THE AUSTRALIAN

METROLOGIST

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Vehicle Speed Measurement II

The Australian Synchrotron

Quantification 4

Riverside Reflections

THE AUSTRALIAN METROLOGIST

From the Editor

This issue focuses on the conference to be held in Canberra later this year - *Smart measurements: Metrologists Advancing Industry*. There is also an insert with all the details you may need. If you wish to participate actively in the conference, I'm sure the closing dates are flexible due to late publication of this issue of TAM.

As well as Jeff Tapping's continuing series *Quantification*, we start a new column by Ron Cook - *Riverside Reflections*. Both are entertaining and thought provoking.

A late inclusion is a brief article on the Australian Synchrotron at Clayton, Victoria. Following completion of stage 1 of the project an Open Day was held recently. The facility is expected to become operational in 2007. The cover photo shows the inside of the building (photo: .

It is usual to present MSA conference articles here from time to time. In this issue I have included a paper on vehicle speed measurement from MSA 2004, which raises a number of issues affecting us all when we get behind the wheel.

- Maurie Hooper

Cover: The Australian Synchrotron building at Clayton. (Photo: Delwyn Hewitt, FocalFX Photography).

The Australian Metrologist

The Australian Metrologist is published four times per year by the Metrology Society of Australia Inc., an Association representing the interests of metrologists of all disciplines throughout Australia. Membership is available to all appropriately qualified and experienced individuals. Associate membership is also available.

Contributions

Articles, news, papers and letters, either via e-mail, disk or hard copy, should be sent to:

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The deadline for the next issue is 16th May 2005.

Positions Wanted/Vacant

Need a Position?

Write or e-mail the Editor with your details including years of experience and qualifications. This service is offered free of charge.

Need a Metrologist?

If you have a position vacant, write or e-mail the Editor with the details. A charge of $20 for up to 10 lines applies. (The circulation may be small but it is well targeted.)

The deadline for positions wanted/vacant is as above.

Letters to the Editor

Letters should normally be limited to about 300 words. Writers will be contacted if significant editorial changes are considered necessary.

Editorial Policy

The Editor welcomes all material relevant to the practice of Metrology. Non-original material submitted must identify the source and contact details of the author and publisher. The editor reserves the right to refuse material that may compromise the Metrology Society of Australia. Contributors may be contacted regarding verification of material.

Opinions expressed in *The Australian Metrologist* do not necessarily represent those of the Metrology Society of Australia.

Editor: Maurie Hooper

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MSA Membership Fees

Fellows	$45 Joining Fee $45 Annual Subscription
Members	$40 Joining Fee $40 Annual Subscription
Associates	$35 Joining Fee $35 Annual Subscription

President's Report - March 2005

Teddy bears, photos and measurement.

As a mother of young children it never ceases to amaze me how much life has changed in such of short space of time. Well it seems a short space of time since I was at school. Last year my daughter started school. As one of the activities to help parents understand what school is about they had a "Teddy Bear Mathematics Night". This involved us turning up one evening with teddy in hand to do a whole range of maths activities. The idea is to expose the parents to modern teaching methods so they can help the kids at home. My expectation was that we would be doing a few counting exercises, number recognition and that sort of thing - they are only Preps when all is said and done.

In fact we were in for a heavy night of metrology! Yes, I said metrology. We spent the evening, weighing our teddies, working out how many little plastic teddies weighed the same as our favorite bears. Estimating how far across the hall a line of teddies back to back would reach. Finding out how long teddy was in units of matchsticks, icy-pole sticks and beans.

Another more recent experience in metrology was my first move into digital photography. I lashed out and bought myself a new digital SLR camera, my pride and joy. I spent the first week taking photos of anything and everything that moved or didn't, much to my family and friends' annoyance. With great expectation I transferred the photos to the computer. At this stage disappointment set in. The photos were all incredibly dark and some were almost impossible to view.

I grumbled about this to a friend who works in the photography industry. He said "Oh that's easy fixed, you need your screen calibrated. But you would know about that anyway, being in the MSA!" With some chagrin I said "Yes of course". Last week he kindly turned up with an intriguing little device that you hang on the screen and it calibrates you screen for true RGB or CYM. Aside from the fact that now my photos all look stunningly better, it made me realize how much we take metrology for granted.

I know I sometimes assume it stops at the laboratory door, but the above show it goes a lot further than that. In a modern society such as ours it impinges on every aspect of our lives. When we buy our fruit and veg, petrol, watch TV and play sports. The point is we also tend to take it for granted.

Having been a NATA technical assessor for a number of years now I have noticed that when I do audits, it is more often than not the simplest and most straight forward of tests that trip laboratories up. They are concentrating on the difficult and unusual and forget that those simple tests actually need effort. It may be because the other tests are more interesting but I think it is more likely they are taking the metrology for granted.

It is the role of the metrologist to make sure, that in every measurement they take, the impact of environment and method is taken into account and that the results are sensible. But it is also the role of the metrologist to make sure that those outside the field understand this as well. Metrology faces a threat if everyone learns the basics of measurement, an outcome I encourage; but they may also become complacent and assume it is easy to do!

I also don't want us to take for granted what has happened in the metrology community in the past few months; the official launch of the National Measurement Institute. This is major recognition by Government that measurement is fundamental to our modern society. But it is only the first step in a long journey. The education system also seems to have also recognized the importance of measurement. We need to be vigilant to ensure that at both policy and practical levels we are not taking measurement for granted.

We have an opportunity later in the year to have the voice of metrology heard at the highest levels of Government and industry. The conference this year is to be held in the national capital, Canberra. We need to send the message to the policy makers and industry in general that the growth of Australia's industry; manufacturing, exports, tertiary and high technology industry are dependent on metrology. Make your contribution, big or small. Submit a paper, participate in the workshops and enjoy the experience.

- Dr Jane Warne

Contents

MSA 2005

Smart Measurements: Metrologists Advancing Industry

The Metrology Society of Australia's 6th Biennial Conference

19th to 21st October 2005, Australian National University, Canberra, ACT

The Metrology Society of Australia will stage its 6th Biennial Conference in the Australian Capital. The Conference will focus on issues such as measurement techniques, education, practical application of measurement, showcasing metrology's relevance to industry and Government. With trade displays, seminars and workshops the Conference will provide a good opportunity for interaction between metrologists, industry leaders and Government. The Conference will commence with an evening cocktail party on Wednesday 19th October 2005. October 20th and 21st will be packed with an exciting and innovative program aimed to stimulate discussion and interaction on issues related to the role of metrology in assisting Australian industry to be world class.

SCOPE OF THE CONFERENCE

The conference will welcome contributions from all areas of metrology. The topics include but are not limited to:

- *Metrology in industry*
- *Metrology and globalisation*
- *Education and training*
- *Chemical metrology*
- *Dimensional metrology*
- *Measurement of Heat and Temperature*
- *Optics and Radiometry*
- *Electrical metrology*
- *Pattern approval*
- *Trade measurement*
- *Metrology in medicine*
- *Environmental metrology*
- *Measurement uncertainty*

SUMBMISSION GUIDELINES

Authors are required to submit a short abstract (maximum half a page) before **31 March 2005**. The abstract should clearly describe the work and also indicate the preferred from of presentation (oral paper, poster paper or workshop). Submissions will be reviewed on the basis of their relevance to the theme and aims of the conference and to the development of metrology skills. Successful applicants will be notified, by **15 April 2005**, at which time they will receive guidelines on the preparation of the full papers to be published in the conference proceedings. Full papers are due **1 July 2005**.

VENUES

The conference venue will be Australian National University (ANU). Accommodation will be available at ANU and a block of rooms have been reserved at $106 to $129 per room including breakfast. The conference dinner will take place on Thursday 20 October in the new section of the Australian War Memorial under "G for George", the famous WW II bomber.

CONFERENCE FEES

Registration	**Before 15 Aug**	**After 15 Aug**
MSA Members/Speakers	$270	$300
Non-Members	$370	$400
Full Time Students	$100	$130
Day Pass	$150	$180
Conference Dinner	$80	$80

The fees include welcome cocktail party, morning and afternoon teas, lunches and conference proceedings.

ABSTRACT SUBMISSION AND ADDITIONAL INFORMATION

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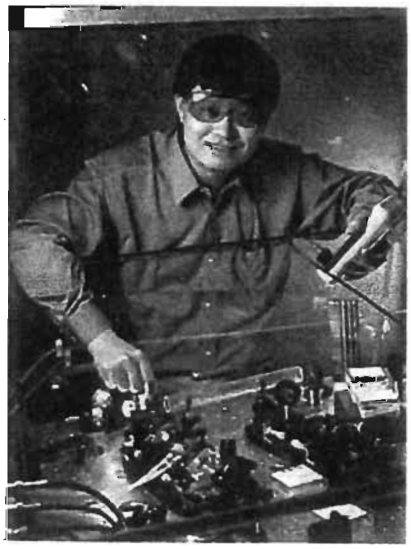
Up to date information appears on the MSA website at http://www.metrology.asn.au/.

Metrology Society of Australia

New NIST Instrument for Gas Chemistry

In recent years there has been interest in measuring low concentrations of various gases in the atmosphere associated with industrial activity. Also there have been difficulties in measuring low NO levels in dwellings using gas appliances. Existing instruments suffer from insufficient sensitivity, resulting in measurements being made right at the bottom end of the operating region and the lack of good traceable reference standards for calibration at low concentrations. Now the first problem has been overcome by NIST physicist Jun Lee. The following text comes from a NIST press release.

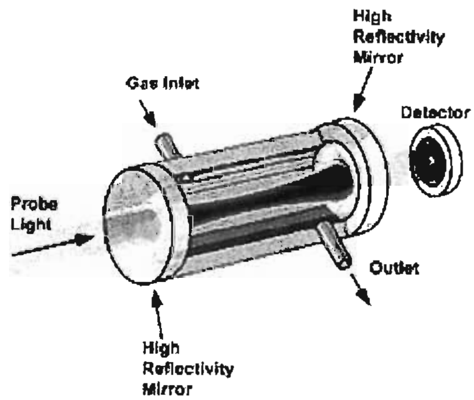
A laser-based method for identifying a single atom or molecule hidden among 10 trillion others soon may find its way from the laboratory to the real world.



NIST physicist Jun Ye in his laboratory.

Developed by physicists at the National Institute of Standards and Technology (NIST), the technique is believed to be more than 1,000 times more sensitive than conventional methods. Vescent Photonics of Denver, Colo., hopes to commercialize the method as an "optical nose" for atmospheric monitoring. The portable sensors would rapidly identify chemicals in a gas sample based on the frequencies of light they absorb. Other applications eventually may include detection of chemical weapons and land mines, patient breath analysis for medical diagnosis or monitoring, and industrial detection of leaks in subterranean pipes or storage tanks, the company says.

Vescent recently signed a Cooperative Research and Development Agreement with NIST. The company will work with NIST physicist Jun Ye (co-developer of the technology) to apply the public domain "optical nose" technique to detecting and quantifying trace quantities of atmospheric gases. Ye works at JILA, a joint institute of NIST and the University of Colorado at Boulder.



Schematic drawing of the optical nose components.

The technique is a product of years of work and several innovations by NIST scientists. A gas sample is placed in an optical cavity containing two highly reflective mirrors. An infrared laser beam is directed into the cavity, where the light bounces back and forth many times. The repeated reflections increase the path length on which laser light will interact with gas molecules in the sample. In addition, the laser frequency is quickly and systematically varied in a way that enables scientists to observe and subtract background noise from the signal.

The approach allows analysis of gases that are present in minute concentrations and at very low pressures, which may enable identification of compounds such as explosives that are difficult to detect by other means.

■

An Invitation from your National Committee

The National Committee is well aware that the MSA requires a better way for members to communicate, interact and learn. We are spread out across Australia and beyond and often in quite remote locations where the opportunity to share ideas or to discuss problems with other professional and practicing metrologists are not always convenient.

The National Committee is also glaringly aware that skills shortages and training of metrologists has become a serious problem and a very important issue for Government at both State and Federal levels. The focus of this years MSA Conference is "Smart Measurements: Metrologists Advancing Industry" and is to be held in Canberra in October to highlight the skills shortage issues and its impact on industry.

As a method to address both these issues the MSA is keen to use its web presence. But a web presence on its own is not enough. We also need useful and valuable material on our web site and we need people interested enough to visit regularly and to contribute. The National Committee has the resources, the capability and a very strong desire to upgrade our web site but is very much lacking the resources to maintain our web site in the longer term. This maintenance issue must be addressed up front or our efforts may be in vain. This is where you, the members come in.

At present the MSA has a few somewhat active special interest groups who meet at every opportunity, exchange ideas, lobby industry and government and generally make a contribution to further there own special interest and make life easier and more interesting for themselves. These are the CMM users group and the Pressure group.

The committee will be preparing MSA member only sections of the web site for use by these groups which will include the opportunity for MSA members to participate in a moderated question and answer forum. This type of forum can provide a vital communication link which can be used to stay in touch with other like minded metrologists and as a useful ad hoc training ground.

At present the committee has identified seven user groups which we feel represent a significant number of our membership. We are seeking suggestions for other groups and we are looking for a moderator for each group. A moderator will be required to filter e-mail to assure only valid and relevant questions and answers are posted (filter out the spam and rubbish) and to provide occasional new material for the user group page. A moderator does not require any proficiency in web page writing or html and we have a web master who posts all material on the web site.

Our seven proposed user groups are:

CMM: for dimensional measurement and related metrologists.

Pressure: for all pressure measurement issue.

Electrical: for all electrical and data acquisition issue.

Uncertainty: the cross discipline issue we all have.

Training & Education: to bring together resources and issues.

States: each state can have a presence.

Commercial Links: we will provide links to commercial organisations.

The MSA is what the members make it. The National Committee can come up with ideas and implement new strategies. But it is the members who will truly make it happen. If you would like to propose other user groups or to act as a moderator in one of the groups we have listed above, contact Neville.owen@measurement.gov.au or any committee member noted in this TAM. We'd be delighted to hear from you.

- *Neville Owen* ■

The Australian Synchrotron

Stefanie Pearce

Australian Synchrotron Project,

Government of Victoria

Australia's Brightest New Source of X-rays: the Australian Synchrotron

To compete in the global innovation economy, Australia needs world class science infrastructure, and the $206 million Australian Synchrotron, under construction in Melbourne, will be an essential tool for new science and industrial innovation throughout the nation.

The design of the Australian Synchrotron ensures it will be a state-of-the-art machine with an energy of 3 GeV (giga electron volts) and a capacity to provide intense beams of light across a wide range of wavelengths in the electromagnetic radiation spectrum, by delivering photons from the infrared region (0.001 eV) to the hard x-ray region (120,000 eV). The Victorian State Government is funding the construction of the synchrotron machine as the light source required to generate the photons, and the building that will house the machine and associated laboratories, at a cost of $157.2 million. Funding for the beamlines that form the experimental drivers of the facility is being sourced from research organisations and other governments. To date $25 million has been committed towards an initial suite of 9 beamlines by CSIRO, the Australian Nuclear Science and Technology Organisation (ANSTO), Monash and Melbourne Universities, and a consortium of New Zealand Government and universities.

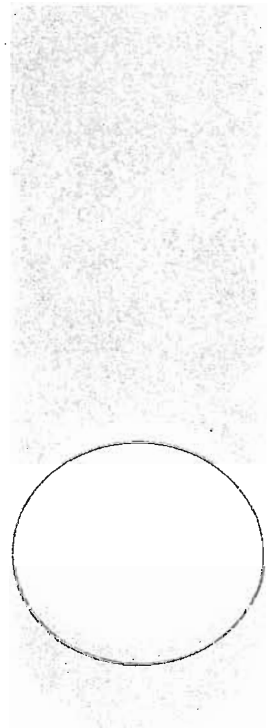
At full capacity, the Australian Synchrotron will be able to accommodate more than 30 beamlines, operating simultaneously and engaging hundreds of medical researchers, engineers and technologists in the pursuit of scientific discovery and understanding across a broad range of disciplines.

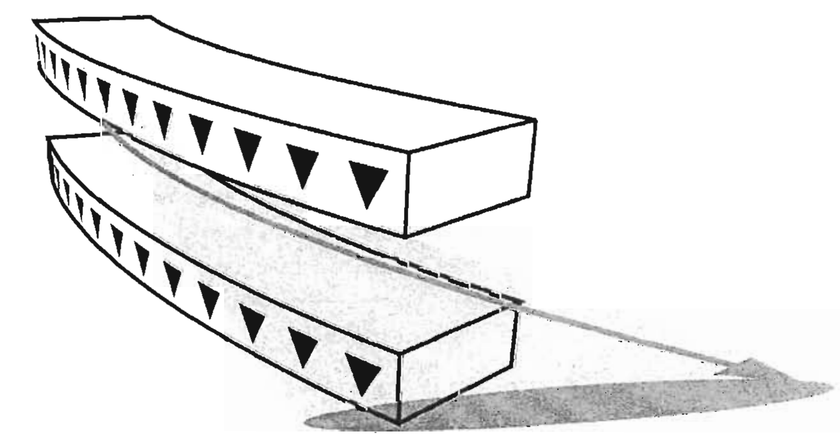
The nine top priority beamlines comprise four beamlines for crystallography, x-ray diffraction and scattering, four beamlines for spectroscopy and one beamline for x-ray imaging.

Synchrotron light (electromagnetic radiation) is emitted when charged particles (electrons in the Australian Synchrotron design), moving at velocities close to the speed of light, are forced to change direction under the action of a magnetic field. The synchrotron light is emitted in a narrow cone in the forward direction, at a tangent to the 'circular' orbit of the electrons, and has a number of unique properties. These include high brightness, hundreds of thousands of times more intense than that from conventional x-ray sources and a million times 'brighter' than the sun, highly collimated (i.e. non-divergent, like a laser-beam), across a wide energy spectrum from deep infrared to x-rays, tunability to any selected wavelength, highly polarised, and pulsed, typically in less than nano-second pulses.

To carry out experiments, the cone of light originating from the synchrotron ring travels out of the ring at a tangent and down a vacuum tube called a beamline. The appropriate light wavelength is selected from the spectrum and then directed to an experimental end-station.

X-ray diffraction is the most widely used approach for 'imaging' substances at atomic resolution and elucidating their structures. The ability of the synchrotron to produce intense, highly collimated x-rays and to focus them with x-ray optics to a very small spot size enables diffraction to be performed on small single crystals of materials where previously this has been impossible. With its high intensity and



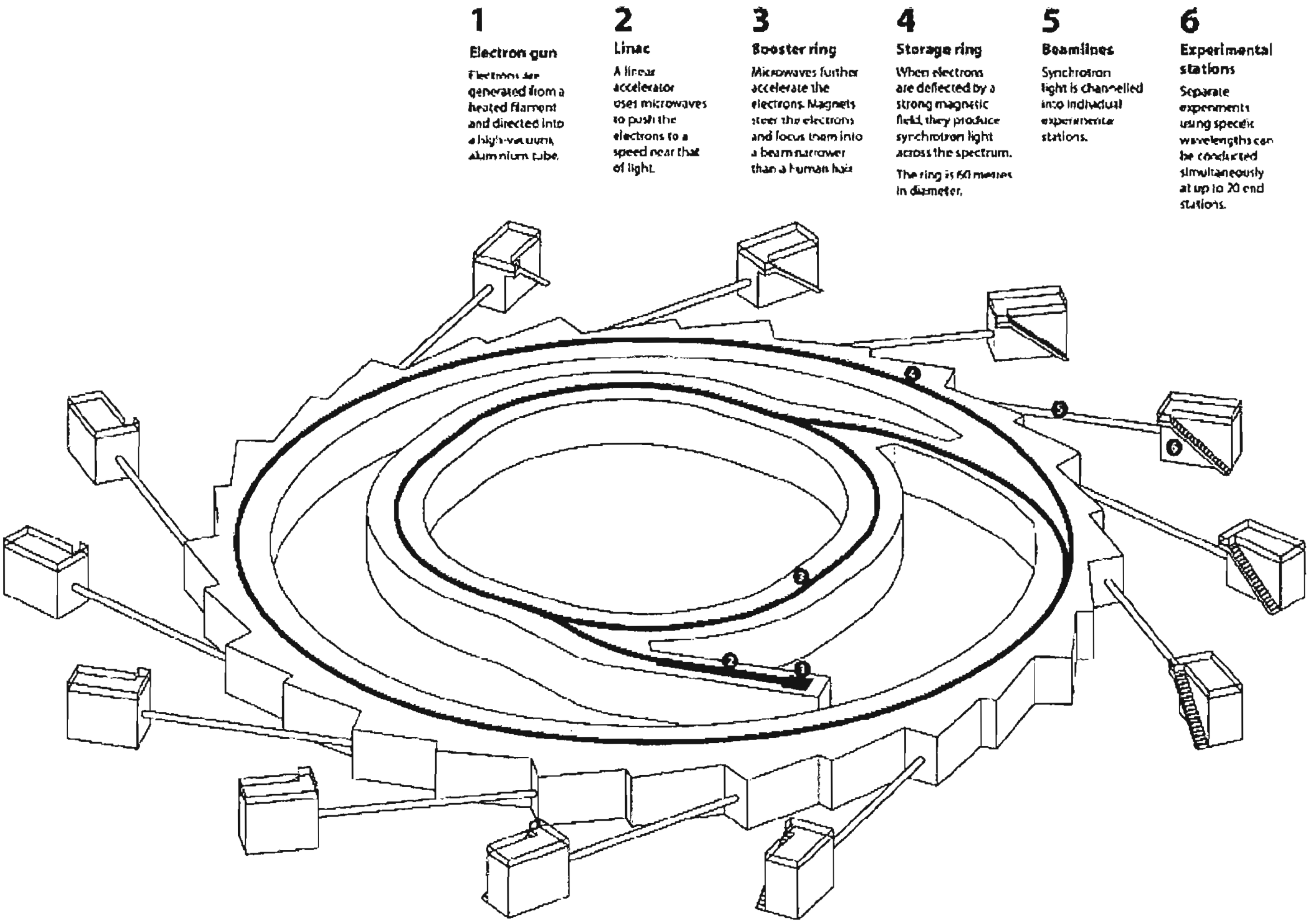


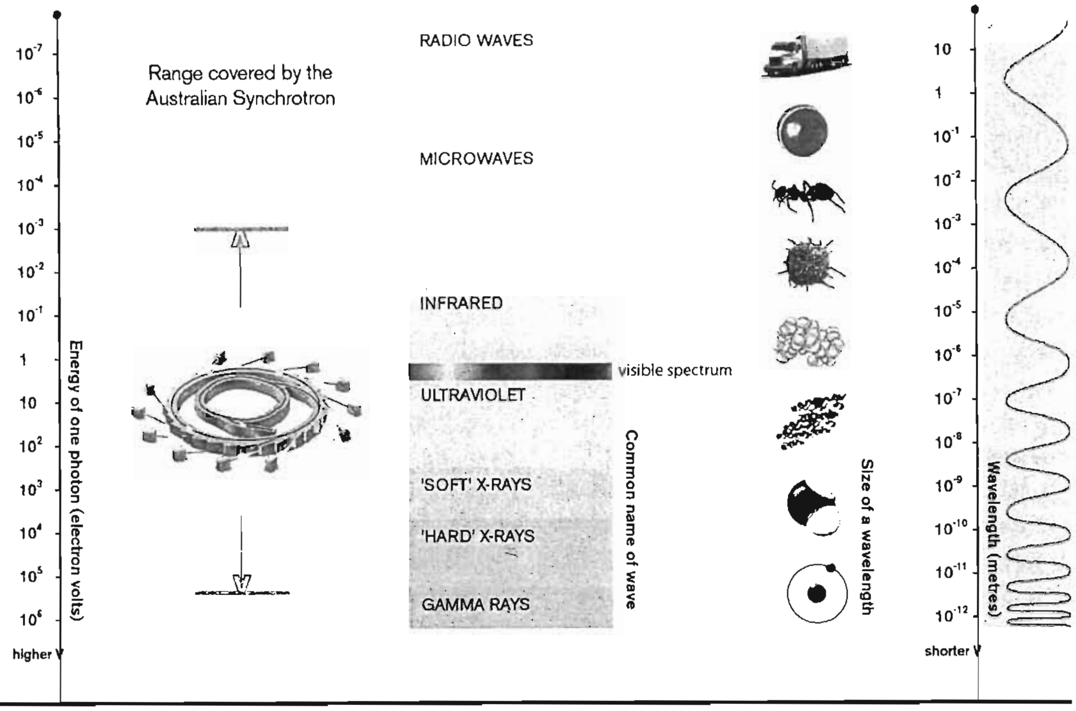
BENDING MAGNET Sweeping Searchlight

highly collimated incident beam, synchrotron light can be of great assistance in resolving overlaps of powder diffraction rings; it also improves the signal-to-background-noise level and can increase the range of observations. Thus diffraction data obtained from synchrotron-based instruments provide much greater accuracy and resolution compared with conventional instruments.

Another important aspect of synchrotron light is its tunability. A particular wavelength of the light beam can be selected to maximise the visibility of certain elements in the sample. A synchrotron technique known as multiple wavelength anomalous dispersion is particularly useful for protein crystallography, because it enables measurement of the diffraction patterns created at a number of wavelengths close to the sample's x-ray absorption edge.

X-ray absorption spectroscopy (XAS) is a well-established, quantitative analytical technique to obtain atomic-scale structural and chemical state information for a wide range of systems in both liquid and solid form. XAS probes both the short- and medium-range order of a sample and as such is complementary to x-ray diffraction. An XAS experiment is the measurement of the absorption coefficient of a sample as a function of incident photon energy. Samples that may contain many elements would usually need to be carefully examined for multiple absorption edges and thus XAS measurements are not practical on a laboratory-based system. XAS measurements need an intense, tunable source of photons afforded only by a synchrotron. The Australian XAS user base comprises the largest proportion of the Australian synchrotron science community. Because of the current usage and demand, the Australian Synchrotron will have a dedicated high-energy XAS beamline, set up to be user-friendly for novices and seasoned practitioners, with measurement capability at temperatures from ~10 to 1273 K (e.g. from cryostat to furnace).



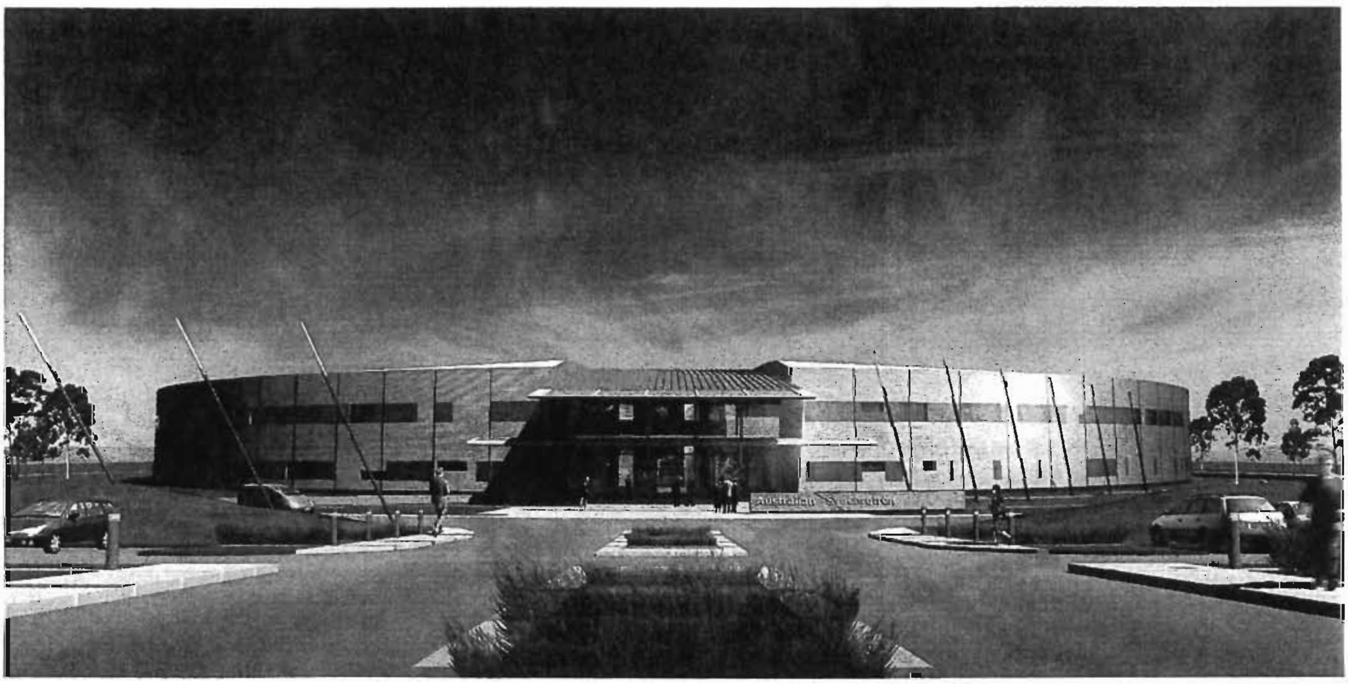


EMR The Electromagnetic Spectrum

Synchrotron research covers a broad range of disciplines, including biological and biochemical sciences, and particularly 3-D structural studies of proteins for modern pharmaceutical development (protein crystallography); chemical sciences, such as the study of catalysts, metals and alloys; earth sciences, where the synchrotron will give Australian scientists an edge in research into mineral ore deposits and processing; environmental sciences with many applications for research on pollutants in soil, air, freshwater and marine environments; the development of new materials including semiconductor devices and the novel properties exhibited by materials at the nanometre scale.

Independent economic analysis has indicated that the Australian Synchrotron will result in economic benefits of $65 million per year and 2,500 direct and indirect jobs once fully operational. However, in the words of eminent Australian scientist Sir Gustav Nossal: "The uses of synchrotron science are limited only by our imagination".

For more details see www.synchrotron.vic.gov.au or phone free call 1800 797 818.



Quantification - Number 4

Jeffrey Tapping

First let's look at the list of words in the last edition. The first four are again words in ordinary English language usage.

Are is one which you will kick yourself over if you did not get it. It an SI unit of area, and ten of them make a *hectare*. The word itself has the same root as "area". Now all you smarties, what is the width of a square that has an area of one *are*? You have ten seconds to answer.

Quarter is an imperial unit, equal to quarter of a ton, five hundredweight (see below), forty stone, or 560 pounds. Have you fixed all that in your memory? I had to when I was in primary school, so why shouldn't you suffer as well? And another question for you smarties: why is correct to write "forty stone", not "forty stones"?

Scruple is a unit of weight in the Apothecaries' measurement system. It is equal to one twenty-fourth of a troy ounce, about 1.3 grams. The common word refers to moral or ethical restraint and hesitation. Both uses have their root in the Latin *scrupulus* meaning a small sharp stone. One source suggests that the common meaning derives from the advisability to be scrupulous about where you tread to avoid getting stones in your sandals, but I rather like an explanation based on the prick of conscience. It seems clear that any explanation is speculation, so you can choose the one you like best.

Fathom is a unit that you should have been able to fathom out easily. It is a distance, equal to six feet, most commonly used in recent history for depths of water. The origin of the term is as the distance between two out-stretched hands, and indeed one old meaning of the word given in the Oxford dictionary is to encircle something with arms. The use of the word for "comprehend" may originate from the same concept as "grasping an idea", or possibly "getting to the bottom of something".

Quintal is a unit of weight with a complicated history and many values. Its main root seems to be for an amount of 100 pounds in ancient Rome, deriving from the Latin *centenarius.* From there the term was taken up in various regions of Europe previously under Roman influence, and also became the Arabic unit, the *qintar*. It probably also resulted in the unit the *cental* mentioned in the last issue.

After the Roman empire faded, measurement units of all kinds became controlled locally and their values drifted and changed with time. The pound was one of these units, and so although the quintal was 100 pounds in most places the actual weight was quite varied. An exception was Britain (and consequently most of its colonies), where it was equated to the *hundredweight*, which was 112 pounds, probably because this was equal to one twentieth of an imperial ton. Here is a quick run-down on some of the amounts that the quintal became.

U.K. and its colonies: 1 hundredweight, 112 pounds, 50.80 kg

U.S.A. 1 hundredweight, 100 pounds, 45.36 kg

Spain and Mexico 100 Castilian pounds (libras), 45.99 kg

Argentina 100 Argentinian pounds (libras), 45.94 kg

Portugal 128 Portugese pounds (libras or arratels), 58.75 kg

Metric system 100 kg exactly.

When I did a search on my Encyclopedia Brittanica program of the word quintal, I was puzzled to find it threw up Joan of Arc! On careful reading I found that Claire Quintal had co-authored a biography of the saint. So I got a bit of additional history instruction along the way. I learned that Joan of Arc was burned at the stake for heresy in 1431 by the English, when captured following her victory over the invading English army. She then became a French heroine but was surprisingly not canonised until 1920. So the French obviously had a longstanding burning resentment against the English (pardon the pun), which could have influenced negotiations on things measuremental. So maybe there is a tiny thread of relevance there if you use your imagination.

Duplicity

I have come up with some more units representing different quantities. While 1 gal means one gallon, 1 Gal indicates one galileo. And of course you all know that 1 Gal is an acceleration of 1 cm per second per second (0.01 m s^{-2}). The Gal, or more correctly the milligal (symbol mGal), is used in geophysics when mapping the variation in gravitational acceleration over a region to get clues about sub-surface structure. Then there is the pound, which has been used as a unit of currency in many countries, as well as being used for weight.

Which leads to another question. We old folks recall that the symbols used for the pre-decimal currency of pounds, shillings and pence were £, s, d, also known as "L, S, D" (long before the advent of LSD, another substance that causes mental aberrations in people). So where did these symbols come from? The name *pound* comes from the fact that it was originally a weight of silver coins. The coins were called "sterlings", and hence "pounds sterling". The word "sterling", I find, is a corruption of "starling", used originally to apply to a silver coin which had a small star embossed on it. The symbol for the pound, a capital L (in script format), with a stroke across it, probably comes from the Roman word for weight, libra, which is also the source of the symbol "lb" for pounds weight. The "d" for pence seems to have come from the Roman coin, the denarius. The "s" for shilling is a bit more murky, and may have come from the initial of the word, or that of "shield", a name that was applied to early shilling coins which had a shield embossed on them.

Free Bonus Paragraph

Here is a little bit of interesting information I stumbled across, which I will pose in the form of a question, then give the answer. Now most of us know that at the beginning of the twentieth century there was a battle between proponents of a.c. and d.c. electricity supply. And of course a.c. won the battle for a number of good, practical reasons. So in what year was the last direct current mains supply terminated in Sydney? Would you believe 1985, a full 81 years after the first d.c. supply was switched on to drive the city's street lights. This question (and also the answer), was found in Mrs. Tapping's cook book, on the back of a recipe for fruit cake in a brochure from the Sydney County Council, the electricity supply authority at the time.

I recall reading a story about the a.c. - d.c. battle, that claimed that Thomas Edison, a proponent of d.c., effectively invented the electric chair by electrocuting animals to show the dangers of a.c. Edison may have regarded this as one of his failures, because he was actually an opponent of capital punishment!

And now some questions to ponder before the next issue.

What do these units represent?

thermie
frigorie
cubit
pieze
poiseuille

And,

What is the relationship between a Degree Rankine and a Degree Sikes?

What is the difference between "density" and "densité"?

What is the difference between a standard atmosphere and a technical atmosphere?

Why is the U.S. gallon different from the Imperial gallon?

Finally, this issue's trick question. What is the origin of the unit, the *foot*?

■

Riverbank Reflections

Ron Cook

G'day. When one retires it's time to go fishing, right? Well, fishing is as much about getting to some picturesque and relatively deserted spot and spending some time relaxing and ruminating as it is about catching fish. Catching fish can be incidental, indeed with our vanishing fish stocks it is becoming less likely that one can come home with a feed. So, as I sit and gaze out on the river, the stillness of my rod is not relevant. Stationary ripple patterns form naturally from the flow of water and interaction with protruding twigs and reeds. A pattern develops about the point where my line enters the water. The envelope shape tends to be triangular; certainly it's not that of a Normal distribution.

This leads me to recall that not everything in nature that has some randomness involved is Normally distributed and that many of our measurement processes have random errors with definite but non-normal distributions. That's not a problem if they have symmetry but there isn't, at present, any "sanctioned and blessed" way of dealing with the non-symmetrical ones when doing measurement uncertainty estimates. The ISO Guide to the Expression of Uncertainty in Measurement (GUM) says that recognized statistical methods may be used but gives no clear guidelines beyond that. That leaves those of us who have only a smattering of statistical knowledge with no idea of what to do. Some of us make conservative estimates and assume some symmetry in order to get an answer. This isn't statistically correct and fortunately help is at hand. The ISO has a proposal to issue a supplement (Number 2) to the GUM describing the application of the Monte Carlo Method to measurement uncertainty analysis.

This method has the wondrous quality of allowing the use of asymmetric distributions as well as the usual symmetric Normal, rectangular and U distributions. Monte Carlo analysis draws its name from the city with the casino, and involves numerous trials or dice throws. The draft version of the GUM Supplement Number 2 (GUM S2?) recommends one million trials and the use of some good but not cheap mathematical software such as MATHCAD. How does it work?

Each and every term in the measurement model has its value varied randomly by an amount and manner dependent on its associated uncertainty distribution. For each value the measurand is calculated. The result is a set of one million measurand values that can be analyzed to give the mean and the range encompassing 95% of the values. The latter of course represents the expanded uncertainty.

Provided the model is correct and each component with uncertainty can have the distribution characterized the result is very reliable. The advantages of this seemingly ponderous method are that it deals with correlation, high order terms, and non-symmetric distributions. A past colleague, Robert Rigby, was a proponent of the program @RISK to do this sort of analysis many years ago. At that stage I had not had any experience with asymmetric uncertainties and thought the standard formulas were sufficient and faster to use than @RISK. Now I understand that there are circumstances where the Monte Carlo approach is the better way.

Why a million trials? Testing has shown that while a lesser number can give excellent results, to ensure that the results are reliable for all distributions a million trials is an appropriate number.

Instruments that have a digital display and truncate the reading prior to displaying it are an obvious example where an asymmetric uncertainty applies. The reading can be anywhere between the indicated reading and plus 1 digit. Say the instrument is a speed measuring instrument and it is indicating 100 km/hr. The resolution uncertainty has a range of -0, +1 km/hr. The GUM suggests that for digital instruments the resolution is symmetric, and so it is, most of the time. However, in this case the uncertainty component has bounds of 100 to 101 km/hr and not 99 to 101 km/hr nor 99.5 to 100.5 km/hr. For speed enforcement the rounding down is done partly because it gives the "client "a little leeway and partly because it simplifies the computations in the instrument.

Fishing for trout involves a process of casting about likely spots, a sort of Monte Carlo approach. But it requires continuing action on the angler's part. That's why I stick to bait fishing.

Oh Damn! The end of my rod is thrashing about. Talk to you again later.

- Ron Cook ©2005

VEHICLE SPEED MEASUREMENT II

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Abstract

This paper discusses uncertainties and errors in vehicle speed measurement and the legal implications of these. It provides a proven method of measuring vehicle speed over its working range, without the use of extrapolation, which is conducted in a controlled environment rather than on public roads.

Keywords: speed, speedometers

Introduction

Both federal and state legislation set standards for the accuracy of speedometers installed in motor vehicles. Unless these legislative provisions are compatible, and prosecution policies recognise the accuracy achievable by speedometers installed in vehicles, there is danger that motorists could offend unwittingly. This paper will discuss the interaction of the federal design standard, individual state prosecution policies and the performance of speedometers and associated testing equipment.

The Australian Motor Vehicle Standards Act, (known as the Australian Design Rules, or ADR [1]) sets requirements for speedometers installed in vehicles to be used on the road throughout Australia as:

"indicate the actual speed, for all speeds above 40 km/h, to an accuracy of ± 10 percent."

State Legislatures have also set their own minimum requirement. For example New South Wales Traffic Law [2] requires that speedometers:

"indicate, when the vehicle is travelling at a speed in excess of 50 km/h, a speed that is not more than 10% less than actual speed".

The individual State requirements are all worded differently and may impose different constraints on the performance of speedometers. However none change the *"10% less"* requirement, which is a main contributing factor to the system failure. This accuracy guide method has severe limitations and is only used by persons with a lack of understanding of measurement.

Uncertainties are an integral part of regulations administered by the National Standards Commission, such as those concerning the weighing of products in commerce. Since there is a trend to base the level of fines on exactly how much the speed limit is exceeded, the policy should recognise the effect of uncertainty of measurement and fall into line with other measurements with financial implications. The ADR [1] should take account of the requirements of the ISO Guide to the Expression of Uncertainty in Measurement [3]. This reference to uncertainty is an integral part of weight measurement and is found in Australia's adoption of "Organisation Internationale De Métrologie Légale Recommendation R111" [4].

There is a system that would enable drivers to reliably determine if they are travelling within the posted speeds limits. This paper will endeavour to prove the accuracy and safety aspects of a test system that once used, will enable the public to travel within the posted speed and furthermore be <u>expected</u> to do so.

Monash University Research Notes

The Monash University Accident Research Centre published research notes with the heading "Accuracy of vehicle speedometer readings with respect to speed enforcement tolerances" [5]. Table 1 gives a compilation of statistics summarised in the notes.

The University used some collated results from other sources and whilst the test methodology was not described these results indicate either a failure by manufacturers to meet the minimum requirement of the relevant ADR [1], or that other mechanical factors are affecting the results.

Actual speed relationship to indicated speed in km/h					
Actual	40	60	80	100	120
Max indicated	43	64	83	108	130
Min indicated	27	48	71	84	105

Table 1: Summary of results of speedometer tests carried out by Monash University Accident Research Centre and others between 1982 and 2001.

Speed indication errors and variations

Speedometers in vehicles respond to the rotational velocity of the wheels. Errors and variations in vehicle speed indication will then be due to either the relationship between a rotation of the wheels and the actual distance travelled, or to the errors in measuring rotational velocity. The nature of the tyres contribute the first type, and instrument errors the second.

Rolling road testing

The speed indication in a vehicle is tested by either measuring the time to travel a known distance (measured by numerous methods), or on an apparatus consisting of rollers with known circumference and measurable rotational velocity (a "rolling road"). Some instrument repair companies merely "check" the odometer over a distance and conclude the speedometer accuracy from this data. Some have recently used GPS units. The latter options require conducting tests on public roads.

Testing of speedometers should ideally be conducted throughout the usable range as this eliminates the need for extrapolation. There are obvious safety implications if speedometers installed in vehicles are tested throughout their range on public roads. However using a rolling road for such measurements reduces the safety issues and the latest computerised rolling road machines provide a printout of the parameters tested.

Another machine that utilises rollers is the dynamometer and these can be used to test speedometers. Most rolling road testers are primarily a dynamometer. Its main function is to introduce resistance to wheel rotation by absorbing test vehicle energy into a load, and measuring the force developed by the drive wheels. Care should be taken when using a dynamometer that slippage is not induced by the machine's resistance. Some operators use the loading to minimise hunting (the failure to maintain a constant speed due to engine behaviour). Load generation should be minimised as should tie-down pressures. It is normal practice to chain or strap the vehicle under heavy loading conditions for measuring engine torque to avoid the vehicle climbing up and out of the roller valley. In these tests, lateral restraining of the vehicle was used instead of tie down, since vertical restraining caused tyre distortion, which can lead to an error in the region of 2 km/h. It would be difficult to balance normal tyre load distortion, aerodynamic and centrifugal force to a corresponding offset for the rollers, because the forces are not linear and combined to create a complex response curve. At best only a "best fit" correction can be given.

Except where indicated otherwise, the tests described in this paper were carried out on a free-running rolling road, that is, without applying a load to the wheel rotation. This machine held a current NATA accredited certificate of accuracy. The measurements described in this paper are traceable to an Australian National Standard and have adhered to the requirements of ISO 17025 [7].

Tyre contributions

Errors due to tyres may be long-term (e.g. tyre type and size), medium-term (e.g. tread wear), or short-term (e.g. pressure and loading). The author undertook measurements of both true and indicated vehicle speed with varying tyre brands, wear and tyre fill pressures.

Inflation pressure:

Increase in pressure will occur as the tyre increases with heating due to use. This pressure increase is as much as 28 kPa (4 psi). An increase in tyre temperature will increase pressure and cause the indicated speed to be lower. The tyre inflation pressures referred to in the following tests were hot pressures and should not be confused with cold pressures settings recommended by manufacturers. Tyre pressures were adjusted after the tyre had reached operating temperature.

To examine how pressure affects the tyres, they were initially inflated to 160 kPa. The first run at this pressure was followed by tests in increments of 30 kPa to a maximum tyre pressure of 280 kPa. One of the tests was conducted with a standard tyre pressure of 190 kPa and the equivalent weight of four adult males in the car, all the other tests in this series were with one adult male only. The deviations from true speed occurring at indicated speeds of 30, 60, 80 and 120 km/h were recorded. Three readings were made at each speed and pressure, and mean of the readings were calculated. Results of these tests are given in Table 2.

Speedometer error versus tyre pressure						
speed ⇓	280 kPa	250	220	190	160	190 + load
30	1.5	1.4	1.4	2.3	2.6	1.8
60	1.9	1.6	1.8	2.3	3.6	3.8
80	1.8	1.6	2.3	2.6	3.3	3.7
120	3.4	3.6	3.4	4.1	4.8	5.1

Table 2: Speedometer error variation with tyre pressure.

Brand and model:

Examination of model and brands were undertaken using 17 and 18inch rims with low profile tyres. Some 20 different tyre models were tested to consider variations between brands. It was found that a variation of speedometer reading of 1.5% resulted from the same vehicle and speedometer calibration settings over the twenty types.

Wear:

The change in the tread depth of a Dunlop Monza 205/65R15 tyre, from new through to the 1mm above wear indicator bars, was measured to change the diameter by 12 mm (although the diameter change can be 14 mm if worn completely). This is equivalent to a change in circumference during its life of 2.0%.

Tyre distortion

On the face of it, the circumference of a tyre is constant whatever the tyre pressure. However tyres compress as the tyre surface changes shape when it meets the road surface squeezing and then stretching each portion of tread during a cycle so that the distance travelled per revolution of the wheel changes. It was found that a worn tyre does not compress to the same amount as a tyre with new tread although smaller in circumference. During these experiments it was found that tyre growth under the influence of centrifugal force was only significant when the tyres were under-inflated and at speeds of more than 120 km/h. A Dunlop 215/60R16 95V inflated to 240kPa was roller-driven to 160 km/h and had expanded 3.5mm on radius or approximately 1.1% of indicated speed. This expansion increases with speed in an approximate logarithmic fashion.

Experiments showed that a Dunlop Monza 205/65R15 tyre fitted to a rim had an undistorted radius of 320mm at a pressure of 220 kPa, a compressed radius of 295mm and, a compressed radius of 290mm at a pressure of 190kPa. The calculated circumferences for the three radii were 2011mm, 1854mm and 1822mm respectively. The distance travelled in one rotation, for the compressed tyres was measured to be 1966.5mm at 220kPa and 1908.0mm at 190kPa. The difference in the measured distances travelled was 0.7% yet the radii differed by 1.7%. Further clarification of this phenomenon would require test throughout the pressure range for a number of combinations of vehicle and tyres. The actual results from direct comparison to laser and radar measurements at speeds from 30 to 160km/h had indicated only a 0.7% difference at 100km/h dropping to 0.4% at 160km/h. This suppression may be a result of aerodynamic behaviour of the vehicle. The results are given in Table 3.

Indicated	30.0	60.0	80.0	100.0	120.0	160.0
Rollers	29.7	57.3	76.3	96.4	116.1	157.3
Laser	30.0	57.0	77.0	96.0	116.5	156.5
Radar	29.5	57.0	77.0	96.0	116.0	156.5

Table 3: Comparisons of different methods of speed measurement.

Roller effects

When speed is measured using rollers the compressed diameter of the tyre varies from the compressed diameter of the same tyre on the road surface. This is due to the rollers creating two curved surfaces rather than one flat surface on the tyre (load surface area and shape, or tyre footprint).

The effective circumference of a tyre on the road can differ with brand, ply rating, belt type (steel or nylon) and tread depth. This circumference variation can be minimised when the vehicle is on the rollers by increasing the tyre pressure. The required increase will depend on tyre type, but early test results indicate it is about 30 kPa.

Experiments on the tyre distortion with different diameter rollers was undertaken starting with 203mm (8.0 inch) to 266mm (10,5inch) in 12.5mm intervals. Some experiments are still being analysed that look at leading edge roller speed sensing verses trailing edge roller speed sensing. This plays a roll in the effective diameter seen be the rolling road tester.

Tyre slippage for a sedan on the roller was measured at a range of speeds using a strobe light and was found to be minimal. Great care was given to minimise slippage during the tests, and the measured slippage was less than 100 mm over the test distance of three kilometres. The total effect of slippage on speed accuracy was not deemed as significant in free-rolling testing.

Instrument Errors

Systematic corrections that are not eliminated during calibration or applied as a correction, will contribute with opposite sign to the results of speed measurement by a police pursuit vehicle. For example, consider a police car tested at 100 km/h with a reported error with new tyres of +1.5 km/h (that is, the true speed is 1.5 km/h lower than the indicated speed) and which eventually has tyres at half wear equating to 1km/h. A motorist's vehicle is then perceived to be travelling 2.5 km/h faster than actual. If the motorist has a speedometer error of -1.5 km/h and is travelling at an indicated speed of 100 km/h we can see that it has been measured to exceed the speed by 4 km/h, enough to be considered a breach of traffic rules. These errors created by, (a) tyre wear, (b) not applying calibration corrections, and/or (c) the roller-to-road anomaly, are critical to the overall picture, since the accumulative affect can be as much as 4 km/h. These three items were intentionally not calculated in this first view of the uncertainty assessments (subject discussion to follow) since the corrections may or may not be deemed as uncertainty components.

To calculate the uncertainty associated with a driver's knowledge of the true speed of his or her vehicle, a review of the components of uncertainty arising from interpretation of speedometer indication, vehicle load, engine power management and tyre behaviour was undertaken by the author.

The driver's ability to accurately determine the vehicle speed using an ordinary speedometer is affected by:

*The intrinsic accuracy of the instrument (the residual systematic error after calibration).

*Parallax error.

*Size of minor graduations (normally 5 or 10 km/h).

*Readability (usually one fifth of one minor graduation).

Based on these factors uncertainty (expressed as 95% confidence intervals) for a speedometer read to 2 km/h was as follows:

60 km/h is ±8 km/h

80 km/h is ±10 km/h

110 km/h is ±13 km/h.

A calibrated speedometer read to 2 km/h and tested with certified speedometer testing reaches a better accuracy than the ADR18.5.1.2, that is the accumulated uncertainty described in this paper is less than the ±10% specified by ADR. The calculated uncertainty is ±4.9 km/h at 110 km/h without any account for tyre wear and roller to road anomaly. This assumes that the speedometer was either adjusted to read true or the calibration correction was applied. Failing this, the uncertainty must be calculated with an uncertainty components added for the systematic errors.

The needle in an analogue speedometer will be about 2 mm from the gauge face. This results in a parallax error, which will depend on the position of the driver's dominant eye. The maximum error derived from experimentation was less than 2 km/h. With the advent of liquid crystal displays with either synthesized analogue or numerical readout, parallax problems are not an issue. On the other hand rounding of the displayed speed may create errors but these would be less than 1 km/h.

Analogue instruments display information by indicating with a needle or a pointer. The graduations on the display face limit the precision of the instrument readability. With a minimum division of 5 km/h and a needle width of the equivalent of 1 km/h, resolution to a fifth of a division or 1 km/h can be expected. Examples of the application of this convention can be found in Australian Standard AS1349 [6].

Since infringements can occur in just a few metres, we investigated other sources of speed control and measurement and found a significant problem with smaller vehicles. Measurements with an air-conditioned four-cylinder vehicle showed a 5km/h variation in speed with the air-conditioning compressor cycling. This variation is created by the driver compensation for power fluctuations by his efforts to maintain constant speed. Policy makers may wish to include this in the big picture.

Calibration of the testing machine

The measurements of the roller diameters and rotational speed gives a standard uncertainty component of less than 0.1 to 0.3 km/h between the speeds of 30 and 180 km/h. The stability of performance of all the roller machines tested throughout most of Australia over the last six years has been in the region of ± 0.2 km/h. Plotted roller wear on the Adelaide based unit was less than 0.01% over six years.

Police tolerances for speed infringements

The inconsistency between Australian States in their tolerance of small infringement of speed limits means that there is no single system in use. The most widely used system is the decade method. The posted speed limit can be exceeded by 9 km/h eg 69 in a 60km/h zone (89 in 80 km/h zone etc) and incurs a fine if 70 km/h is detected. This method was introduced to compensate for the ADR 18.5.1.2 speedometer error of ±10%.

One State has recently introduced a 3km/h tolerance, since their detecting equipment carried an uncertainty in the region of ±2 km/h. This system has the implicit assumption that the drivers must not exceed the speed limit regardless of measurement errors and the onus is upon the driver to ensure that they comply with the law irrespective of accuracy of their speedometer.

Discussion

Achievable aims:

The statistics collated by the Monash University, the police departments, the Royal Automobile Association and myself, indicate that a high proportion of speedometers are set to read 3 km/h high to minimise liability and supposedly to compensate for possible drift. There has been no response from manufacturers confirming this practice. The application of this offset does not improve the accuracy of speedometers. The latest manufactured vehicles have an accuracy of 3% or better, of reading with one brand offering an adjustable version correct to within 2% of full scale. In the first instance, the use of "3%" is an archaic method of describing accuracy and creates a distorted view of the errors expected. Statistics have shown that ADR [1] should be amended to read:

"an accuracy of ±(0.65% of full scale + 1.75% of reading)",or *"±(1.5 km/h + 1.75% of reading)"*.

This would ensure that the tolerance does not limit the lower values to impossible accuracies or the upper value becoming too large.

Tyre behaviour:

The tests conducted were not intended to measure individual effects of tyre behaviour on speed but was a measure of an overall effect. The "lumping" of the tyre effects was purely to extract expected overall variations in speed measurement.

Tyre wear and low fill pressure just resulted in a higher indicated speed, which may not be of concern in a motorist's vehicle, but in a police vehicle will result in a high reading of the speed of motorists. A worry for motorists is the fact that tyre pressure increases from cold to hot, lower indicated speed.

Improved method:

With the adoption of the suggested changes to the design rules, and with roller anomaly taken into account, we can then address the policy of dealing with the error caused by tyre wear, so that the uncertainty can be calculated considering all significant components. The author suggests taking measurements for the tyre wear at the half wear point since a tread depth at time of test can be obtained and results of the speedometer test mathematically corrected to the half wear point. The tyre wear can then be included in the uncertainty to reflect results by tyres wear being other than half worn. The combined uncertainty components mentioned earlier and these latest additions were calculated to be ±6.7 km/h for a Dunlop Monza 205/65R15 tyre at 110 km/h.

No mans land:

In some Australian States road works and children's crossing zones are automatically classed as 25 km/h zones. As the wording of the design rules (ADR 18.5.1.2) does not call for any accuracy for speeds below 40 km/h, the driver has no assurance of the vehicle's true speed in these zones.

Driver's responsibility:

Other errors that have been attributed to outside interference (for example incorrect tyre size fitted, or differential ratio altered), or a deviation from manufacturers specifications are a separate issue. With vehicles made to the amended ADR as suggested above in paragraph *"Achievable aims"*, the uncalibrated speedometer would have a lower calculated uncertainty of speed measurement and can be expected to perform within a smaller infringement tolerance.

Breach of natural justice:

The calculation of uncertainty associated with speeds up to 120km/h shows that the decade method used by police forces allows infringement notices to be issued to drivers travelling within the region of uncertainty. The issuing of infringement notices using the 3 km/h tolerance system can be even unfair to drivers who use a speed-measuring instrument conforming to Australian design rules.

A temporary measure:

A suggested policing policy is to allow 7 km/h at speeds of up to 50 km/h and an additional 1 km/h for every 10 km/h of speed up to 110 km/h speed. This policy will prevent infringements notices being issued for the region of uncertainty and therefore should not be legally challengeable. This policy of expanded tolerances would only be an interim measure to correct the present situation, prior to public testing facilities being introduced.

The solution:

I believe that this paper lays the groundwork to give the Federal Government, State Governments, State Police Forces and motorists the tools to operate motor vehicle speed control measures correctly and fairly. If all recommendations are accepted, a fixed tolerance of 7 km/h (or a sliding scale of tighter constraint but more cumbersome to apply) can be used without compromising the motorists and afford them their right to an accurate form of speed measurement. However this policy assumes the application of calibration offsets to correct the speed value. The process of testing and calibration of rolling road testers that is traceable to a national standard must be made publicly available. A series of approved testing stations should be available so that motorists can confirm their speedometer accuracy and drive accordingly.

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References:

1. The Australian Motor Vehicle Standards Act 1989, Design Regulation 18.5.1.2

2. New South Wales Traffic Law, Ninth Edition, Road Transport Regulation 1998 Section 41.

3. ISO Guide to the Expression of Uncertainty in Measurement. International Organisation for Standardisation, Geneva, 1993 ISBN 92-67-10188-9

4. Organisation Internationale De Métrologie Légale" Recommendation R111 titled Weights of classes E1, E2, F1, F2, M1, M1-2, M2-3 and M3

5. Monash University Accident Research Centre, "Accuracy of Vehicle Speedometer readings with respect to speed enforcement tolerances".

6. Australian Standard AS1349-1986, Bourdon tube pressure and vacuum gauges, Section 1.3 (Definitions), 1.3.4 (Scales and scale markings).

7. Australian Standard ISO/IEC 17025-1999, "General requirements for the competence of testing and calibration laboratories."

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