HRH The Prince of Wales with John Rae during a visit to NPL's Bushy House in May 1999.

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MANAGING DIRECTOR'S FOREWORD 2

Welcome to the National Physical Laboratory's Review of 1999. Our purpose here is to provide NPL's many stakeholders with a report of the Laboratory's work over the last year. In the following pages you will find more than fifty case studies illustrating the quality and variety of our projects.

Measurement science and materials characterisation, our core competencies, are vital to the economy. It is impossible to control product or process quality without accurate measurement and the case studies presented include innovative projects for applications as diverse as steel making and the development of new cosmetics. These skills are vital, also, to increasing mankind's understanding of our environment. In this Review you will find NPL's measurement technology probing deep into space, assessing the stratosphere, monitoring atmospheric quality and scanning the oceans.

The case studies are grouped according to the national measurement programme by which they are funded; or, in the case of commercial projects, the programme area with which they are associated. One of the great strengths of NPL is the synergy between our national laboratory mission and our rapidly growing commercial activity.

A brief rationale is provided for each programme area. You will see three core values repeated: a commitment to the national standards laboratory mission; a devotion to scientific integrity; and a determination that the know-how and technology we generate should be valuable and accessible to the end user. You will find frequent references to collaboration, whether with respect to partners in the science base or in industry.

Inevitably this Review focuses upon the work of our scientists. However, I should not let the opportunity pass to recognise the NPL staff in the many support functions, such as Safety, Procurement and Personnel, which make it possible to deliver so many successful project outcomes.

The Review also includes reports on our international commitments (1999 has seen NPL taking a leading role in the move towards mutual recognition between the world's national standards laboratories); and on what is perhaps the most significant single activity in the year, the building of a superb new laboratory on our Teddington site, to house our staff in the new century.

I should like to acknowledge our reliance, in achieving the successes reported here, upon the strong partnership established between NPL Management Limited and the Department of Trade and Industry (DTI), our primary customer and the Laboratory's owner. As we move towards NPL's centenary in 2000, we are committed to strengthening that partnership still further, to establish the firmest possible foundation for the Laboratory's future.

Over the last year, increased attention to international metrology has been a hallmark of NPL's mission.

INTERNATIONAL METROLOGY 4

By its very nature, metrology is an international activity, involving worldwide consistency of International System (SI) units of measurement; harmonised national measurement systems; mutual acceptance of accurate calibration systems; and traceability to the SI units.

As globalisation and cross-border business increases, so industrial sectors require equivalent and acceptable measurement. National Metrology Institutes (NMIs) now have to respond and raise their horizons still further from the domestic to the international. Over the last year, increased attention to international metrology has been a hallmark of NPL's mission. We expect this to accelerate further in the years to come.

MUTUAL RECOGNITION

Much of the driving force for internationalisation has come from an Arrangement being co-ordinated by the International Bureau of Weights and Measures (BIPM) to implement the Mutual Recognition of national measurement standards and of calibration and measurement certificates. This will bring enormous benefits to UK exporters and we are anticipating formal signing of the Mutual Recognition Arrangement (MRA) before the end of 1999.

In order to comply with the MRA, all NMIs must declare their calibration and measurement capabilities, take part in international comparisons of standards and maintain a quality system. Preparation for the implementation of the MRA has included the following:

- ***EUROMET has established a new subject field Group - Interdisciplinary Metrology - chaired by NPL's Andrew Wallard and with Andrew Lewis of NPL as Secretary. This Group is playing a key role in setting the European framework for agreeing how to review NMIs' calibration and measurement capabilities (CMC) statements and how to give an opinion on whether their quality system meets the MRA requirements. This is placing a huge demand on NPL's technical resources as we are represented on all the major European Measurement Committees.***

- ***Some 100 'key comparisons' have been identified by the Consultative Committees of the BIPM. These test the techniques used at NMIs to realise the SI system locally and will be an important technical validation of the CMCs. NPL is involved in virtually all the comparisons in our area. As these must be replicated in EUROMET, this work will dominate much of our international technical activity in the years to come.***

- ***Mathematical and statistical analysis of key comparisons will be a major task for the Consultative Committees. Here NPL's mathematicians have played a central role with Professor Maurice Cox presenting the keynote address to a meeting of experts at the BIPM in January 1998.***

- ***Quality systems, mainly those built around the ISO Guide 25/EN45001 system, are a requirement of the MRA. Here our decision in 1993 to begin the process of third party accreditation has proven to be a wise one and we now have all the internal processes needed to comply with the MRA. NPL's Quality Director, Joyce Brick, is representing the Laboratory on the relevant European quality systems Group.***

EUROMET

EUROMET is a group made up of 24 European NMIs and the European Commission created to serve, collaboratively, the needs of European metrology.

The group's Chairmanship has passed from Kim Carneiro of Denmark to Luc Erard of France. NPL continues to support EUROMET strongly and the UK has more EUROMET projects than any other country. One recent project has paved the way for the MRA by researching issues related to the mutual acceptance of NMI calibration and test certificates between the EU and the US. Whilst no fundamental scientific measurement issues emerged, it was clear that more attention needs to be paid to transparent traceability and quality systems and that awareness of metrology, uncertainty and traceability needs to be raised within the regulatory bodies in the US and EU. This will be pursued in 2000.

INTERNATIONAL PROGRAMMES

NPL continues its policy of strong collaboration with NMIs elsewhere, under our Global Metrology Initiative. We have, for example:

- *designed and supplied a wide range of NPL instruments, including stabilised lasers, cryogenic radiometers, acoustic standards and vacuum systems, to other NMIs under commercial contracts*

- *presented our contractorisation experience and programme prioritisation methodologies to international seminars and workshops as well as to several Governments in other countries*

- *worked on several consultancy projects either directly to NMI clients or under programmes supported by the European Commission and other agencies*

One of the more substantial consulting projects involved a series of seminars, lectures and training programmes for the Gulf States on quality systems and methodological requirements for standards. Others include work for Brazil on assessing the economic impact of metrology, and with Mexico on the NPL experience of contractorisation.

On the scientific front, we have continued to play a full part in the Versailles Project on Advanced Materials and Standards initiative and in the scientific advisory panels of a number of leading international research institutes.

SEMAT - EAST MEETS WEST

SEMAT (Secondment in European Measurement and Testing) is funded by the DTI and by NPL. Linkages between laboratories in the UK and partner countries from Central and Eastern Europe are developed through secondments of between three and six months of young, highly qualified scientists to UK laboratories. This gives the opportunity for face-to-face knowledge transfer and encourages strong personal links between the partner laboratories that lead to co-operation and potentially to collaboration and trade in the future. It also allows laboratories to discover each other's capabilities first hand which will give confidence to mutual recognition.

Placements are made in laboratories all over the UK in diverse fields, from food and water testing to physical metrology at the highest level.

This year, NPL has itself hosted six SEMAT secondees in various fields. One secondee was Gergely Vargha from OMH in Budapest, Hungary, who spent three months in NPL's Environmental Standards section working with gas standards. Gergely is an expert in the field of high precision gas chromatographic analysis of natural gas. His experience in this field was useful to NPL at a time when we are setting up a similar facility analysing a wider variety of gases. Gergely participated in some projects as a result, which gave him ideas for developing further his own work in Hungary.

ACOUSTICAL METROLOGY 6

The Acoustical Metrology Programme supports the maintenance and development of measurement standards for sound in air and water and the development of standardised methods of measurement for sound, noise and ultrasound.

The programme aims:

- ***to maintain and develop national measurement standards in the fields of acoustics, noise, underwater acoustics and ultrasonics, at a level consistent with the current and future needs of UK industry, national and local government, and the health service***
- ***to ensure that UK measurement standards in acoustics are harmonised with those of the UK's trading partners***
- ***to develop new methods of measurement for sound, noise and ultrasound to meet identified UK private and public sector needs, and promote international standardisation of these methods***
- ***to promote technology transfer from the programme and the adoption of good measurement practice***

NEW DEVELOPMENTS IN UNDERWATER ACOUSTICS

The frequency range over which underwater acoustic hydrophones can be calibrated depends on the size of the tank in which the measurements are performed. At 1 kHz sound in water has a wavelength of 1.5 m and tanks have to be large enough to accommodate several wavelengths of the acoustic signal.

NPL has recently installed a new large open tank which extends the range of hydrophone calibrations down to 1 kHz. The wooden tank is 5.5 m in diameter and 5 m deep and is equipped with a high-resolution positioning system, which allows transducers to be located and moved with great accuracy and precision. We believe that it is the most accurate positioning system in any underwater acoustic test facility in the world.

Not only do we provide a hydrophone calibration service based on this new facility, but we can use the tank to investigate the properties of acoustic positioning systems to understand the effects of underwater noise on such systems, and to predict the far-field behaviour of transducers from near-field measurements. In the near future we shall be commissioning an acoustic pressure vessel which will allow us to simulate ocean conditions at depth and over a range of temperatures. These two new developments represent a substantial improvement in NPL's underwater acoustics facilities, allowing us to respond to a wider variety of customer needs and to undertake a challenging programme of research.

FINITE ELEMENT MODELLING OF ACOUSTIC TRANSDUCERS

Modelling and prediction of the performance of acoustic transducers are challenging tasks. The properties of transducer materials are not well understood and the mathematics of the non-linear acoustic fields generated by these transducers is complex.

NPL, in conjunction with a commercial software company and researchers at Bath University, is developing a Finite Element (FE) modelling program that will enhance the design capability of UK transducer manufacturers. A model ultrasound physiotherapy transducer has been designed and built and is undergoing tests to confirm the theoretical performance predicted by the FE package. The work is funded under NPL's Strategic Research Programme.

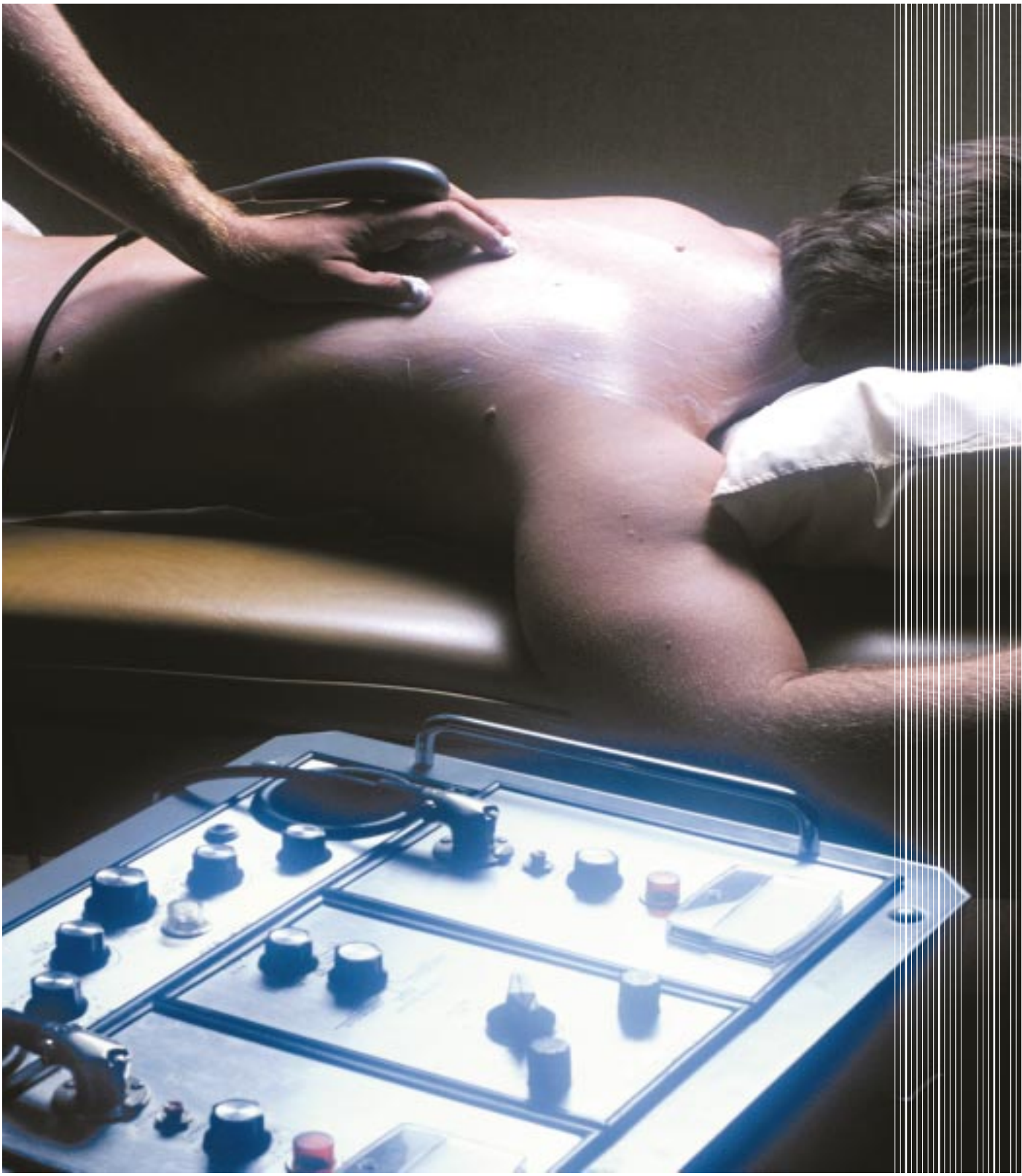
The purpose of the work is to extend the use of the FE package to the higher frequencies needed for applications in medical ultrasonics. This will provide improved methodologies for calibration and testing and form the basis of a service to transducer manufacturers, allowing a clearer understanding of vibro-acoustic design fundamentals.

NEW MATERIAL MAKES PHYSIOTHERAPY EQUIPMENT SAFER

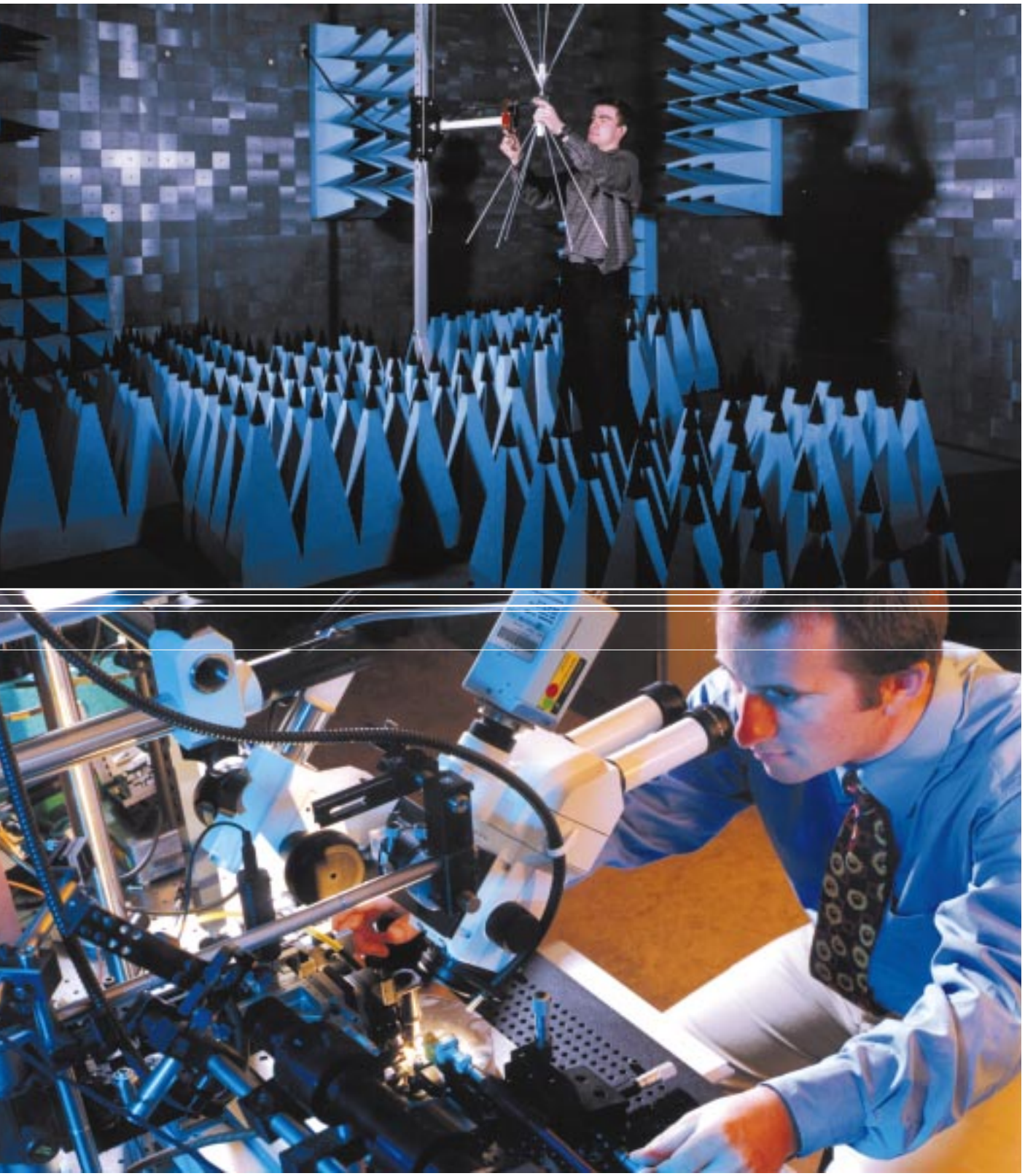
Ultrasonic physiotherapy treatment heads are required to emit with an intensity of less than 3 W per cm^2. Until recently measurement of this critical safety parameter has demanded the use of expensive and time consuming beam-plotting techniques using miniature hydrophones.

NPL has brought an entirely new measurement capability to this area with the introduction of its aperture accessory for commercially available radiation force balances. The accessory consists of a set of apertures ranging in diameter from 4 mm to 30 mm and a holder which can be adapted for the particular radiation force balance to be used. A series of power measurements is made with the differing apertures and the effective radiating area of the ultrasound equipment conveniently determined. The apertures are fabricated from a special polyurethane absorber material originally developed by the Ministry of Defence and extended by NPL to cover the MHz region. The apertures are precision cut by water jets. The absorber material combines high transmission loss and high echo-reduction and is designed for use at frequencies above 0.7 MHz.

Sets of apertures are now available from NPL. Further applications for the material include targets for ultrasound absorbing radiation force balances and anechoic lining material for ultrasound test tanks.



NPL has improved the measurement of critical safety parameters for ultrasonic physiotherapy equipment.



Jeremy Jee adjusts an antenna in an experiment to minimise the quantity of ferrite tiles required to line a screened room for EMC testing. Below, Richard Dudley uses an electro-optic probing station for measuring microwave circuits up to 110 GHz.

ELECTROMAGNETIC MEASUREMENT 10

The Electrical Programme covers the development, maintenance and dissemination of a wide range of measurement parameters across the electromagnetic spectrum.

The programme aims to provide:

- ***measurement standards, and related techniques and expertise to ensure an effective and timely technical capability at UK national level***
- ***access to standards through effective technical services made available by NPL and other National Measurement System (NMS) contractors to the direct beneficiary community in the UK***
- ***awareness and availability of the expertise and knowledge generated by NMS-supported work to the beneficiary communities, and measures to ensure responsiveness of the NMS work to evolving need***
- ***activities to promote best practice and exploitation of the UK's expertise in the relevant measurement fields***

EMC IN ANECHOIC CHAMBERS

Current standards for electromagnetic radiated emissions compliance measurements on electrical and electronic products require that such measurements are made either on an open area test site (OATS) or in a semi-anechoic room. However measurements made with both these methods suffer from experimental limitations and require relatively expensive facilities.

As part of an EU project, NPL has been evaluating the use of fully anechoic rooms (FARs) for emission testing. FARs are currently widely used for pre-compliance testing of products for electromagnetic compatibility (EMC) and offer a number of significant advantages for radio frequency (RF) emissions testing including: absence of ambient RF signals; the possibility of a single facility for emissions and immunity testing; and a controlled environment. The fact that a screened room is being used allows the measurement of high field strength. NPL has been working on cost reduction of EMC testing in anechoic rooms, in particular on the optimisation of room size and the placement of ferrite tiles (acting as an absorber). Chamber correction factors can be calculated for use below 150 MHz. An accurate and efficient model has been developed and results show that up to 20% of the tiles can be removed and still remain within the chamber performance specification.

FARs have been shown to be a more cost effective, reliable and faster environment for EMC testing and smaller chambers may be used. International regulatory bodies will be agreeing limits for the use of FARs over the next year, which will allow them to be used without reference to OATS.

MOBILE PHONE POWER

The expansion of the use of mobile phones throughout Europe has led to phone system operators moving to higher frequency bands as present allocated frequencies become saturated. These market-led changes together with the development of proposals for third-generation standards in the mobile communications industry require the introduction of new test and measurement equipment traceable to national standards.

Measurement equipment for continuous wave power is well established, however modern digital communications use a variety of pulsed power systems. NPL is developing a traceable power measurement service for the wireless communications industry that will cover the major radio frequency communications systems, as well as the higher frequency line-of-sight, point-to-point links. A detailed specification has been developed in consultation with industry, but the system will be capable of measuring between 0.1 mW and 100 mW covering a variety of modulation techniques, and monitoring both average power for a transmission burst and the peak power of individual pulses within a burst.

MICROWAVE CIRCUITS PROBED BY OPTICAL TECHNIQUES

On-wafer testing of monolithic microwave integrated circuits (MMICs) is an increasingly important measurement technique in the design and production of products for telecommunications, radar and direct broadcasting. Existing techniques rely on automatic network analysers (ANAs) in conjunction with high frequency electrical probes for contact to the circuit. This limits measurements to specific input and output ports on the circuit under test.

NPL has developed an electro-optic sampling (EOS) measurement technique and evaluated its accuracy. The technique depends on the effect induced in an electro-optical crystal by the electric field in a MMIC circuit. By monitoring the polarisation of an optical beam passing through the crystal the electric field can be determined. Good agreement between measurements using ANA and EOS has been determined. An advantage of the EOS method over conventional techniques is its ability to measure the electric field profile at any point on the circuit. This can reveal areas of device failure and also sections suffering crosstalk and coupling: vital information to designers and manufacturers of MMICs.

The work has highlighted the relative merits of EOS and is being extended to study more complex passive and active MMICs.

ENVIRONMENTAL METROLOGY 12

While there is no overarching environmental programme within the National Measurement System (NMS), it is evident that measurements of the highest quality are essential to understanding and responding to the needs of the environment.

As a centre of measurement excellence, NPL has built up world-class teams focused upon difficult environmental challenges. Growing out of its NMS programmes in Optical Radiation Metrology, Ionising Radiation Metrology, Valid Analytical Measurement and others, NPL is undertaking a range of environmental projects for the UK Government, both for the DTI and the Department of the Environment, Transport and the Regions (DETR).

BALLOON INSTRUMENT HELPS MONITOR OZONE HOLE

The Third European Stratospheric Ozone experiment is monitoring stratospheric ozone loss in the northern hemisphere. The ozone present at high altitude absorbs harmful ultra violet radiation. The experiment includes a series of balloon flights from mid and northern latitudes which collect a variety of atmospheric data using a package of instruments.

NPL has developed a compact laser spectrometer that is used to measure methane concentrations during the flights. The work was in collaboration with Cambridge University and was funded by the EU, Natural Environment Research Council (NERC) and DETR. The heart of the spectrometer is a novel gas cell that is inherently stable and very lightweight. The whole spectrometer package is less than 6 kg and operates independently of other instruments, so that it can be easily transferred between experimental platforms. The gas cell is 0.5 m long but the optical path within it is effectively 101 m giving very high sensitivity - the detection limit for methane is 1.4 parts per billion. Methane is measured as a tracer species, which allows the variation in other gas concentrations, such as ozone, to be accurately determined and allows for the variation in pressure and temperature at different altitudes to be compensated. The data is used to validate models of atmospheric transport effects and to investigate areas where the numerical models are 'data poor'.

The spectrometer has participated in six short duration flights (giving vertical profiles of species up to 30 km altitude) and one long duration flight where the balloon package was allowed to drift with high altitude currents. NPL has been asked to contribute to proposals for a further series of experiments to extend the data obtained.

AIR QUALITY NETWORKS

Improving ambient air quality is a complex task. Immediately banning all polluting emissions is not practicable and air quality regulation is based on setting upper limits on concentrations of individual pollutants. Accurate measurement of these pollutants is therefore essential in order to apply legislation, gauge trends and refine predictions.

NPL provides field calibrations for 25 air quality monitoring sites operated by local authorities in the London area, as well as the 38 sites covered on behalf of DETR around the UK. In addition, NPL is an active member of the CEN working groups for: oxides of nitrogen, sulphur dioxide, carbon monoxide and ozone; benzene; small particulate matter (PM2.5); diffusive samplers; and quality assurance of automated measuring systems. These groups are concerned with the implementation of the EU Air Quality Directive, which will have a direct effect on how national networks are run over the next few years, and are developing the harmonised standards that will specify reference methods and other quality control measures. These standards will ensure that measurements throughout the EU have an uncertainty demonstrably within the limits set out in the Directive.

NPL will continue to develop air quality measurement methodologies to anticipate and respond to future air quality issues. Such issues may include: measurements of newly identified pollutants, clarifying their effects on health; determination of indoor air pollution issues; investigation of pollution 'hot spots'; and continuing support to collaborative projects on this international problem.

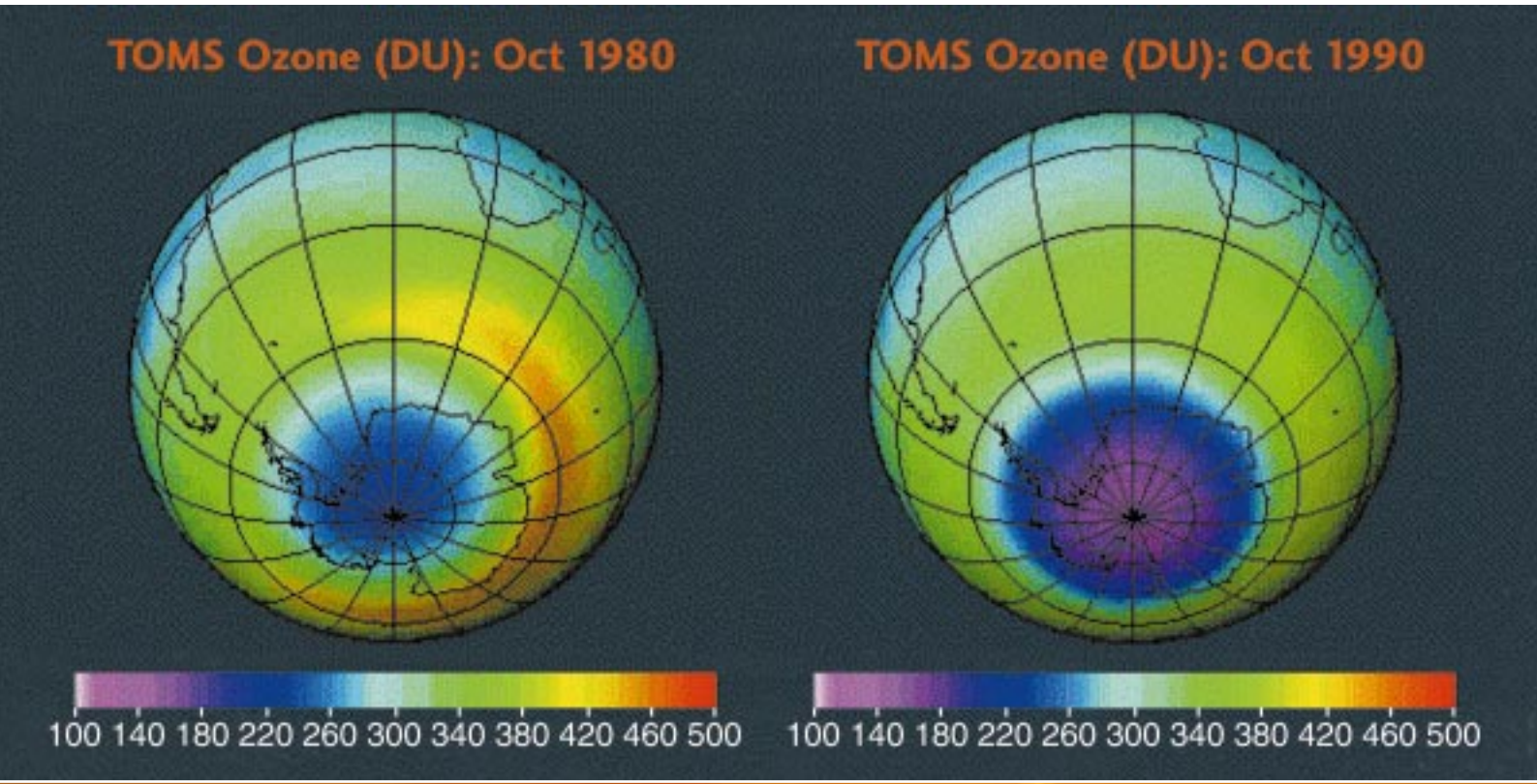
NPL PRODUCES NEW INDUSTRIALLY-REQUIRED GAS STANDARDS

NPL has, for a number of years, been preparing a wide range of primary standard calibration gas mixtures to underpin industrial and legislative requirements. These are produced, using an internationally agreed method, in which individual gases are weighed accurately into specially passivated gas cylinders. These are then used to certify secondary standards which are supplied to customers. The gas standards produced include those required for industrial and vehicle emissions, and for environmental monitoring.

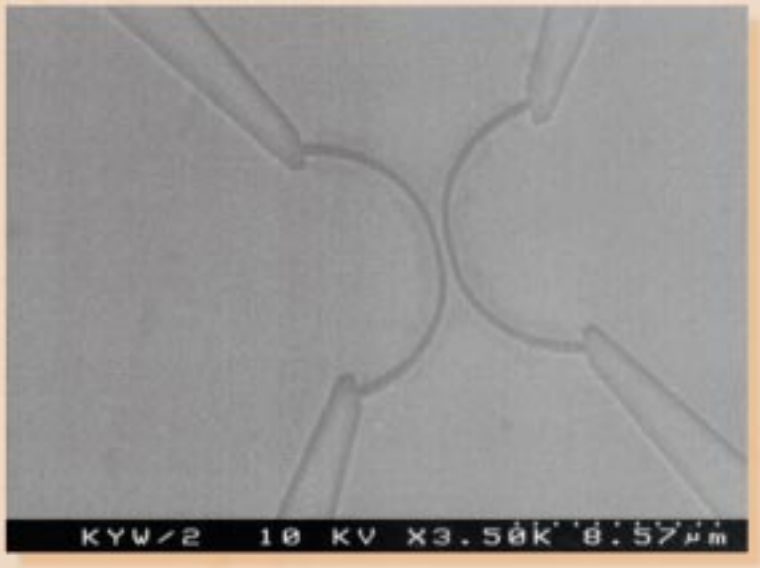
The diversification and deregulation of the UK's natural gas supply now require very reliable measurements of its calorific value, since this underpins the pricing and international trading in natural gas. Such determinations of calorific value are most accurately made by measurements of the concentrations of the wide range of gaseous components which make up natural gas, and these measurements need to be calibrated using accurate gas composition standards.

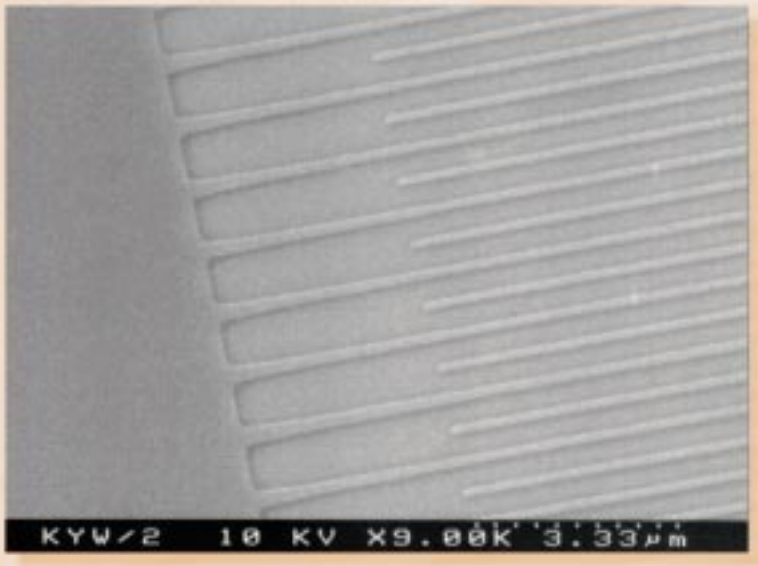
Under DTI's Valid Analytical Measurement (VAM) Programme, NPL's expertise in preparing internationally accepted natural gas standards has been used to produce multicomponent primary standards of accurately known composition. These cover the most important range of components present in the UK, both from offshore and continental Europe. At each stage in the process of producing these standards the highest levels of quality control are implemented, including comprehensive analyses of the purities of all components before they are used.

Further work is in progress on the production of primary gas standards for inorganic pollutants. These include sulphur dioxide, ammonia, chlorine, hydrogen fluoride and carbonyl sulphide which supplement NPL's existing portfolio. These have applications across a range of industries, and fulfil the requirements of legislative enforcement bodies and research organisations. They are also technically challenging as they are reactive species which will require special gas handling and cylinder passivation processes.



NPL is involved in current research into stratospheric ozone loss. The scale of this problem is illustrated in the figures above which show changes in the Antarctic ozone layer as measured by NASA's satellite-based Total Ozone Mapping Spectrometer. NPL also has a leading role in developing measurement standards and techniques used to monitor air pollution.





NPL is committed to research in fundamental standards. Above, Ian Robinson works on a moving coil balance, a new way of measuring mass in terms of fundamental constants. NPL is also making measurements on a quantum current standard which uses surface acoustic waves launched by a transducer (right) to transfer electrons through a one-dimensional channel (left).

FOUNDATION METROLOGY 16

The Foundation Programme is unique within the National Measurement System (NMS) portfolio of programmes in that it provides the longer term underpinning research to support the top level infrastructure of the NMS and its ability to provide traceability to internationally agreed primary SI units of measurement - the core function of the NMS in support of UK industry.

The programme aims to provide innovative investigations into those aspects of fundamental physical phenomena which have potential long-term impact on the NMS, specifically:

- ***monitoring the long-term trends and needs of the UK NMS at the highest level of measurement accuracy***
- ***contributing at an international level to the knowledge and measurement of those fundamental constants and SI units which progress the present and future national measurement system and to safeguard UK interests in international measurement system forums***
- ***carrying out development work relating to the exploitation of atomic and quantum phenomena for the next generation of measurement standards***
- ***exploiting developments in quantum functional materials and processes, including, for example, superconductivity***

THE ELECTRIC KILOGRAM

The kilogram is unique amongst the base units of the SI system as it is defined in terms of a man-made object - the prototype kilogram. In contrast the metre and the second are linked to the unchanging fundamental constants of nature.

NPL is working on a moving coil balance which can place the kilogram on the same footing as the other SI units. The apparatus consists of a balance and a large permanent magnet. A cylindrical coil is suspended in the magnetic field from one arm of the balance. A mass is added to this arm and the balance is brought into equilibrium by the force generated passing a current through the coil. The current needed to balance the system is accurately measured in terms of the second and the fundamental constants h (Planck's constant), and e (the charge on the electron). In a second part of the experiment the mass and current are removed, and the coil is moved through the magnetic field. The induced voltage and the velocity of the coil are then accurately measured. Combining the results from both parts of the experiment gives an expression equating electrical and mechanical power, which is independent of the coil geometry and the magnetic field, provided that both are sufficiently

stable. The two-part method eliminates the need for corrections due to energy losses during measurement. The apparatus is operated in a vacuum to eliminate errors such as the buoyancy effect of air on the mass.

The best existing mass standards may drift by 1 part in 100 000 000 in a year. The NPL apparatus is intended to monitor these changes and the present experiments are achieving a comparable resolution from a single overnight run. Further work on refining measurements of voltage and alignment is in progress and will increase accuracy.

IMPROVING THE ACCURACY OF ENVIRONMENTAL MEASUREMENTS BY MASS SPECTROMETRY

A new project in the DTI's Foundation Programme focuses on research into the use of high accuracy mass spectrometry to carry out measurements of gases. This research will underpin the accuracy of standards disseminated in the UK for measurements of environmental gases at ambient and emission concentration levels. It will also lead to an understanding of how the accuracy of other chemical measurements can be improved.

The project uses the technique of isotope dilution mass spectrometry (IDMS) which is capable of making measurements of chemical concentrations in unknown samples that can be referred to primary standards which are prepared gravimetrically. A mass spectrometer has been specially designed which has a unique quadruple input capability. It achieves an internal consistency of measured isotope ratios of 5 parts in 10^5 over a dynamic range of 1 000. This should be compared with the typical accuracy of chemical measurements which rarely exceeds 1 part in 10^4 and the accuracy of isotope ratio measurements (at natural abundances) which is also typically 1 part in 10^4. During the coming year the new mass spectrometer will be used to make accurate comparisons of gas mixtures prepared in small volume cylinders by high accuracy weighing traceable to UK mass standards.

The results of the project will have implications beyond the measurement of gases. They will serve as a demonstration that the isotope dilution approach is across the field of chemical measurement, where substantial requirements exist for an infrastructure to support improved analytical measurements.

QUANTUM CURRENT STANDARD

Recent work at Cambridge University has observed quantised electric currents in special semiconductor devices. Essentially this means that single electron events have been observed. These experiments offer the prospect of completing the 'metrological triangle' linking h, e and frequency and the possibility of establishing the basis for a quantum current standard.

In order to confirm this, very accurate measurements of current are required. The current generated in the new devices is typically 1 nA and the relative uncertainty must be less than 1 part in 10^7. This requires a current resolution of better than 10^{-16} A. NPL is working on a cryogenic current comparator (CCC) bridge technique to achieve the necessary resolution. The CCC consists of a large winding (40 960 turns) surrounded by a superconducting shield. Any change in the current in the coil is detected by a pickup coil linked to a SQUID (a detector exploiting superconducting phenomena). The CCC, pickup coil and SQUID are all cooled to 4.2 K in liquid helium. Measurements on two different single electron devices have shown that the present apparatus has an uncertainty of 5 parts in 10^6. Further work on improving temperature control and the magnetic shielding of the CCC are proposed to achieve the necessary resolution to measure quantised currents with the same accuracy as quantised Hall resistance and Josephson voltage.

This work is producing results that significantly advance fundamental metrology research. However applications in device manufacture are already being discussed. Single electron effects and quantum effects will be significant technologies in advancing the power of microchips and accurate measurement of currents in these devices is essential for their development.

IONISING RADIATION METROLOGY 18

The National Measurement System (NMS) Ionising Radiation Metrology Programme underpins all UK measurements of ionising radiation and radioactivity for all types of radiation, over a wide range of energies and dose rates. The accurate measurement of ionising radiation and radioactivity is vital to an ever-increasing range of activities and applications as diverse as medicine, industrial processes, nuclear power, environmental monitoring and scientific research. National regulations for health and safety, many of which arise from European Directives, as well as medical controls and economics, require accurate measurements that depend on well-calibrated instruments and well-defined test methods traceable to national standards.

NEW CALIBRATION SERVICE HELPS MINIMISE PATIENT DOSE

Radiation from diagnostic medical X-rays comprises more than 80% of the total exposure of the UK population to man-made radiation. Any steps that can be taken to minimise the individual doses from the estimated 35 million X-ray examinations that are undertaken each year in the UK should be explored. Accurate calibration of the X-ray devices in hospitals will ensure that patients are not exposed to unnecessary levels of radiation. The National Radiological Protection Board, in conjunction with the Royal College of Radiologists, has recommended a set of specified reference doses for a number of common examinations.

NPL undertook a survey of hospital X-ray equipment used for the dosimetry of diagnostic and mammographic X-ray beams, to assess the practical calibration requirements. This has led to the establishment of a calibration service for diagnostic and mammographic X-ray dosemeters at NPL. It is now possible for hospitals to have their instruments calibrated directly against the NPL air kerma primary standards at appropriate X-ray qualities and air kerma rates. It is recommended that the calibration interval for hospital secondary standards should not exceed three years.

The calibration service requires a different configuration from the other services offered in the X-ray facilities and so will be offered during one period (June-July) each year. This will minimise the cost of calibration to customers, as the annual cost of setting up the service will be distributed over all those participating.

INDUSTRIAL RADIATION COMPARISON HELPS BEST PRACTICE IN EUROPE

Sterilisation of single use medical devices, such as syringes, by ionising radiation is increasing throughout Europe. EU standards require that the medical device industry calibrates instruments with reference to traceable standards to ensure that measurements of absorbed radiation doses are accurate.

NPL has been working in collaboration with the Risø national laboratory in Denmark on a three-year EU project to evaluate current practice in industrial radiation sterilisation plants throughout Europe. The survey included both gamma ray and electron accelerator facilities. An initial survey of industrial calibration performance was undertaken and followed up by a workshop on best practice. A second intercomparison has just been completed and

the results evaluated. A significant improvement was seen during the second survey - especially in electron beam plants. A comprehensive set of guidelines for calibration of industrial dosimeters has been written and published as an NPL report (CIRM 29).

A summary of the results of the intercomparisons is to be published in the open literature.

IS THERE RADON IN THE HOUSE?

Radon is a radioactive gas that is produced in uranium and thorium bearing rocks and is continually outgassed into the surrounding environment. It is estimated that radon accounts for over half the annual dose of naturally occurring radiation experienced by the UK population. Radon itself is inert, however its decay products can be harmful. At the current Health & Safety Executive action level of 200 Bq m^{-3} the lifetime risk of premature lung cancer from radon is 3%.

Radon levels vary with the natural geology of the UK, but it can accumulate in unventilated buildings. New housing in areas of high radon activity is required to provide facilities to mitigate radon build-up. NPL was contracted by DETR to assess methods to quantify radon levels in domestic premises. NPL evaluated two economic methods that are available for home application: an activated charcoal method and a nuclear track-etch method. The charcoal technique requires the placement of two charcoal canisters in the house, one on the ground floor and one upstairs. These are exposed for a week to the environment before being sealed and posted to a laboratory for analysis. The track-etch uses a material which records the decay of radon and its daughter atoms directly. Again two devices are placed in the house but the exposure period is three months before the devices are sent to a laboratory for evaluation. The NPL study determined that the effectiveness of both methods was similar but that the quicker turnaround of the charcoal technique had advantages for domestic measurements.

The results of the project have been submitted to DETR. One particular concern was the apparent lack of traceability of radon measurement techniques to national standards. Further work in this area may be required.

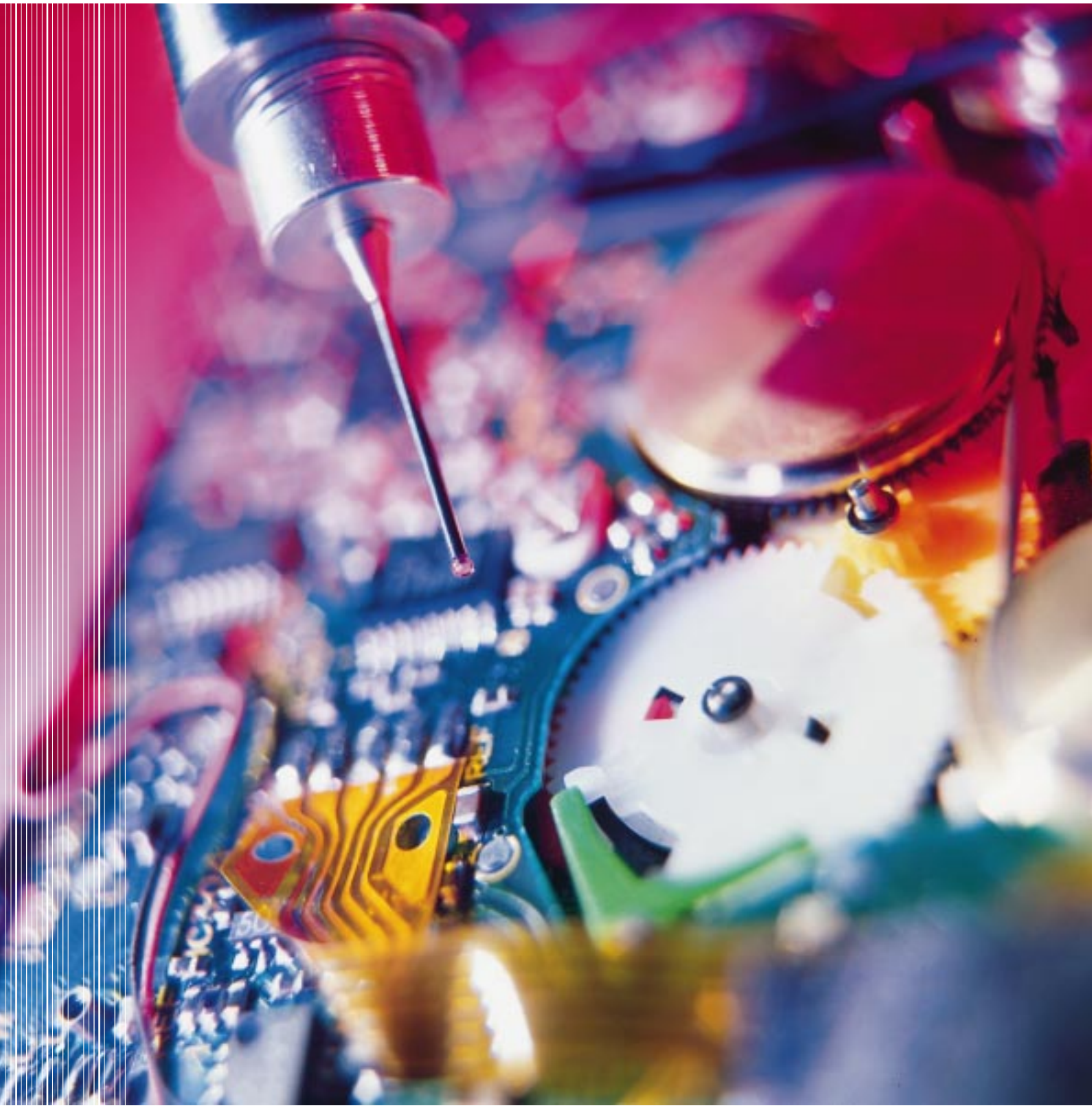
NON-PHANTOM METHOD VALIDATED

Personal radiation dosemeters are worn by workers in power stations, medical radiography, the radionuclide and other industries. Clearly, it is essential that the devices are accurately calibrated.

Fast neutron personal dosemeters are routinely calibrated on a 'phantom' - a torso-sized block of perspex or water that represents the human body and allows for the backscattering of radiation from the body. The use of a phantom restricts the number of devices that can be calibrated at any one time. NPL has undertaken a series of experiments to evaluate dosemeter response to the backscattered component of radiation. Dosemeters issued by all the approved dosimetry services in the UK were evaluated using two neutron sources and two types of phantom. The results showed the response to the backscattered component to be of the order of 5% and to be consistent across all the dosemeters measured. The results will allow personal dosemeters to be calibrated without the use of a phantom with confidence and increase throughput of calibration samples.

Radiation transport calculations indicate that the backscattered dose is considerably greater than the figure of 5% measured. Further work will be undertaken to understand why the response to the backscattered component is low. Two effects are expected to have a bearing on this: firstly the lower energy of the backscattered radiation, since the dosemeters are more efficient to higher energies, and secondly the spread of angles for returning neutrons as the dosemeters are most efficient for incident angles close to normal.

Nicky Horwood attaches neutron personal dosemeters to the face of a phantom in an experiment to evaluate dosemeter response to the backscattered component of radiation.



The continuing trend towards miniaturisation in manufacturing has led to a need for a co-ordinate measuring machine capable of measuring very small features on miniature components.

LENGTH METROLOGY 22

The Length Programme covers the development, maintenance and dissemination of a wide range of measurement parameters in dimensional and optical technology.

The programme aims to:

- ***realise and maintain the primary metre standard in accordance with its international definition***
- ***disseminate the unit of length and related derived standards to users in UK industry, commerce, the science base and elsewhere through the National Measurement System (NMS), by the provision of calibration and measurement services traceable to national standards***
- ***deliver an innovative programme of research and development addressing future UK requirements for length metrology***
- ***maintain and modernise existing national facilities***
- ***encourage best practice in dimensional measurement in the UK through a range of technology transfer activities***

MEASUREMENT FOR MINIATURE MANUFACTURING

The continuing trend towards miniaturisation in manufacturing has led to a need for a co-ordinate measuring machine (CMM) capable of measuring tiny features on small components such as optical fibre interconnectors and hard disk components. Such a device would bridge a technology gap between conventional CMMs and nanometrology instruments such as atomic force microscopes.

As part of a collaborative project with industrial partners and funded by the DTI, NPL has developed a miniature CMM that has a working volume of 50 mm x 50 mm x 50 mm and a measurement uncertainty of ±50 nm. This is the first generally applicable CMM to achieve accurate 3D measurements in this size range. The machine uses a multiple-axis laser interferometer system to measure the CMM probe position. A key feature of the instrument is that the interferometer sytem is also used to calibrate, in situ, the flatness of three mutually orthogonal mirrors attached to the probe system and to check the alignment of the mirrors with the measurement axes. The new machine has a thermally stable, rigid metrology frame and also features a novel 3-dimensional probe of low probing force that reduces the potential for damaging component surfaces during measurement. The whole

system can be kinematically mounted on a conventional CMM and interfaces via a dedicated PC to the CMM controller.

NPL is now offering a measurement service using the miniature CMM and is continuing to collaborate with its partners to develop a larger device capable of measurements in a 600 mm x 600 mm x 600 mm volume to an uncertainty of ±300 nm.

NEW COMPACT LASER STANDARDS

Iodine stabilised HeNe lasers are used as primary laser reference standards for the realisation of the metre and precision length metrology, as well as serving as calibrated references for stabilised lasers and high resolution spectroscopy.

NPL has been producing HeNe reference lasers to order for other NMIs for some years. These lasers were designed as laboratory based devices. Recently NPL has refined its design to produce a more portable system. The new 633 nm iodine stabilised HeNe reference laser maintains the performance of the original design (relative frequency stability ~1.5 x 10^{-12}) but is fully portable with slimline electronics that fits into a 19 inch by 3U module.

Prototype portable lasers have been produced and are being tested in industrial applications. The new portable device offers the capability for direct calibration of high accuracy laser length-measuring equipment against a laser standard used for the practical realisation of the metre.

NEW TESTS FOR ADVANCED SATELLITE THRUSTERS

The Laser Interferometer Space Antenna (LISA) is an international space mission that is planned to measure gravitational waves early in the next century. The mission will consist of three satellites positioned 5 million kilometres apart in an equilateral triangle in the outer solar system. One of the key technology challenges for the LISA mission is that the position of the individual satellites needs to be controlled to an accuracy of 10 nm, counteracting the radiation pressure of sunlight which varies with time.

Field emission electric propulsion (FEEP) systems have been developed for accurate positioning of communications satellites and other space science missions - these systems produce an appropriate low thrust (tens of micronewtons) that is well controlled. NPL has won a contract from the European Space Agency (ESA) to develop a calibration and test facility for FEEP thrusters. The project is a considerable technical challenge as sub micronewton force accuracy was required on a thruster weighing several hundred grams. NPL's experience in both metrology and materials was invaluable in producing a prototype calibration facility that achieves the required accuracy and is not influenced by ambient vibrations. The final design is a horizontal thrust balance which could be reconfigured to become an incredibly sensitive seismometer.

The prototype calibration facility will be delivered to ESA towards the end of 1999 and FEEP thrusters are scheduled to be flown on a shuttle mission in early 2000.

MICROLENS ASSEMBLIES FOR 3D IMAGES

Lens Assemblies for Image Recording and Display (LAIRD) is a DTI Link Photonics project, involving a number of partners, which is demonstrating technology for recording and displaying lifelike 3D images in colour, without the use of lasers or viewing aids.

NPL's role in the project is to provide expertise in the design, fabrication and measurement of microlenses and in assessing the 3D images generated. Arrays of spherical microlenses are produced by several methods, including melting small cylindrical islands of material formed by photolithographic techniques. Arrays for the LAIRD project require lenses to be spaced by intervals ranging from 90 μm to 850 μm with some arrays containing tens of thousands of lenses. The microlenses are assessed by instrumentation developed at NPL.

An array of lenses forms an array of images of an object, each seen from a different perspective. If the array of images is recorded through a special lens array system it can be projected back through a lens array to form a 3D reconstruction of the object. The LAIRD project has produced a prototype 3D camera, consisting of a number of lens assemblies, that has recorded static images and high speed events and has produced 3D demonstrators in the form of back-lit transparencies. It is believed that this is the first time that 3D images reconstructed in colour with full parallax in all directions and natural accommodation and convergence have been demonstrated.

Future work on the project will include the construction of a Mark II camera using large area (30 cm x 30 cm) matched pairs of lens arrays and hexagonal close-packed lenses to improve the image quality.

MASS METROLOGY 24

The Mass Metrology Programme supports the maintenance and development of measurement standards for mass-related quantities - specifically mass, density, force, torque, hardness, pressure, vacuum, and trace humidity - and the development of standardised methods of measurement for these quantities.

The programme aims:

- ***to maintain and develop national measurement standards for mass-related quantities, including the UK's primary mass kilogram standard, at a level consistent with the current and future needs of UK industry, national and local government, and research, in order to make these standards accessible to customers in as practical and economical a form as possible***
- ***to ensure that UK measurement standards for mass-related quantities are harmonised with those of the UK's trading partners, through intercomparisons and collaborative research leading to mutual recognition***
- ***to develop new methods of measurement for mass-related quantities to meet identified UK private and public sector needs, and promote international standardisation of these methods to ensure consistency in practical measurements, especially where these are used for regulatory or trading purposes***
- ***to promote knowledge transfer from the programme and the adoption of good measurement practice, and to provide technical support and advice to UK organisations and individuals undertaking mass-related measurements***

COMPARISON OF VACUUM STANDARDS

Primary measurements of vacuum standards are undertaken by two methods internationally: a static method using series expansions of a known, fixed amount of gas in linked vessels of known volume ratio and a dynamic method that uses measurement of gas flow through well-characterised orifice plates. International comparison of vacuum standards relies on the use of physical models to calculate the uncertainties in the measurements. Historically, comparison of data and uncertainties from the two experimental methods has been a source of controversy.

Using a new experimental facility, NPL has been able to make measurements on both dynamic and static systems using a unique pressure interlock and common gauging. The results have shown that the two NPL systems agree within their own uncertainties. The data generated has

allowed NPL to revisit the physical models used in both methods and critically challenge their basis - for example calculations of conductance in the orifice model. New models are being formulated that revise assumptions and remove oversimplifications and allow more robust uncertainty calculations.

Further measurements on the NPL facility are being made to refine the models. The models will help to increase the validity of international comparisons of vacuum standards.

MASSIVE MASS INTERCOMPARISON IMPROVES INTERNATIONAL RELATIONS

Intercomparison measurements are central to maintaining international traceability. In the mass area NPL has recently led two European intercomparison initiatives: one involving EUROMET partners and the other being part of the EU-funded PHARE programme.

The EUROMET initiative was part of a wider global intercomparison of one-kilogram stainless steel mass standards and incorporated results from ten regional laboratories. The results are to be published and will be followed up by a larger intercomparison of stainless steel standards and a parallel intercomparison of one-kilogram platinum/iridium standards held by National Measurement Institutes (NMIs).

The purpose of the PHARE project was to assist and assess the measurement infrastructure in Central and Eastern Europe. As part of the project, staff from NPL visited 22 laboratories in 13 countries during three extended tours. A variety of laboratory facilities and methodologies was examined at both NMIs and industrial laboratories, using a set of standard weights ranging from 1 g to 5 kg.

NPL expects to become more actively involved in international comparisons as the work gives benefits in terms of improving UK standards and sharing best practice with developing laboratories overseas. The potential to sell appropriate technology to these laboratories is a further bonus.

NEW LIGHT ON AIR

NPL is developing a technique to measure directly the density of air. This long-term project relies on accurate weighing of different artefacts with the same mass but differing volume both in air and in a vacuum. The limit of the technique is the mass stability of the artefacts - surface finish being an important parameter. NPL has the world's best facility for weighing in vacuum and initial data from the experiments is being shared with international partners.

UK REGAINS HARDNESS RESOURCE

The hardness of a material is one of its most important properties. Hardness is measured by virtually all manufacturing companies. Some 5 billion hardness measurements are made in the UK every year and goods worth tens of billions of pounds depend on such measurements. Hardness is an unusual property, measured in terms of an impression made in the sample material by an appropriate probe applied with a specified force.

NPL, in collaboration with Instron Ltd, has been commissioned by the DTI to develop new national hardness standards for UK industry and to establish a centre of expertise. Two machines have been built by Instron and delivered to NPL. The smaller machine covers the force range up to 1 500 N whilst the second machine can apply forces up to 30 kN. The machines are designed to meet the accuracy requirements of the various ISO standards for hardness (Rockwell, Vickers and Brinell) but to be cheaper than equivalent deadweight machines. The machines' performance has been verified and depth and force sensors calibrated with direct traceability to NPL force and length standards. A metallurgical microscope fitted with a laser interferometer and an image analyser ensures the best possible measurements of indentation widths. A separate system for geometric verification of indenters has been commissioned and calibrated.

The machines are being compared with standards facilities at the Istituto di Metrologia 'G Colonnetti' in Italy. Further intercomparisons with European standards laboratories will follow and a calibration service to UK industry will be available in early 2000.

NPL led an intercomparison to establish the equivalence of the kilogram across Europe.

Accurate data on the operating limits for materials in varying or challenging environments is essential for predicting safety parameters.

MATERIALS METROLOGY 28

The Engineering Industries Directorate supports a range of programmes of research in materials measurement. These programmes aim to increase the confidence of companies in using new materials and encourage better design with and processing of existing materials. The five programmes are: *Composites Performance and Design*, *Characterisation of Advanced Materials*, *Materials Degradation in Aggressive Environments*, *Materials Measurements which affect Processability*, and *Performance of Adhesive Joints*.

These materials programmes aim to:

- ***improve the understanding of materials behaviour and performance***
- ***develop new measurement methods, equipment and standards***
- ***provide predictive procedures for performance***
- ***provide design methodologies and software***
- ***encourage best practice in materials measurement design and processing through a range of technology transfer activities, including clubs, publications, courses and technical advice***

ZERO DEFECTS FOR SOLDERING

Microelectronics underpins almost all modern technology, whether in commercial, industrial or consumer markets. A major technical headache in production of electronic systems is the quality of soldering when assembling surface mounted components on small printed circuit boards.

The issues relevant to characterising soldering technologies were recently unravelled by NPL in a BRITE supported collaborative project with industrial partners. In addition, a standard method for testing solderability (IEC 68-2-69) has been developed. NPL has now, in co-operation with Multicore Solders, developed a new device to measure the solderability of small electronic components. The Multicore Universal Solderability Tester (MUST) uses a tiny 25 mg or 200 mg pellet of solder in a heated, circular iron pit. The change in wetting force when a component connection pad or lead is dipped in the molten solder is measured. The larger the increase the better the solderability of the component. The instrument is more flexible than previously and has much greater sensitivity.

The purpose-built instrument is now available for industrial use in process control, assessment of new components and surface finishes. In addition NPL holds regular one-day workshops on solderability issues for industry, sharing best practice and giving hands-on experience of state-of-the-art equipment.

CASTING DEVELOPMENTS

In competitive markets, such as the automotive sector, success depends on the ability to respond quickly and efficiently to new products, providing enhanced value to customers. Traditionally items such as automotive body components have been designed by manufacturers in isolation from the tooling producer. Such tools consist of large 'one-off' iron castings, and optimising tooling design can be expensive and prone to human error.

Accurate thermophysical data derived from traceable measurement techniques has been supplied by NPL for use in a new approach to tackling tooling design. In collaboration with the Casting Development Centre (CDC), a concurrent engineering and modelling approach was adopted using Finite Element Analysis (FEA) and casting simulation predictions to produce a die assembly for a saloon car roof component. This was combined with rapid prototyping and advanced manufacturing facilities to provide improved casting designs for the tooling. The result was a robust, lighter, cast product with optimised product quality produced in a short timescale and at reduced cost.

CDC is the largest UK provider of technical consultancy to the casting industry and will use the experience gained from this project to assist customer-supplier partnerships to achieve optimum design and performance in tooling applications throughout industry.

VISCOSITY AT HIGH TEMPERATURES

Measuring viscosity accurately at high temperature is very difficult, however such data is vital for controlling liquid metal processing such as casting, welding and spray forming.

NPL's oscillating viscometer has been adapted to operate at temperatures as high as 1 620 °C. The viscometer is based on a torsional pendulum with the sample contained in a closed alumina crucible supported on a suspension rod connected to a long thin wire. The crucible is positioned in a two-zone furnace. Viscosity is determined by monitoring the damping effect of the liquid metal on rotary oscillations propagated in the system.

Intercomparisons with researchers in Japan have shown good agreement for measurements on liquid iron up to 1 600 °C. Further experiments are being carried out on cobalt alloys for use in artificial joints and on steels for use in automotive and structural applications.

STEEL AND POLYMER DATABASES

Accurate data on operating limits for materials in varying environments is essential for predicting safety parameters. NPL has launched a database covering safe operating limits for duplex stainless steel in a wide range of environments in applications ranging from marine to oil refining. The CD-ROM contains 6 000 entries on general corrosion, stress corrosion cracking, pitting and crevice corrosion. In addition, a database to help designers predict the likelihood of environmental stress cracking (ESC) in polymers - the cause of 30% of all failures in engineering plastics - has been launched. Exposure to fluids such as cleaning agents or lubricants may induce ESC in plastics. The database contains information on 900 plastic-liquid combinations. In parallel NPL has published a *Measurement Good Practice Guide* on residual stresses in plastics (No. 10).

Two further industrial guides are being developed: one will give guidelines for measuring ESC in plastics and the second will help designers of plastic mouldings to reduce the risk of ESC due to residual stress.

PLASTIC PROCESSING COSTS REDUCED

The manufacture of many components, including parts for cars, computers and consumer goods, involves processing synthetic polymers in a hot, viscous state under pressure. Changes in viscosity affect the quality of finished products and the speed at which they can be produced - both having cost implications for the manufacturer. Accurate temperature control in such industrial processes is therefore essential.

In co-operation with Magna Projects and Instruments Ltd, NPL has modified a high-pressure high-speed Rapid Advanced Capillary Extrusion Rheometer (RACER) to generate data on the flow properties of a wide range of polymers in industrially relevant conditions. Industrial processing routes are increasingly decided via computer aided design and development (CADD) studies which rely on the accuracy of such data. The viscosity of plastics is altered by the high pressure (e.g. 100 MPa) experienced during processing. If high pressure effects are ignored then viscosity data in CADD programs may be in error by as much as 500% resulting in serious manufacturing problems. The data generated by the new facility can be used in CADD programs that will increase the efficiency and quality of industrial plastics processing.

OPTICAL RADIATION METROLOGY 30

The Optical Radiation Metrology Programme covers the development, maintenance and dissemination of a wide range of measurement parameters in the optical radiation spectral region (i.e. the ultraviolet, visible and near infrared).

The programme aims to provide:

- ***measurement scales of sufficient accuracy to meet national needs and which are consistent with those of our trading partners***
- ***measurement standards and related techniques and expertise to ensure an effective and timely technical capability at UK national level***
- ***access to scales and standards through effective technical services made available by the NPL and other National Measurement System (NMS) contractors to the direct beneficiary community in the UK***
- ***awareness and availability of the expertise and knowledge generated by NMS-supported work to the beneficiary communities***
- ***activities to promote best practice and exploitation of the UK's expertise in the relevant measurement fields***
- ***technical input to, and representation of, UK interests on national and international standardisation and metrological committees***

GERB CALIBRATION

The Geostationary Earth Radiation Budget (GERB) instrument will be flown on the METEOSTAT second generation satellite in 2002. The instrument will be the first to measure a spatially and temporarily resolved Earth radiation budget (a crucial measurement in research on climate change and atmospheric processes) from a geostationary orbit. Currently such measurements are made from low earth orbit and do not offer the possibility of continuous monitoring.

NPL has assisted the GERB team, led by Imperial College, London, by providing visible and infrared primary standards to calibrate GERB to an extremely high accuracy. NPL has also calibrated all optical subsystems (mirror reflectance, filter transmittance, detector response etc.). The calibrations used state-of-the-art techniques and will give GERB unparalleled uncertainty characteristics. The GERB instrument will be able to perform spatially resolved measurements over the North Atlantic/European sector every 15 minutes.

The GERB instrument is currently being integrated into the METEOSTAT launch package. However the success of the project has already resulted in the funding of GERB2 and GERB3. NPL will be involved in similar calibration activities for these instruments.

HIGHEST TEMPERATURE BLACK BODY

Black bodies (BB) give improved spectral coverage with higher temperature. NPL has recently taken delivery of the world's highest temperature BB, which will form the basis for the establishment of a new primary spectral emissions scale in the UK. Accurate calibration of spectral emission is vital for research in areas from climate change to street lighting.

The new BB, which can operate at up to 3 500 K for short periods and at 3 000 K for an extended time, was funded by the DTI. The high temperature capability is due to the use of a pyrolytic graphite in the BB chamber which was developed in Russia for defence applications and has only recently become available to the outside world. The BB was delivered in February 1999 and is now installed and being characterised. The BB will form part of a key international comparison of emission scales, led by NPL, that is due to begin at the end of 1999.

In addition to work on primary scales the BB will be used to directly calibrate highly accurate satellite instruments for a number of upcoming space missions. These include the remote sensing instrument CHRIS and SOLSPEC, a solar spectral irradiance instrument, due to be flown on the International Space Station.

APPEARANCE IS ALL

The visual appearance or finish of consumer products is often one of the most critical parameters affecting consumer choice. However, a complete description of appearance is complex and cannot be achieved by the definition of the colour of the object alone. Other attributes such as surface texture, the direction of lighting, pattern and translucency contribute to our perception of the object.

Work at NPL has recently begun to define and measure the various parameters that affect the appearance of an object. The initial project is co-funded by the DTI and a number of companies and is split into three work packages: translucency, complex visual surfaces and imaging systems. Many products, for example shampoos and cosmetics, are translucent in that light diffuses within them to give neither completely opaque nor transmitting appearance. The project will propose a formal definition for translucency and a measurement specification. Complex visual surfaces and materials, for example metallic vehicle paints and cosmetics, have no internationally accepted measurement specification or traceability - the project will compare current measurement techniques with the aim of defining a standard methodology. Imaging systems are used in an increasing number of applications for quality control on production lines.

Measurement of appearance is potentially a very wide research area and is of key importance to the fully manufactured consumer goods sector. As the results of the initial work are assessed it is anticipated that the programme will expand to tackle other aspects of visual appearance.

CUSTOMER SERVICE IS THE KEY WITH OPTICAL MSU

The Measurement Services Unit (MSU) within the Optical Radiation Measurement (ORM) Group aims to provide convenient and efficient access to the measurement services offered by ORM. Before the setting up of MSU, the three areas of customer service offered by ORM (detectors, sources and materials work) were co-ordinated separately.

Since MSU was established two years ago, bringing all the customer services together, response times have been much improved and turnaround for services, such as recalibration, have been halved. The key to the improvement is a combination of improved customer contact and the increased flexibility of NPL resources. The introduction of a recall system, where the customer can be given an early reminder for an artefact that requires recalibration, helps scheduling of work. Customer satisfaction is monitored by questionnaires that are sent out with every completed job. Satisfaction levels are very high and increasing - MSU is working towards 100% satisfaction. The fact that Jason O'Halloran from MSU won the NPL 1999 staff prize for exceptional customer service underlines the spirit in the Unit.

MSU is expanding services for customers with initiatives such as the Calibration Exchange Scheme where newly calibrated artefacts are exchanged for the customer's old artefact. The old artefact could then be reused following calibration. The scheme reduces turnaround to a few days. Other schemes being considered involve lending artefacts during recalibration and leased equipment.

Work has begun to define and measure parameters, such as translucency, that affect appearance. The cosmetic use of pearlescent and gloss effects, as well as colour, presents a measurement challenge.

NPL is developing OTDR techniques for the distributed characterisation of optical fibres.

PHOTONICS METROLOGY 34

The Photonics Metrology Programme brings together all DTI-funded measurement activities relating to the photonics industry. It will facilitate the identification of the key measurement priorities and provide a sharper industrial focus for existing and future measurement services in this rapidly changing field.

The programme aims to provide:

- ***measurement standards, facilities and expertise to ensure effective and timely technical capability at UK national level***
- ***access to traceable measurements through effective technical services made available by NPL and other National Measurement System (NMS) contractors to the direct beneficiary community in the UK***
- ***improved awareness and availability of the expertise and knowledge generated by the programme across all relevant industrial sectors, and measures to ensure responsiveness of the NMS work to evolving needs***
- ***mechanisms to promote best practice and exploitation of the UK's expertise in the relevant measurement fields***

INDUSTRY PARTNERSHIP - ANRITSU CORPORATION

One of the key strengths of NPL is its wealth of expertise in understanding those characteristics of a measurement instrument which make it intrinsically accurate and easily calibrated. In general, to produce the best instrumentation, the measurement related characteristics of individual components need to be understood in detail at an early stage of design.

Within the Photonics area, NPL has been working closely with Anritsu Corporation, a major fibre optic test equipment manufacturer, to develop a new fibre optic power meter, capable of measuring accurately the optical signal levels encountered in amplified, multi-wavelength communications systems. NPL's skills in the detailed characterisation of solid state detectors and optical attenuation techniques have been used by the company to identify the best component technologies available on the market. These will be used in manufacture to indicate the operating conditions and power meter design which will best serve Anritsu Corporation's requirements. Critical to the success of this project is that NPL has been brought in at the early stage of design so that the instrument is developed with calibration and overall accuracy in mind. Through this route, Anritsu Corporation and its customers can be confident that stringent product specifications are met.

Such a collaboration also provides knock-on benefits to UK industry as a whole. It enables NPL to develop expertise in technology and techniques beyond those supported through the DTI metrology programmes, leading to improvement in standards and measurement techniques.

EUROPE-WIDE FIBRE NETWORK

Over the past twenty years, fibre optic technology has had a huge impact on the telecommunications industry. Through this technology the power of the Internet has been harnessed, and the everyday worldwide communications we take for granted have been made possible. However the benefits of fibre optic technology are now being realised in many other industrial sectors - aerospace, automotive, healthcare and the lighting industry to name but a few. New applications bring new measurement challenges, and engineers working in these new fields can benefit from the experience of those in other sectors in solving similar problems.

Under the Photonics programme and supported by the European Commission, the Fibre Optic Technology Network (FOTN) has been set up to provide a pan-European forum for the cross sector dissemination of measurement information and the sharing of measurement research in the field of fibre optics. One of the important roles of the network is to support the European technical input to many of the standardisation issues which relate to the use of fibre optic technology. Regionally based, it has hubs in Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden and the UK.

DISTRIBUTED MEASUREMENTS IN OPTICAL FIBRES

Fibre optic networks are an important feature of modern telecommunications and IT systems. Single optic fibres are now routinely manufactured in lengths greater than 25 km although cabled sections are more typically 2 km to 5 km long. Non destructive testing of fibres, especially of longer length, can save measurement time and give insights to signal propagation characteristics.

As part of the recently launched NMS Photonics Metrology programme, NPL has been investigating the use of Optical Time Domain Reflectometer (OTDR) equipment. The OTDR operates by sending a short pulse of light down a fibre. The pulse is attenuated and some of the light is scattered. A fraction of this light is captured by the fibre and returned to the OTDR where it is detected as a function of time. An OTDR has been used to measure attenuation of signal along fibres for some time. NPL's work has now extended the range of measurements to cover mode field diameter, cut-off wavelength and other information. The accuracy of the data predicted by OTDR measurements is good and the limits of applicability of the technique have been assessed.

The Photonics programme will facilitate the identification of the key measurement priorities and provide sharper focus for existing and future measurement services in this rapidly changing field.

SOFTWARE SUPPORT FOR METROLOGY 36

The Software Support for Metrology Programme is designed to tackle generic issues which affect more than one of the other National Measurement System (NMS) programmes. Some of the issues require the application of established software engineering practices to metrological problems, whilst others require advances in mathematics, software engineering or theoretical physics.

The programme aims to provide:

- ***means for identifying and disseminating best practice across all metrology fields in the development and use of relevant software and mathematics***
- ***technical services and information to meet the needs of the industrial sectors upon which the programme would have most impact; this covers almost all engineering sectors***
- ***the results and recommendations from systematic objective testing of mathematical functions in software packages used in metrology***
- ***awareness and availability of the expertise and knowledge generated by NMS-supported work to the beneficiary communities***

SPREADSHEETS - QUALITY CALCULATIONS?

Spreadsheets are widely used to analyse data arising in scientific and engineering applications. However, metrologists rarely perform testing and validation on such packages and it is not clear that all mathematical functions in commercially available packages are sufficiently accurate or stable for use in precision measurement applications.

Initially under the Valid Analytical Measurement programme and now under the Software Support for Metrology programme, NPL has tested some of the common functions used by metrologists in a range of popular software packages.

The packages were tested using specially generated reference data sets having known reference results and against well-defined reference software. The results show that serious problems can occur even with relatively simple functions such as the standard deviation and geometric mean - in one package tested the geometric mean of a set of values grouped around 0.5 was given as zero. This serious loss of accuracy is also found in some specialised mathematical products. One cause of the problem is the use of unstable algorithms by the software. High quality algorithms, such as those in the NAG library, built up over many years and developed for mainframe applications, seem to have been abandoned in the move to the PC environment.

NPL is embarking on a campaign to raise awareness of this issue and to provide assistance to both suppliers and users of software. NPL can also supply objective data sets to test a range of software and numerical algorithms. Training, confidential testing and consultancy can be provided.

CRAFT PROGRAMME HELPS SMEs

Surveys suggest that the market for Traded Telecoms Software Components will grow to four billion ECUs over the next ten years. This represents a major opportunity for European Small and Medium Sized Enterprises (SMEs). However, the nature of the business means that global telecoms networks are reluctant to entrust this critical area of their operations to third parties. A defective component could potentially cause a total network failure, so the network customers require testing of individual components to an appropriate standard for the particular application.

In order to allow entry to this market for SMEs and for a thriving components market to be enabled, a cost effective, impartial testing regime needs to be developed that will replace current semi-manual methods. With funding from the EU via a CRAFT project, NPL, in collaboration with a range of SMEs, is producing a test generation tool that will automate the development of test suites. The software uses an existing NPL search algorithm that can determine a sequence of test events to achieve a given test purpose. The algorithm is embedded in a standard test suite environment and will enable SME partners to offer a cost effective test generation service in the telecoms, automotive and associated fields. It is estimated that the new tool should offer an 80% saving over current testing technologies.

In trials the software has demonstrated its ability to generate test paths for large component specifications in a matter of minutes. NPL's experience in this area also confirms that the tests are both appropriate and comprehensive. The tool will be used on a range of real examples chosen by the SMEs.

BIOMETRICS - DO THE EYES HAVE IT?

Many physiological features such as fingerprints, face and iris patterns are unique to the individual. Measurement and comparison of these features can allow systems to recognise individuals automatically. Such biometric technology is being used in applications such as passport control, bank cash machines and building access control. However the performance of such systems in the laboratory may not reflect that obtainable in real life.

To address this problem NPL, together with a group of users and developers of biometric systems in the ESPRIT project BIOTEST, has developed a set of objective performance metrics allowing real-world comparisons to be made. The BIOTEST approach considers accuracy (rate of false rejects and false acceptances), usability (stability and robustness of the user interface) and vulnerability (tampering, mimicry etc.) of the systems and allows devices based on different technologies to be compared.

A testing service for biometrics has been established and independent performance testing and verification of a variety of devices is being conducted. NPL is providing consultancy on biometric testing and could in future provide certification against recognised standards for biometric systems.

VIRTUAL FEATURES

Manufactured components coming off a production line are regularly inspected and compared to design specifications. However, since no manufacturing process is perfect, different choices for the points of measurement for, say, a nominally circular feature, will result in different best-fit circles when the data is analysed by feature-fitting software. As a consequence, different estimates of key parameters (e.g. radius) will be obtained for comparison with the corresponding design parameters and their tolerances. These differences are predominantly due to form errors, the departures of the component from the nominal form.

Recently completed work carried out by NPL, in conjunction with EU partners, has provided a methodology for assessing the influence of form error in industrial components. The basis of the method is the production of a virtual feature or mathematical definition for the curve or surface of the real feature to be measured. The virtual feature can be used to synthesise real measurements according to a range of measurement strategies, deduce the uncertainties associated with different measurement strategies and define the optimal strategy for a given feature.

The use of virtual features provides a practical approach for assessing the influence of form errors in geometric tolerance assessments and allows bias and uncertainties in parameter estimates to be quantified. This approach is now being applied to some of the more challenging calibration problems within NPL.

NPL has developed a methodology for assessing the influence of form error (such as in nominally circular features) in components coming off a production line.

Rosenfeld Images Ltd/Science Photo Library

NPL was contracted to develop a method for measuring the thermal conductivity of rolled metal sheet as a function of applied load.

THERMAL METROLOGY 40

The Thermal Metrology Programme covers the development, maintenance and dissemination of thermal measurement standards, from near absolute zero to over 3 000 °C, to a wide range of industry and business.

The programme provides specifically for:

- ***the maintenance and development of national measurement standards in the field of temperature (the International Temperature Scale ITS-90), thermophysical properties of materials and temperature-related humidity standards***
- ***UK standards that are consistent with those of other countries, particularly in Europe, North America and the Pacific Rim, and appropriate collaborations and intercomparisons to rationalise and harmonise the UK standards with those of trading partners***
- ***the promotion of technology transfer from the programme and the adoption of good measurement practice, to provide technical support and advice to UKAS, their accredited laboratories and industry***

NEW SQUID SENSES CHARGED PARTICLES

At present measurements of current in charged particle beams, such as those used in mass spectrometry, have to be measured invasively. Accurate on-line measurement of ion beam currents would be of great use in verifying quantitative mass spectrometry measurements and provide more accurate process control possibilities in the semiconductor industry.

NPL, in collaboration with Strathclyde University, has produced a High Temperature Superconductor (HTS) Superconducting Quantum Interference Device (SQUID) current comparator which can measure charged particle beams non invasively to an accuracy of better than 0.1%. Measurements are in the range 1nA to 1mA. The ion beam, which can be maintained at ambient temperature, passes through a liquid-nitrogen-cooled superconducting tube. Due to a fundamental property of superconductors (the Meissner effect) a current that is equal but opposite to that of the beam is set up on the outside of the tube. This current distribution is highly insensitive to the position or spatial distribution of the beam within the tube. The external magnetic field set up by the current is measured by a SQUID which indicates the total beam current with very high accuracy.

Further work on the HTS SQUID will attempt to increase the sensitivity of the system - extending the range down to pA (10^{-12}A) and experiments will examine methods to servo the beam current to maintain it constant to better than ±0.1%.

The technique also offers a possibility of direct measurement of the Faraday fundamental constant and from there a possible direct determination of the Avogadro number and

a new method of determining the primary standard for the kilogram in terms of an atomic scale.

HEAT TRANSFER THROUGH METAL SHEETS

In the materials industry rolled metal sheet is often heat treated whilst coiled. In a large coil of sheet metal pressures experienced will vary between the centre of the coil and the sheet on the outside. The thermal conductance of the metal varies with pressure and in order to understand and control heat treatment processes, accurate data on heat transfer parameters is required.

NPL was contracted to develop a specially designed thermal conductivity apparatus which can fit within an Instron servo-electric load-testing machine. This allows thermal conductance data to be obtained whilst the sample is subjected to various pressures. The sample consists of 100 thin metal disks (approximately 0.33 mm thick) and measurements are made at loadings of 1 MPa to 100 MPa and up to 200 °C.

The data generated so far for aluminium is being extended to steel and the effects of various metal surface finishes (polish, oil etc.) and different thicknesses are also being investigated. The results are helping to produce better models of heat flow within metal sheet coils and are improving the efficacy of heat treatment processes.

INTERNATIONAL SPACE STATION REQUIRES NEW TEMPERATURE STANDARDS

Part of the European Space Agency's (ESA) contribution to the International Space Station (ISS) will be the development of a high temperature furnace for micro-gravity experiments in the Materials Science Laboratory (MSL). The furnace will need to be capable of operating at temperatures up to 2 000 °C for extended periods with precise control of temperature gradients.

Improved methods of accurate temperature sensing, directly traceable to national standards and stable over hundreds of hours at elevated temperatures, are vital if the MSL is to provide a controlled processing environment for a range of experiments including crystal growth and alloy processing projects. An NPL-led team has been awarded an ESA contract to investigate various thermometry options. The team is currently assessing available techniques and their applicability for use in the MSL. In particular, non-contact techniques such as single crystal sapphire fibre optic probes and laser absorption pyrometry are being considered.

Following the initial survey a test plan for the sensing cartridge will be developed using conditions that replicate the MSL environment. The results of these tests will be analysed to enable final recommendations on the development of the MSL quenching furnace to be produced.

NPL SHEDS NEW LIGHT ON HEAT TRANSFER STANDARDS FOR THE BUILDING INDUSTRY

NPL plays a major role for the UK in drafting harmonised standards within the EU and has, in recent years, made major contributions to the formulation of new standards for the measurement and calculation of heat transfer through windows and other glazed building products. These standards should encourage the production of units with improved thermal properties and are therefore an important factor in the efforts being made by governments to reduce energy consumption and so in turn reduce the emissions of carbon dioxide and other pollutants.

To achieve improved thermal properties of building components it is necessary to be able to carry out precise measurements and calculations of the thermal performance of new and current designs. Although the procedures for measuring heat transfer through vertically mounted units (e.g. windows and doors) are now well specified in the new standards, the measurement of heat transfer through products in other orientations is not well understood. With the increase in the use of roof-windows, shaped roof-lights and atria, it is important that procedures and standards are developed to facilitate precise measurements of heat transfer properties over the range of orientations found in practice. NPL is therefore designing and constructing a large hot-box apparatus that will allow the thermal performance of building components to be measured in different orientations. The apparatus can accommodate test elements up to 2.4 m x 2.4 m and can hold deep structures as well as flat units. The hot-box employs a proven wall-guarded design which has been used with great success in previous NPL-designed apparatus for measuring vertically mounted specimens.

Data from this new apparatus will be used to aid product design and the development of simulation tools and will also provide information that will contribute to the drafting of the future EU standards, which are essential for manufacturers striving to improve the thermal performance of their products.

TIME AND FREQUENCY MEASUREMENT 42

The Time and Frequency Programme covers the development, maintenance and dissemination of time and frequency measurement standards.

The programme aims to:

- ***maintain the UK national time and frequency standard, UTC(NPL)***
- ***provide ready access to UTC(NPL) in a variety of formats appropriate to the major time and frequency user communities in the UK***
- ***provide information and advice on time and frequency matters to the time and frequency user communities in the UK***
- ***develop improved time and frequency transfer methods for comparing international standards***
- ***develop improved time and frequency transfer methods for the benefit of UK users***

MEASURING TIME – THE LATEST DEVELOPMENTS

The committee that redefined the second in terms of the caesium atom some 32 years ago can be well satisfied with their draftsmanship. The 1967 definition remains robust even though our ability to measure time has improved by several orders of magnitude since then. Looking to the near future, caesium technology holds great promise for further improvements.

The fundamental limit to the accuracy of caesium frequency standards is set by the time the atoms interact with the microwaves used to trigger the atomic transition. The longer the interaction time, the greater the accuracy with which the second can be measured. Conventional caesium standards shoot a beam of atoms through the microwave cavity, but a new technique uses lasers to cool the atoms, slowing them down from speeds of 200 metres per second to just a few centimetres per second. Inside a caesium fountain standard, clouds of cold atoms are repeatedly launched upwards and then fall back down under gravity, passing through the microwave cavity on the way. The method was pioneered by our colleagues at the Laboratoire Primaire du Temps et des Fréquences in France, and NPL is one of a number of leading laboratories developing the technology. Early results from the experimental caesium fountain at NPL were presented at an international conference (EFTF/IFCS) in April 1999. Experience gained with this system is being used in building a second fountain that will be developed to operate as a primary frequency standard.

For the next step forward, caesium fountain technology is to be tested on the International Space Station. ESA's Atomic Clock Ensemble in Space (ACES) project, scheduled for launch around 2002, will make use of the microgravity environment in space to obtain an even more accurate measurement of time. NPL is part of a consortium studying the microwave communications link that will be used to transfer ACES time back to Earth.

CELEBRATING THE MILLENNIUM

The dawn of the year 2000 is clearly a significant event in our lives. For those involved in protecting their infrastructure against Y2K problems, it is a threat and a burden (although an opportunity for others in the field!). For many, it has a positive emotional impact, with the perception of moving into a new era. NPL has a place in both camps. We have invested significant effort in protecting our business against the Y2K problem. We have a very special connection with the Millennium through our role in timekeeping and that connection is being celebrated in a book, and two museum exhibitions.

The Royal Greenwich Observatory was established as the reference for the first global time system in 1884. As a consequence, the term 'Greenwich Mean Time' or 'GMT' is recognised worldwide today. Greenwich will be a natural focus for Millennium celebrations throughout the year 2000 and the National Maritime Museum will open its ten month long 'Story of Time' exhibition there in December 1999. The exhibition will cover all aspects of time and rhythm, with two galleries dedicated to a display of clocks and time-pieces. In addition to seeing Harrison's chronometers elsewhere in the museum, visitors will find the 21st century equivalent - a caesium fountain frequency standard, courtesy of NPL and the DTI.

While Greenwich naturally looks to its own history, the Science Museum more fully explores the move to atomic timekeeping in the 20th century. They hold two items of special interest. One is the caesium clock developed at NPL by Essen and Parry in the mid-1950s, the device that marks the passage from astronomical to atomic timekeeping. The other, for a more contemporary view of atomic time in our everyday lives, is a special interactive Time Exhibit which runs until March 2000.

The story behind the development of atomic clocks and their use today is presented in *Atomic Timekeeping*, a new book by Tony Jones to be published by the Institute of Physics. The book was produced with NPL's support and co-operation.

TIME TRANSFER

The world's time system relies on time transfer as well as atomic clocks. The daily time deviation expected from the most accurate caesium standard today is just 200 picoseconds. Light travels just six centimetres in that time frame, and comparing atomic clocks many hundreds or thousands of kilometres apart is then a non-trivial exercise.

There are two generic time transfer technologies in use today and NPL is actively involved in developing both. One method is known as Two-Way Satellite Time Transfer (TWSTT) where two time laboratories simultaneously transmit time signals to each other via geostationary communications satellites. If configured correctly, the time taken for the signals to travel from one laboratory to the other (a large fraction of a second) can be measured and removed, leaving just the difference in time between the clocks at either end. The method and equipment has been developed and tested by laboratories in Europe and North America over recent years and went into operation in calculating Coordinated Universal Time (UTC) for the first time in July 1999. Additional TWSTT links will be added to UTC on a month by month basis, adding greater robustness to the world time system.

The other generic time transfer method is the common-view of navigation satellites. Here, two time laboratories compare their clocks at the same instant with those on board a navigation satellite. By calculating the delays for radio signals to propagate from the satellite to the clocks, the time difference between the ground-based clocks can be found independently of the time on the satellite. The method relies on good position information to calibrate the delays, as well as knowledge of the atmosphere to account for refraction. Over the last year, NPL has contributed to two international measurement campaigns designed to improve the global time and position infrastructure. The first is a pilot project designed to integrate the time community and the scientific Global Positioning System (GPS) community more fully, recognising that we face similar problems and use the same 'geodetic' GPS technology. The second, was a measurement campaign to provide an improved common time and position data set for the two main global satellite navigation systems - the US GPS and the Russian global orbiting navigation satellite system (GLONASS). The drive for better compatability between satellite navigation systems is expected to continue in the future, as new civilian-operated systems come on stream… and NPL will work with our international partners to develop that global infrastructure and ensure that the UK has a solid reference point in the network.

National Maritime Museum, Greenwich, London

The Royal Greenwich Observatory was established as the reference for the first global time system in 1884. However, since the development of the caesium atomic clock in the 1950s, followed by new standards for the second in the 60s and for global timekeeping in the 70s, NPL has been the focus of timekeeping in the UK. Below, Setnam Shemar (standing) with the new two-way satellite time transfer equipment at NPL which allows two laboratories to compare their time signals simultaneously.

NPL is a knowledge transfer business. Above, TCS Associate, Chris Stevenson, examines innovative windscreen wiper blades at Trico Ltd. Below, Steve Austin shows a group of students at the Tomorrow's World Live exhibition the joint NPL/*New Scientist* Time website.

TECHNOLOGY AND KNOWLEDGE TRANSFER 46

NPL operates at the interface between the science and industrial bases of the United Kingdom. For us, success depends upon forming strong partnerships with academic institutions and industry, making scientific advances practicable and valuable for engineers and industrialists. We are, in short, a knowledge transfer business.

You will see, in reading this Review, that each of our major national programmes includes a significant technology transfer or dissemination project. These are aimed at the particular UK technical and business communities likely to benefit most directly from the programme in question. Such projects include the management of 28 industrial clubs, which bring together organisations sharing common technical interests. These groups have a key role in transferring the results of existing programmes to industry and in helping to direct future programmes. Membership fees are kept to a minimum and there are regular newsletters.

Our commercial work (now accounting for a third of project activity) is also an important vehicle for technology transfer and in recent years we have begun to extend the application of NPL's knowledge transfer skills beyond our own technical areas of expertise. The following case studies illustrate the range of programmes in which we are involved, both within and beyond our national laboratory mission.

FARADAY PARTNERSHIP

The INTErSECT Faraday Partnership is sponsored by 12 of the UK's largest industrial companies and the Engineering and Physical Sciences Research Council (EPSRC). It is jointly managed by NPL and Sira Ltd. The Partnership undertakes research, exploitation and training in sensors, measurement and instrumentation for the process and manufacturing industries.

An NPL team is participating in a major collaborative research project on acoustic emission (AE) through the Faraday Partnership. The AE project is one of the founding INTErSECT Flagship projects. These were selected from a Partnership call for proposals which resulted in over 20 high quality industrial/academic collaborative research project proposals, all of which were closely aligned to the research, operational or commercial needs of the end-user partners. The AE project, fully entitled Acoustic Emission Traceable Sensing and Signature Diagnostics (AESAD), aims to create a sound scientific basis for the use of passive acoustics as a more reliable means of obtaining meaningful information about industrial machines, processes and materials. A key objective is to produce a set of guidelines for industry on AE monitoring for diagnostics and control purposes.

A collaborative group of ten industrial users and manufacturing companies is actively supporting the project: Rolls Royce, NPL, GlaxoWellcome, Unilever, British Steel and five SME manufacturers. The principal investigator is Professor Barry Jones, Brunel University. The NPL team is working on AE traceability, AE signature diagnostics

and AE application to composite material structures. In a relatively large, complex, multi-discipline and multi-location project such as this effective knowledge flows and technology transfer are vital to its success. The full project research team meet regularly in focused technical workshops and steering committee meetings. This helps to ensure that technology transfer and knowledge flows are fully developed, managed and maintained between the academic and industrial collaborators. A search link has been established with the German Fraunhofer Institute for Non-destructive Testing in Dresden and Saarbrucken.

TCD - ACCESS TO KNOWLEDGE

NPL is now into the second year of a five-year contract to manage the Teaching Company Directorate (TCD) on behalf of the DTI. TCD is responsible for the management and delivery of three major knowledge transfer programmes sponsored by the DTI and others: TCS (Teaching Company Scheme); the CBP (College Business Partnership Programme) and the PTP (Postgraduate Training Partnership).

TCS currently supports over 600 partnerships, involving approximately 300 academic departments in at least fifteen subject areas, with sponsorship from eleven different government departments and research councils. Significant additional DTI funding for the scheme was announced in 1999.

A wiper for the 21st Century

Thanks to a TCS programme with the University of Wales, Trico Ltd, the world leader in screen wiping technology, has been developing products for the next generation of vehicles. Trico Ltd, based in Pontypool, South Wales, has worked with the Department of Mechanical Engineering in Swansea to investigate factors affecting wiper performance and used the University's experience in applying Finite Element Analysis (FEA) techniques and process modelling to solve industrial problems. The important elements of blade design from the profile of the rubber blade to the harness construction were analysed and the critical dimensions to be controlled were identified. New wiper profiles are now being developed.

The TCS programme spawned eight undergraduate and two MSc projects looking at issues affecting wiper performance, including blade aerodynamics and FEA modelling of wiper heads and mouldings.

Success on a plate

A double dose of TCS has enabled Dudson Group, a Staffordshire ceramics company, to become a leading innovator in its field.

The 200-year-old company established an in-house design department with the assistance of the School of Engineering and Advanced Technology at Staffordshire University. Computer aided design and computer aided manufacturing technology was introduced for the surface pattern and shape design of products. The company can now undertake projects in house that it would previously have tendered to external designers - saving time and giving Dudson better control over product development. Designs can be supplied in a wide range of formats, allowing sales staff to offer pre-fired samples and rendered images to customers. The development time for new products has been reduced by over half.

The faster response of the company is enabling it to reach and exploit new and lucrative markets. Since establishing the new design department a number of high-profile, high-value contracts have been won.

THE NATIONAL MEASUREMENT PARTNERSHIP

The DTI's National Measurement Partnership Programme (NMP) creates a powerful network, linking, for the first time, the scientific, industrial and governmental organisations which together assure the development and availability of the accurate measurement techniques vital to UK competitiveness. NPL manages this programme for the DTI.

NPL manages a successful regional and sectoral awareness campaign, Competing Precisely. The campaign targets SMEs and is based upon case study presentations by commercial companies who can speak from experience about the benefits of good measurement practice. Under this programme, NPL has developed close working partnerships with regional and sectoral intermediaries such as Business Links, Government Offices, TECs and trade associations to promote innovation, quality and competitiveness in UK industry.

Promotional activities are backed up by an extensive programme of knowledge transfer. All national measurement laboratories are involved and a national measurement

helpline is being established to give direct access to the UK's leading measurement problem solvers. An annual National Measurement Conference provides, for the first time, a national forum to discuss current technical and operational issues in measurement; and a National Vocational Qualification in measurement has been developed and accredited.

New partnership in Newport

Competing Precisely is committed to following through on initial awareness-raising activities to develop regional networks to respond to local measurement needs. Following a successful Competing Precisely seminar held at the University of Wales, Newport, a strong partnership has developed with the university, TECs and the local branch of the Institute of Measurement and Control. At the first event three local companies presented their own personal view of the importance of good measurement. Fifty delegates spanning a wide range of local industries attended and took part in a lively discussion session. The event included an exhibition of local UKAS-accredited laboratories. Over 80% rated the event as useful and requests were received for several *Measurement Good Practice Guides*. A follow-up event in South Wales is being planned. In February 2000 a workshop on the calibration requirements of quality standards will be held, again in Newport. The workshop will focus and build on the two most popular publications created by the NMP: *Meeting the calibration requirements of ISO 9001/2* and *A beginners guide to uncertainty in measurement* and will enable delegates to increase their understanding of the measurement issues of compliance to quality standards.

IT'S PUBLIC KNOWLEDGE

NPL's General Activities Programme (GAP) promotes the public awareness and appreciation of science and technology, particularly metrology. The rationale for the programme reflects the fact that we are a national institution, an organisation which, unlike other businesses, is part of the fabric of the UK's technical infrastructure. We are, in a sense, accountable to the nation and the public must know who we are and what we do.

A light touch at Tomorrow's World

The GAP programme includes projects focused on increasing science and technology awareness among young people. This objective presents two major challenges: reaching enough young people in one place to make activities economically viable; and presenting the science of measurement in a way that captures their imagination.

In 1999, the Tomorrow's World Live exhibition provided the venue and crowds, but NPL had to present a stand which would be both educational and fun. We chose colour and light as topics that young people could relate to. An interactive darkened tunnel was built that enabled people to view different effects of colour and light and there was a balcony area where they could be measured by laser. Interactive displays are best, assuming that you are confident that your exhibit can withstand the attention! At the stand we offered school teachers a poster on measurement and provided information for them to answer a range of questions.

The new NPL building is rapidly taking shape. The photographs illustrate the progress between February and September 1999.

THE NEW NPL BUILDING 50

NPL's major new laboratory facility is currently being constructed on our existing site in Teddington.

The laboratory will provide 36 000 m^2 of state-of-the-art scientific laboratories, engineering workshops, offices, meeting rooms, an information centre and other supporting facilities, arranged in sixteen interlinking modules. Collocation of all services within one building will increase NPL's efficiency, and maintain our position as one of the world's great national standards laboratories.

The scientific areas are flexibly designed to meet NPL's demanding metrology requirements well into the next century. Special attention is being paid to high environmental stability, low vibration and minimising magnetic and electromagnetic fields. This will allow the most advanced standards to be realised, many exploiting effects at the atomic level.

The relocation project (known as 'the Decant') is a major project in its own right. The Decant has already begun and most of it will be completed by mid-2001. The relocation will be in phases as individual modules are completed. The Decant database currently has entries for 2 800 rooms from which the occupants and contents (some of which are unique and highly complex science facilities) are to be relocated.

Customer care is another crucial activity throughout the Decant. It is estimated that 20 000 letters will be sent to measurement service and other customers over the next three years, to keep them in touch with service availability.

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