 450 °C.

PUBLICATIONS

Articles in International Journals

M. Noorma, P. Kärhä, T. Jankowski, F. Manoocheri, T. Weckström, L. Uusipaikka and E. Ikonen, *Radiometric determination of fixed point cell temperatures in irradiance mode*, submitted for publication in Measurement Science and Technology.

Conference Presentations

M. Battuello, F. Girard, T. Ricolfi, M. Sadli, P. Ridoux, O. Enouf, J. Perez, V. Chimenti, T. Weckström, O. Struss, E. Filipe, N. Machado, E. van der Ham, G. Machin, H. Mc Evoy, B. Gutschwager, J. Fischer, V. Schmidt, S. Clausen, J. Ivarsson, S.

Ugur and A. Daril, *The European Project TRIRAT: Arrangements for and Results of the Comparison of Local Temperature Scales with Transfer Infrared Thermometers between 150 °C and 962 °C* in AIP Conference Proceedings 684 of the Eighth International Temperature Symposium Temperature, Its Measurement and Control in Science and Industry Volume 7, Chicago, USA, October 21-24, 2002, pp. 903-908.

M. Heinonen, L. Uusipaikka, *An apparatus for testing humidity sensors at low temperatures,* accepted to Tempmeko 2004.

T. Jankowski, P. Kärhä, M. Noorma, T. Weckström, L. Uusipaikka and E. Ikonen, *Detector based method for radiation temperature measurements,* Proceedings of Northern Optics 2003 Espoo, Finland, June 16-18, p.74.

L. Uusipaikka, M. Heinonen, *The use of capacitive relative humidity sensors as transfer standards,* accepted to Tempmeko 2004.

T. Weckström and L. Uusipaikka, *Comparison of Water Triple Point Cells in Finland* in AIP Conference Proceedings 684 of the Eighth International Temperature Symposium Temperature, Its Measurement and Control in Science and Industry Volume 7, Chicago, USA, October 21-24, 2002, pp. 233-236.

MIKES Publications

M. Heinonen, J. Järvinen, A. Lassila (editors), Annual Report of MIKES Metrology 2002, MIKES Publication J1/2003.

M. Heinonen, Comparison of dew-point temperature calibrations, MIKES Publication J7/2003, 28 p.

Ionising radiation

PERSONNEL AND ORGANISATION OF LABORATORIES

Radiation and Nuclear Safety Authority (STUK)
National Standards Laboratory
Ionising Radiation Quantities

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Ikka Aropalo	Technician
Matti Toivonen	Physicist
Markku Tapiovaara	Physicist
Hannu Järvinen	Physicist
Carita Ruuhonen	Secretary

Air kerma, absorbed dose to water

Secondary standards are ionisation chambers used with the irradiation facilities for ^{60}Co and ^{137}Cs gamma radiation and X-ray equipment (10-320 kV). The standard chambers are calibrated at BIPM, France (therapy level), and at PTB, Germany (protection level).

Ambient dose equivalent, directional dose equivalent, personal dose equivalent, absorbed dose to soft tissue

For gamma and X-radiation the dose equivalent quantities are determined using the air kerma standards and physical conversion factors. For beta radiation the standards are beta ray sources (^{90}Sr/^{90}Y) calibrated at PTB, Germany. Other standard beta sources (^{204}Tl and ^{147}Pm) are calibrated in the laboratory using an extrapolation ionisation chamber (a primary standard) and physical data. For fast neutrons the secondary standard is a ^{241}Am-^{9}Be radioactive source calibrated at NPL, UK. For other ^{241}Am-^{9}Be radioactive sources with different activities the transfer standard is a proportional counter.

Reference air kerma rate

The standards are two well-type ionisation chambers with a calibrated ^{60}Co radioactive source. The calibration of the standard ^{60}Co gamma source is traceable to BIPM, France, through the air kerma standards of the laboratory. For gamma sources of ^{125}I, ^{195}Ir, ^{137}Cs, and ^{103}Pd, the calibrations of the well chambers are also traceable to NIST, USA, through the calibrations at the dosimetry laboratory of the University of Wisconsin, USA.

Surface emission rate

The secondary standards are wide-area sources of beta radiation (^{90}Sr/^{90}Y, ^{36}Cl, ^{14}C) and alpha radiation (^{241}Am) calibrated at NPL, UK.

Related to the recognition of NMI under MRA, the quality system of the national metrology activities of STUK were described and presented at the Quality Forum of EUROMET in Istanbul in September 2003. The quality system of STUK is based on ISO 17025, and the reliability is based on self declaration. The national metrology activities related to the maintenance of standards of dose quantities were presented and included in the MRA. The quality system of STUK achieved the general acceptance and confidence of the forum.

A representative of STUK was invited in the 16th meeting of the Consultative Committee for Ionizing Radiation (CCRI, Section I) of CIPM at BIPM, Paris, in May 2003. The invitation was aimed for a permanent membership of CCRI.

For the dosimetry of external beam radiotherapy, the calibration procedures based on standards for absorbed dose to water were taken into use during 2003. The reference dosemeters of all Finnish radiotherapy clinics were calibrated according to the new methods published by IAEA, using standards of absorbed dose to water.

Modernising of the electronics controlling the mechanical movements of the ^{137}Cs gamma-beam irradiator was started. Radiation protection shield of the high-activity ^{60}Co gamma-beam irradiator was improved to allow more safe and convenient working circumstances at the laboratory.

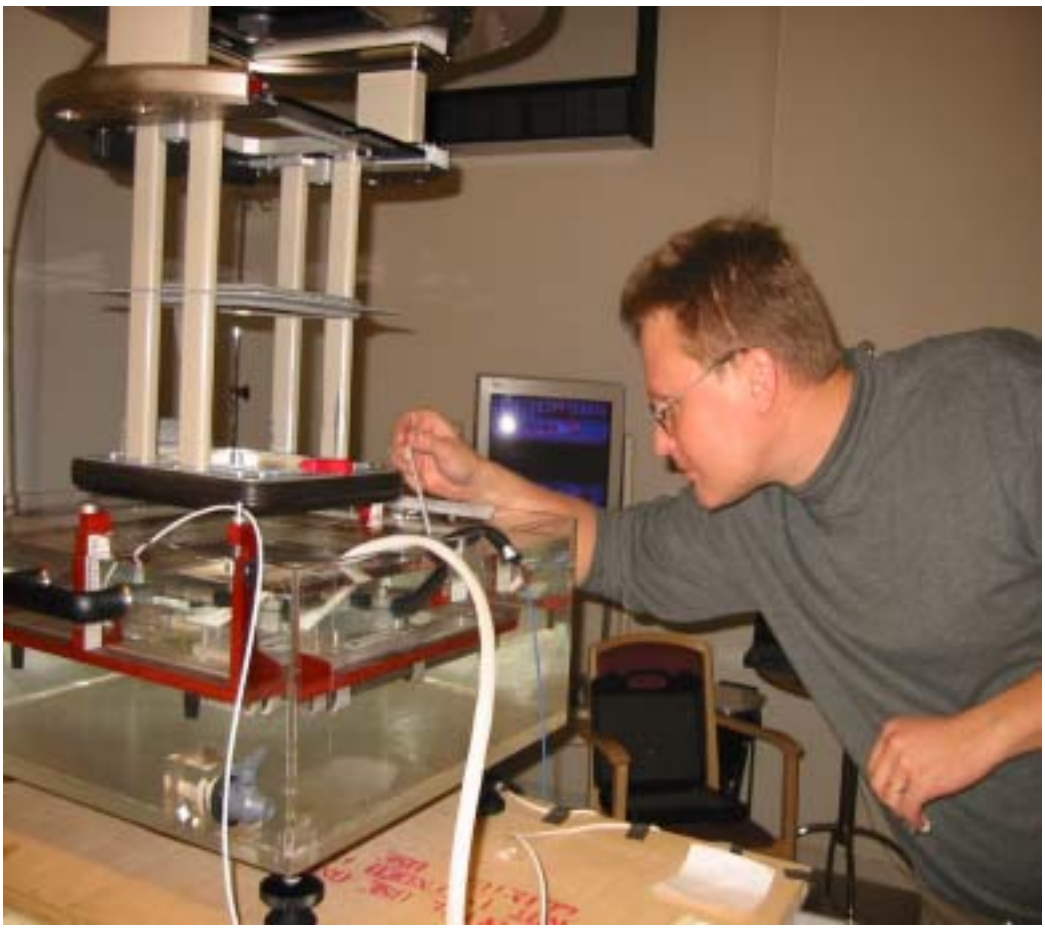

Figure I1. Based on standards of absorbed dose to water and methods published by IAEA, the Radiation Metrology Laboratory of STUK provides cross-calibrations of ionisation chambers used in electron beam dosimetry at radiotherapy clinics. The calibration is performed in the electron beam of the clinical accelerator.

A procedure for the calibration of dose-area-product meters (DAP meters) used in X-ray diagnostic radiology was started. A reference DAP standard was acquired with a calibration directly traceable to PTB primary standards. The development of the DAP calibration methods was also agreed as a common project in the Nordic dosimetry group. It consists of the radiation metrology laboratories of the Nordic radiation protection authorities: Norwegian Radiation Protection Authority (NRPA), Swedish Radiation Protection Authority (SSI), Radiation and Nuclear Safety Authority, Finland (STUK), National Institute of Radiation Hygiene, Denmark (SIS), and Iceland Radiation Protection Authority (GR). The Nordic co-operation in the development of DAP methods is coordinated by STUK.

general, by investigating methods of assessing radiation doses and the risks to patients with a view to optimising the image quality and patient dose, and by developing technical and clinical approaches.

Studies on the optimisation of x-ray equipment and procedures are especially important in digital x-ray imaging and interventional radiology because they do not have a similar instant feedback on high patient doses as film-based radiology. High doses or dose rates are sometimes needed to reach sufficient image quality, and the duration of all procedures cannot always be foreseen. This can sometimes cause high patient doses or even acute radiation injuries in interventional radiology. Carefully optimised technical and clinical protocols are therefore important.

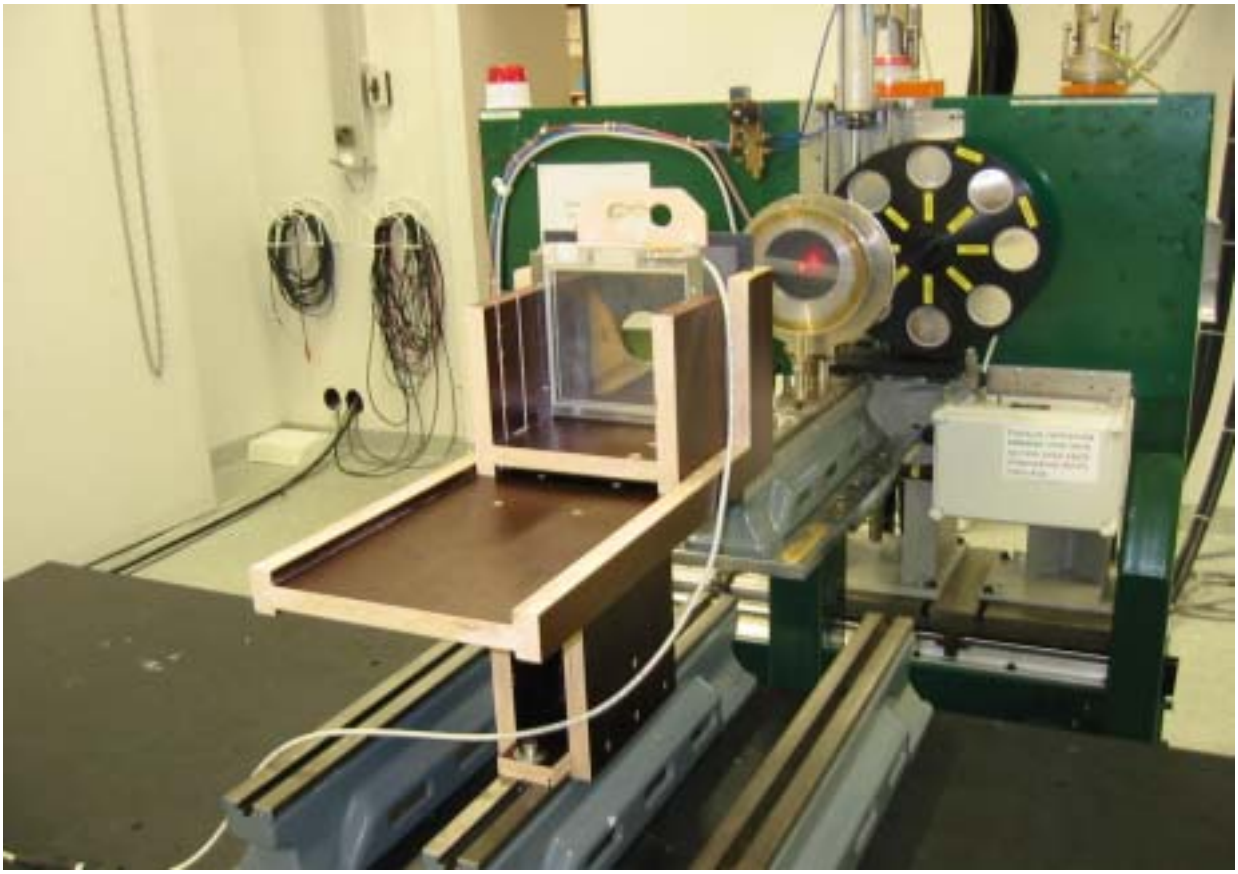

Figure I2. A test set-up for the calibration of DAP meters at the X-ray beam facility of STUK.

The Radiation Metrology Laboratory of STUK participates in an EU-funded shared cost project, DIMOND III: Measures for optimising radiological information and dose in digital imaging and interventional radiology. The project contributes to radiation protection in interventional procedures, digital mammography, and digital radiology in

The DIAMOND III project contains six work packages, each comprised of a series of sub-projects. The first three packages are for basic scientific and clinical research: Clinical quality criteria and technical parameters (WP1), Physical aspects of image quality (WP2) and Reference values and justification (WP3). The other three work packages are aimed to bring the

basic research into clinical practice: Clinical evaluation projects of the special procedures of interventional radiology (WP4), cardiology (WP5) and digital mammography (WP6). STUK participates mainly in the work of WP2-WP5.

The tasks on STUK´s responsibility were: Production of a report and protocol for patient dosimetry in interventional radiology, Report on methods of evaluating skin entrance dose, Description and publication of a mathematical tool for the assessment of image quality, and Experimental verification of the relationship between visualisation criteria and performance indices. Especially the dosimetric tasks are closely related to the standard dosimetry activities at STUK. Three internal project task reports and four related articles were published in 2003.

Collaborators: Quality Assurance Reference Centre, Newcastle (UK, coordinator), Azienda Ospedaliera Santa Maria Della Misericordia, Udine (Italy), Delft University of Technology, Delft (Netherlands), Diakonissen Krankenhaus, Karlsruhe (Germany), General Hospital Evangelismos, Athens (Greece), Haughton Institute, Dublin (Ireland), Katholieke Universiteit Leuven (Belgium), Krankenhaus der Barmherzigen Brüder Trier (Germany), Radiation Protection Department, Ministry of Health (Luxembourg), Regional Medical Physics Department, Newcastle (UK), San Carlos University Hospital and Complutense University, Madrid (Spain), and University of Innsbruck (Austria).

COMPARISONS & PUBLICATIONS

COMPARISONS

International comparisons

The laboratory participated in the annual dosimetry comparison (dosimetry audit) for the determination of absorbed dose to water at ^{60}Co gamma radiation, organised by International Atomic Energy Agency (IAEA).The comparison was carried out with posted TL dosemeters. The difference between the results of STUK and IAEA was 0,2 %, which is well inside the action level of 3,5 % stated by IAEA.

The results of the EA comparison IR3, performed in 2001 for the calibration of radiation survey meters for ambient dose equivalent, were available in 2003. The comparison was carried out by circulation of radiation protection dosemeters. The results of STUK diverged by 1,3 % for ^{137}Cs gamma radiation and by 0,8 % for ^{60}Co gamma radiation from the corresponding reference values. The E_n values were -0,32 (^{137}Cs) and 0,22 (^{60}Co), as the acceptance level of the comparison was 1,0 %. Both of the STUK results were well inside the uncertainties stated by the laboratory.

PUBLICATIONS

Articles in International Journals

H. Koivunoro, I. Auterinen, A. Kosunen, P. Kotiluoto, T. Seppälä, and S. Savolainen, *Computational study of the required dimensions for standard sized phantoms in boron neutron capture therapy dosimetry,* Phys. Med. Biol. 48 (2003) 291-300.

O. Harju, M. Toivonen, M. Tapiovaara, and T. Parviainen, *X-ray tube output based calculation of patient entrance surface dose: validation of the method.* In: Paile W (ed.). Radiation Protection in the 2000s - Theory and Practice. Nordic Society for Radiation Protection, Proceedings of the XIII ordinary meeting, 25-29 August, 2002, Turku/Åbo, Finland. STUK-A195, Helsinki, Radiation and Nuclear Safety Authority (2003) 280-286.

T.Parviainen, M.Toivonen, A.Ylitalo, A. Kosunen and J. Karppinen. *Measurement of staff doses in interventional procedures using LiF TL-detectors and a special diode dosemeter.* In: Paile W (ed.). Radiation Protection in the 2000s - Theory and Practice. Nordic Society for Radiation Protection. Proceedings of the XIII ordinary meeting. 25-29 August 2002, Turku/Åbo, Finland. STUK-A195. Helsinki: Radiation and Nuclear Safety Authority, (2003) 299-304.

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E. Quai, R.Padovani, A. Peterzol, E. Vano, E. Guibelalde, and M. Toivonen, *Maximum skin dose assessment in interventional cardiology: Results in three different European hospitals,* Proceedings of European Congress of Radiology (ECR 2003), 7-11 March 2003, Vienna, Austria. European Radiology 2003; 13 Suppl 1: C542.

T. Parviainen, M. Toivonen, A. Ylitalo, and A. Kosunen, *Measurement of staff doses in interventional procedures and comparison of LiF TL-detectors and a special diode dosemeter*, Proceedings of European Congress of Radiology (ECR 2003), 7-11 March 2003, Vienna, Austria. European Radiology 2003; 13 Suppl 1: C550.

I. Auterinen, T. Serén, J. Uusi-Simola, A. Kosunen and S. Savolainen. *A tool kit for epithermal neutron beam characterisation in BNCT,* in Abstracts of Ninth Symposium on Neutron Dosimetry. Advances in Nuclear Particle Dosimetry for Radiation Protection and Medicine. 28 September - 3 October, 2003, Delft, The Netherlands; p. 104.

Other Publications

O. Harju. *ESD-laskenta-sovellus röntgentutkimuksen aiheuttaman pinta-annoksen laskentaan.* Järvinen H (edit.). Säteilyturvallisuus ja laatu röntgendiagnostiikassa 2003. STUK-C2. Helsinki, Radiation and Nuclear Safety Authority (2003) 35-39.

M. Tapiovaara, *Objective measurements of image quality in fluoroscopic X-ray equipment: FluoroQuality.* STUK-A196. Helsinki: Radiation and Nuclear Safety Authority (2003) 63 pp.

Chemistry

PERSONNEL AND ORGANISATION OF LABORATORIES

Finnish Meteorological Institute (FMI)
Air Quality Research
Contract Laboratory of MIKES

Jari Walden
Head of the laboratory

Veijo Pohjola	Senior researcher, quality manager
Raimo Kartastenpää	Senior researcher
Sisko Laurila	Research assistant
Kaisa Lusa	Researcher
Minna-Kristiina Sassi	Researcher (Leave of absence)
Pirjo Kuronen	Researcher
Helena Saari	Researcher
Markus Talka	Researcher
Kai Lindgren	Technician

Preface

The Centre for Metrology and Accreditation and the Finnish Meteorological Institute (FMI) made agreement for the maintenance of calibration service on the field of gas metrology according to the requirements by the CIPM. The FMI is also nominated as a national reference laboratory in the field of air quality. The calibration laboratory at the department of air quality research carries out both of the duties. The quality system is accredited according to ISO-17025 standard as a calibration laboratory. At the moment there are no other laboratory in the field of metrology in chemistry that is part of the national measurement system in Finland. However the advisory group in metrology seeks candidate expert laboratories to expand the responsibilities in the measurement technology in the field of organic chemistry, inorganic chemistry and microbiology. Clinical chemistry, clinical microbiology and food chemistry are fields of great interest to seek laboratories to join the national measurement system.

Mission of the laboratory

The calibration laboratory performs air quality measurements and calibrations for the background air quality assessment programmes carried out at the Finnish Meteorological Institute. We also serve the needs of local authorities and other customers in industry, trade and research institutes in calibration of analysers or methods or performing measurements of ambient air quality. Our calibration concentrations are traceable to international primary standards and we do research work on the topic of metrology in chemistry.

Important tasks of the laboratory are also the quality control of national air quality measurements, training, and the development of calibration and quality control methods for ambient air trace gas measurements.

Organisation of the subject field

The metrology in chemistry is focused in gas metrology at the Finnish Meteorological Institute. The calibration laboratory at the air quality research maintain calibration and measurement services for certain environmental gas compounds as carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), ozone (O_3) and sulphur dioxide. The traceability of the calibration services i.e. calibration concentration produced in the laboratory is via national metrological institutes: National Physical Laboratory, NPL (UK); Nederlands Meetinstituut, Nmi (Nl); Laboratoire National D'Essais, LNE (Fr); Swiss Federal Laboratories for Materials Testing and Research, EMPA (Ch) and Centre for Metrology and Accreditation, MIKES (FI). The reference gas standards of the laboratory for carbon monoxide, nitrogen monoxide and sulphur dioxide are those of the secondary gas standard of NPL and Nmi. The ozone reference standard (ozone photometer) is traceable to standard reference photometer by NIST through regular calibration of the photometer against the regional SRP at EMPA. The references standard for nitrogen dioxide is the gas phase titration of nitrogen monoxide (NO) gas standard with the ozone (O_3). As secondary standards for nitrogen dioxide and sulphur dioxide the laboratory maintains the permeation method. The gas concentrations are obtained by dynamic or dilution or by static injection of the reference or secondary gas standards.

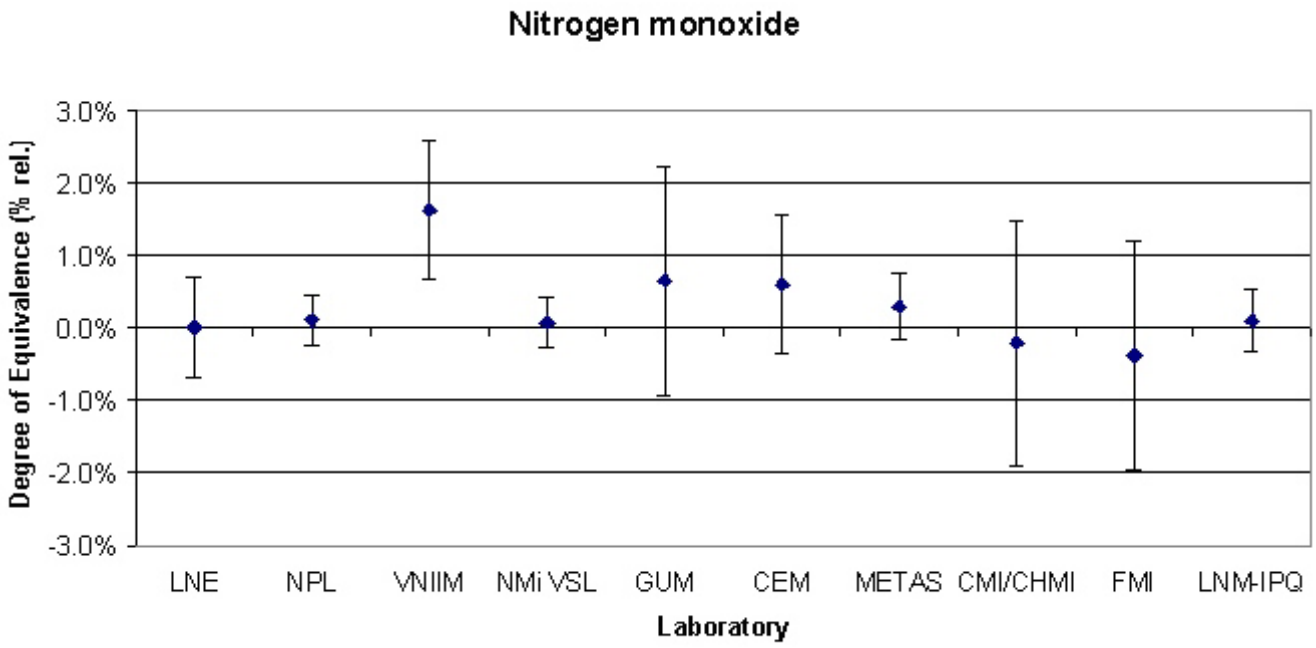

Figure C1. Results of the participating laboratories to the EUROMET 638 (EUROMET.QM-K1C).

RESEARCH PROJECTS

During the year 2003 we joined a research project on the micrometeorological methods for measurements of landfill gas emissions and evaporation. The project consisted field measurement on a landfill area at the Helsinki metropolitan area. Our responsibility at the project was to obtain the fluxes of methane and nitrous oxide by gradient method. The responsibility supported our task in measurement techniques in air quality. The work started in June and will continue during 2004.

COMPARISONS

During 2003 the laboratory made the bilateral comparison of the national ozone photometer between the VNIIM (Russia) and FMI. The intercomparison took place in April 14 to 16, 2003. The bilateral comparison of ozone photometer was aiming the forthcoming pilot project on comparison of national ozone photometer organised by BIPM and the project is labelled as CCQM-P28.

Laboratory participated the EUROMET-638 project in 2002 and the draft report A and B were published in 2003. In the Figure C1 we present the main results of the participating laboratories. The objectives of the project were that of the key comparison project CCQM-K1c: to compare the measurement capabilities of national metrological institutes (NMIs) in measuring amount of substance fractions of nitrogen monoxide in nitrogen.

PUBLICATIONS

J. Kukkonen, L. Partanen, A. Karppinen, J. Walden, R. Kartastenpää, P. Aarnio, T. Koskentalo and R. Berkowicz, *Evaluation of the OSPM model combined with an urban background model against the data measured in 1997 in Runeberg Street, Helsinki.* Atmospheric Environment 37(8), pp.1101-1112.

J. Kukkonen, L. Partanen, A. Karppinen, J. Walden, R. Kartastenpää, P. Aarnio, T. Koskentalo and R. Berkowicz, *Evaluation of the OSPM model combined with an urban background model against the data measured in 1997 in Runeberg Street, Helsinki.* In: Sokhi, R.S. and Brechler, J. (eds.), Proceedings of the Fourth International Conference on Urban Air Quality - Measurement, Modelling and Management, Charles University, Prague, Czech Republic, 25-27 March 2003. University of Hertfordshire, Hatfield, United Kingdom, pp. 34-37.

C. Libiseller, A. Grimvall, J. Walden and H. Saar, *Meteorological normalisation and non-parametric smoothing for quality assessment and trend analysis of tropospheric ozone data.* Submitted to Environmental Monitoring and Assessment.

C. Libiseller, A. Grimvall, J. Walden and J. Paatero, *Meteorological normalisation of tropospheric ozone using back-trajectories*, submitted to Atmospheric Environment.

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Raute Precision Oy Mass and Force Laboratory POB 22 FIN-15801 Lahti tel. +358 3 829 21 fax + 358 3 829 4101	force and torque	Aimo Pusa	aimo.pusa@rauteprecision.fi
Finnish Meteorological Institute Air Quality Research Sahaajankatu 20 E FIN-00880 Helsinki tel. +358 9 19291 fax +358 9 1929 5403	air quality	Jari Walden	jari.walden@fmi.fi

Information about Finnish accredited calibration laboratories can be found on the internet pages of MIKES www.mikes.fi

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