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Testing
To
Limits

Quantification
No. 2

Degrees of
Freedom and
Coverage Factor

Financial
Report
2002 - 03



From the Editor

This issue has two articles relevant to a subject dear to a metrologist's heart - "uncertainty". There is an article by Ian Dollery on testing to limits and one by Ian Bentley on degrees of freedom and coverage factors.

There is a post-Conference flavour with this issue, but regular columnists are here as well, with NML News and Training Courses and Jeff Tapping's "Quantification".

In the next issues you will find a number of the conference papers (- the paper from Ian Dollery in this issue is one such example).

We have had quite a few new members in the last six months. Perhaps this is a good time to invite members to let us know of topics you would like to see covered in TAM articles.

- Maurie Hooper

Cover photo: Hemisphere Conference Centre, Moorabbin, venue for the recent MSA 2004 Conference.

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.

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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 July 2004.

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Letters to the Editor

Letters should normally be limited to about 200 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.

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Editor: Maurie Hooper

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1/3 page	\$150	\$130	\$400
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1/8 page	\$60	\$110	\$150
Colour			
Full page	\$800 per issue		

Insert one brochure in each TAM = \$300

Closing date for copy to be received for TAM is the 16th of the month preceding publication.

Contact the TAM editor for further details.

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Contact either your State Coordinators or the Secretary, Mr Mehrdad Ghaffari on (02) 9413 7381 or fax (02) 9413 7202, e-mail address: mehrdad.ghaffari@csiro.au or write to:

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Webmaster: Mark Thomas (03) 9244 4042

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Members	\$40 Joining Fee
	\$40 Annual Subscription
Associates	\$35 Joining Fee
	\$35 Annual Subscription

President's Report - May 2004

Contents

The year is well under way and in this issue of TAM you will be able to catch up the very successful MSA 2004 Conference. From the reception drinks on the Sunday night through to the BBQ on the closing night it was a great opportunity for people to catch-up, build new relationships and exchange information.

Dr Love, Director of the Bureau of Meteorology, opened the conference and he spoke of the importance of metrology to organisations and the community at large. This was followed by a fascinating presentation by Dr Murray, one of the key people involved in the plans to get the synchrotron built in Clayton. These diverse presentations set the tone for an excellent conference with more variety than I can remember at any previous one - papers on dimensional, electrical, physical, environmental and a first, with a medical metrology paper. Another strong theme of the two days was the focus on impacts of metrology in a social and legal context. Another successful aspect was the workshops on a variety of key issues that allowed the membership to discuss in detail matters of relevance to their industries.

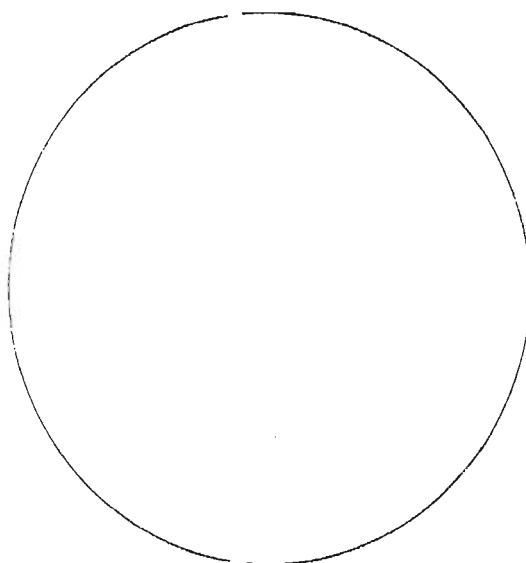
I want to thank the members of the organising committee for their enormous efforts. Steve Jenkins, convenor and Randall Anderson, Leigh MacKinnon, Neville Owen and Carol Sieker did a phenomenal job and all those who attended, I think, would agree that it was a great two and half days.

For those who missed out on this conference then I suggest that you start thinking about the next conference MSA 2005, planned for late next year in Canberra. Start putting those pens to paper and drafting your papers.

As to the rest of this year the plan is to focus on Training. This has come out of MSA 2004 where there was a general consensus that training was a critical issue for the metrology community. We are planning to have a training forum later in the year to bring together the different players in the field. If you have an interest in this area I suggest you keep an eye on the web site or contact Peter Hodgson who is the National Committee member who will be coordinating this initiative.

- Dr Jane Warne

Advertising Rates	2
Editor's Notes	2
President's Report	3
Testing to limits with uncertain measurements	4
News from NML	8
NML training courses	9
Conference photo spread	10
Behind the scenes - MSA Conference 2004	12
Vale - Philip Heskett	13
Quantification No 2	14
Effective degrees of freedom and coverage factors	15
Financial Report 202-03	17
Management Committee	19



TESTING TO LIMITS WITH UNCERTAIN MEASUREMENTS

an Dollery

Bureau of Meteorology,

Melbourne

Abstract

In testing an item to a specification based on limits, the uncertainty in the measurement introduces an extra unwanted category into the 'pass' or 'fail' criteria. The category is where we are uncertain if the item is either a 'pass' or 'fail'.

This paper presents a set of possible Rules with their consequences to assist suppliers, consumers and quality assurance testers in selecting Rules to resolve the assignment of uncertain category in a 'pass' or 'fail' determination.

Keywords: testing, limit, risk, uncertainty

1 Introduction

When quality assurance tests are performed and the result places the item close to either side of a limit, the test uncertainty could place the item on either side of that limit. In this case the test cannot clearly support either a 'pass' or 'fail' [1]. The item then falls into the category of being uncertain. Items falling into the uncertain category can be a source of angst for suppliers, consumers, and for quality assurance testers.

The stress associated with uncertain test cases may be reduced if a fair set of Rules governing the assignment of these cases is agreed on, prior to the commencement of testing.

The key in the above paragraph is the concept of fairness. To determine the fairness of a set of Rules, the risks involved in both acceptance and rejection need to be understood. Once the risks to both parties are taken into account this will provide guidance on selecting a fair set of testing Rules.

What testing cannot do is eliminate the chance of making an error in assigning a 'pass' or 'fail'. Testing is only able to provide evidence to either support or reject a particular choice. Whilst there is uncertainty in measurement we must accept that there is doubt.

2 Benefit Of Doubt

In testing to a set of limits a default position (a hypothesis) is required. The default hypothesis might be: confirm that the supplied item meets its specification.

The default hypothesis in the above statement is

that the item *is assumed to meet the specification* and that the testing will confirm this position. In order to fail an item, the testing needs to provide evidence to reject this hypothesis. This places the benefit of the doubt in favour of the supplier.

An alternative hypothesis is to assume that the item does *not* meet the specification. The testing then needs to show evidence to reject this position and pass the item. This places the benefit of doubt in favour of the consumer.

For example, the testing standard [2] places the benefit of doubt in favour of supplier, and allows the consumer to set the level of risk they will be subjected to.

There is also a third position where both the supplier and the consumer share the risk, using the limits to define the boundary for a 'pass' or 'fail'. The decision on which approach is to be adopted should be handled between the supplier and consumer on a case-by-case basis by considering the consequences for each party.

This paper shows the consequences of each approach using examples, so that an appropriate choice can be made in each situation.

After selection of a default hypothesis, the testing will have four possible outcomes.

3 Outcomes In Testing

The four outcomes from the testing are:

1. The item is *within the specification* limits and the test (*correctly*) passes the item.
2. The item is *within the specification* limits and the test (*incorrectly*) fails to pass the item.
3. The item is *outside the specification* limits and the test (*correctly*) rejects the item.
4. The item is *outside the specification* limits and the test (*incorrectly*) passes the item.

Table 1 is a presentation of the four test outcomes.

	Item meets specification	Item outside specification
Testing passes item	Correct	Type II error
Testing rejects item	Type I error	Correct

Table 1 The four outcomes of testing

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Rule 3

Pass all items that fall within the limits including those within 1 TUR of the limits and fail all outside limits. This is the same rule used by a hypothesis test with the benefit of doubt in favour of the supplier.

Rule 4

Use the above rules, but retest all items falling in zone 2 and use the average of the test results for the pass or fail according to one of the options above. This is, in effect, an increase in the TUR by $1/\sqrt{n}$ where n is the number of test repeats. This uses additional testing to reduce the number of items that fall into the new zone 2.

The following figures present the outcome of using each of the first 3 Rules at different TURs. The same distribution of items described in Example 1 is used in the following figures.

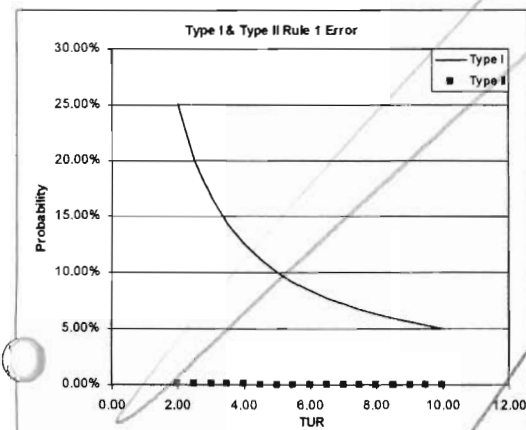


Figure 4 Rule 1 chance of Type I or Type II error

Figure 5 shows the percentage of items resulting in a Type I or Type II error when applying Rule 2 at different levels of TUR with the same confidence interval and distribution of items described in Example 1.

Figure 6 shows the percentage of items resulting in a Type I or Type II error when applying Rule 3 at different levels of TUR with the same confidence interval and distribution of items described in Example 1.

From Figures 4, 5 and 6, minimizing the risk for one party significantly increases the risk to the other party.

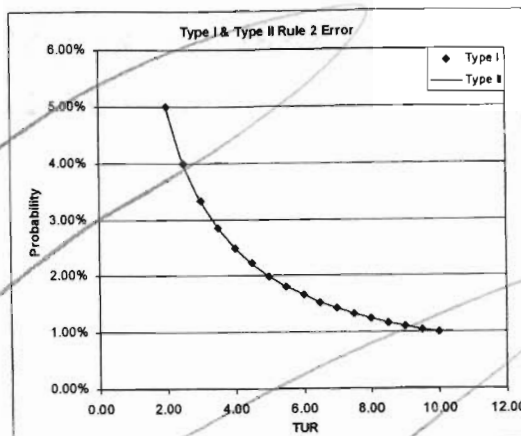


Figure 5 Rules group 2 chance of Type I or Type II error

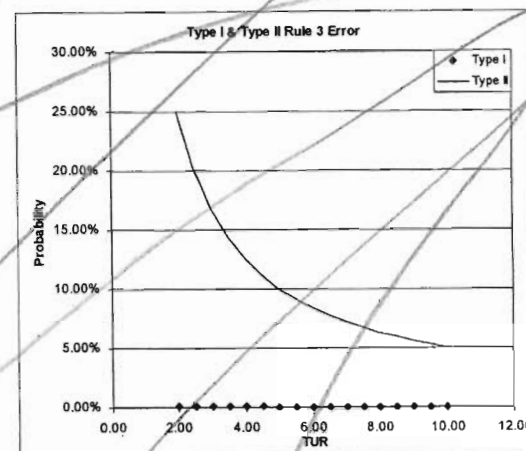


Figure 6 Rules group 3 chance of Type I or Type II error

If Rule 4 is chosen the limit to how many times a test should be repeated to resolve an item into either zone 1 or zone 2 will come out of the commercial return on investment bases. The decision should consider the cost of testing vs. the cost of the type I or type II error. Using figures 4 to 6 will assist in finding an appropriate target TUR.

6 Conclusion

The choice of Rules used to determine a 'pass' or 'fail' has a commercial consequence. Allowing both parties to decide on the acceptance Rules allows them to be prepared to deal with the test results that are unclear, and understand the risks associated with the Rule choice.

Improvements to reduce the testing uncertainty benefit both parties and this can provide encouragement for the supplier and the consumer for improved uncertainties when there is a clear commercial advantage.

7 References

- [1] .A. Duncan, "Deciding when a specification is met, taking into account the uncertainty of measurement", MSA97 Conference proceedings 2nd Biennial Conference, Nov 1997
- [2] AS1199: Sampling Procedures and Tables for Inspection by Attributes, XXXX, Standards Australia
- [3] R.E. Walpole and R.H. Myers., Probability and Statistics for Engineers and Scientists, second edition, Macmillan Publishing Co. Inc, 1978
- [4] T. Skwirczynski., Uncertainty of the calibrating instrument, confidence in the measurement process and the relationship between them, OIML Bulletin, Volume XLII Number 3, July 2001 ppXX-YY
- [5] ISO "Guide to the expression of uncertainty in measurement (GUM)", first edition 1993

from statistics [3] and are paraphrased as follows:

- *Type I error* – where the hypothesis is rejected and it is true. In the above case this could be called the *supplier risk*.
- *Type II error* – where the hypothesis is not rejected and it is false. In the above case this could be called the *consumer risk*.

If we assume that the item supplied has a single true value, then the chance of making either type of error during the testing is dependent on the uncertainty of the test method and its relationship to the acceptance limits. The relationship between the uncertainty and the limits can be determined by calculating the test uncertainty ratio (TUR) [4].

4 Test Uncertainty Ratio

The ratio of the semi-range of the acceptance limits to the test uncertainty confidence interval is the test uncertainty ratio (TUR).

The test uncertainty is the standard uncertainty [5] expanded to give the minimum confidence in the test results required by either party. This level could be 95%, 99% or even 50%.

A test uncertainty ratio of 1.0 indicates that there is a risk of a type I error of the residual probability in the stated confidence interval, where the item's actual value falls exactly between the acceptance limits.

$$P(\text{Type I error}) = 1 - \text{Confidence Interval}$$

Figure 1 shows this type I risk graphically in the case of a TUR = 1.0.

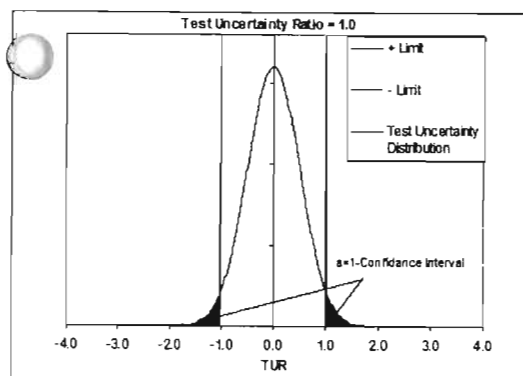


Figure 1 Testing distribution with TUR = 1.0

In figure 1 the tails of the testing distribution extend beyond the test limits, showing that even if the item has a true value exactly between the two limits, there is a chance that a test result will fall outside the limits and the item will be rejected.

Thus if the testing uncertainty confidence interval was stated at 95% and the TUR = 1.0 then you

could expect that 5% of the time, a Type I error would be made, rejecting the item even if it passes.

It follows that TURs of less than 1.0 will have an even greater chance than implied by the confidence interval chosen of this error occurring.

It is possible to calculate the chance that the item will be rejected on testing, for a range of actual item values. The equation for the chance of rejection of the test item at a specified true value is provided as equation 1.

$$P_{\text{Rejection}}(\mu) = 1 - \Phi(+L, \mu, \sigma) + \Phi(-L, \mu, \sigma) \quad (1)$$

Where:

μ	Item's actual Value
σ	Test standard uncertainty
$+L$	Upper Limit
$-L$	Lower Limit
$\Phi(L, \mu, \sigma)$	Cumulative normal probab to L with mean μ and devi
$P_{\text{Rejection}}(\mu)$	Probability of rejecting ite when its true value is μ

Since the probabilities are conserved in a pass or fail test, the probability of acceptance at each value described by equation 2:

$$P_{\text{Acceptance}}(\mu) = 1 - P_{\text{Rejection}}(\mu) \quad (2)$$

Where:

$P_{\text{Acceptance}}(\mu)$	Probability of accepting item when its true value is μ
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If the Rule was to accept all values falling in between the limits and reject all falling outside the limits then using equation 1 and equation 2, a graphical representation of the probability for acceptance and rejection can be drawn.

Figure 2 shows the acceptance and rejection lines with the four decision areas identified for a TUR of 1.0.

The features to be noted in figure 2 are:

- When the true value of the item approaches the limits from within, the chance rejecting the item (Type I error) increases to a maximum of 50%.

- When the true value of the item approaches the limits from outside the chance accepting the item (Type II error) increases to a maximum of 50%.

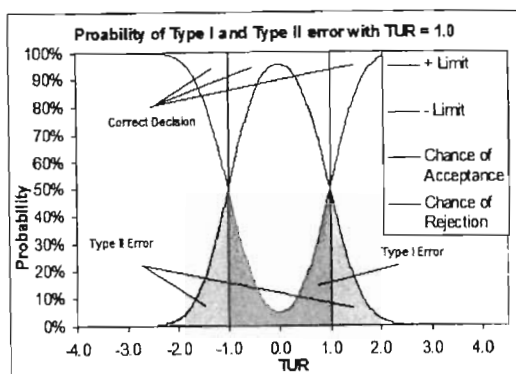


Figure 2 Probability of outcomes at TUR = 1.0

Using an example the consequences of figure 2 to both the supplier and the consumer can be made clearer.

Example 1, the supplier makes 1000 items, distributed evenly (a square distribution) up to but not exceeding twice the required limits. The results of this example are provided in Table 2.

	Item meets specification	Item outside specification
Testing passes item	400	100
Testing rejects item	100	400

Table 2 The four outcomes for Example 1

From Table 2 the chance of either a type I or type II error is approximately 25 % for both the supplier and the consumer.

This example highlights the effect of TUR = 1.0.

To show the effect of an improved TUR figure 3 has been developed in the same way as figure 2 but using a TUR of 2.0.

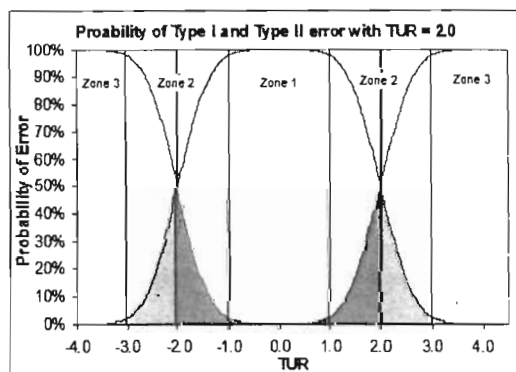


Figure 3 Probability of outcomes at TUR = 2.0

As the test uncertainty reduces a new zone appears between the limits.

To make the consequences of figure 3 to both the supplier and the consumer clear we can apply it to the previous example using the same decision Rule.

Example 2, If we apply example 1 to the TUR = 2.0 we get Table 3.

	Item meets specification	Item outside specification
Testing passes item	450	50
Testing rejects item	50	450

Table 3 the four outcomes for example 2

From Table 3 the chance of a type I and type II error is 5 % for both the supplier and the consumer in these examples.

The results in Table 3 show that if the supplier and consumer chose to share the risk equally, they would each be accepting a 5% chance of incorrectly categorised items.

Reviewing the results from the Tables 2 and 3 highlights the commercial consequence of a different TUR. Developing Tables similar to Table 2 and Table 3 with the supplier, consumer and quality assurance tester shows the commercial advantage of improved TUR and where appropriate justify the cost of improved TUR.

5 Decision Rules

Where one party has a heightened risk associated with either a Type I or Type II error, more complex decision rules may be required to achieve an optimum outcome.

The Rules described below are intended to cover all the options that could be taken after a test is conducted.

The choices in figure 4 provide four ways to separate the test results into a 'pass' or 'fail'.

Rule 1

Pass all items which fall within zone 1 and fail all outside zone 1. This is the same rule used by a hypothesis test with the benefit of doubt in favour of the consumer. This option is recommended if the consequences of passing the item far outweigh the effect on the supplier. i.e. the manufacturer of the oxygen supply regulator for pilots.

Rule 2

Pass all items which fall within the limits and fail

all outside limits. This is a sharing of the risk between the supplier and consumer. This can be used if the consequences to both parties are the same. Note it may be appropriate to take all the items in zone 2 and accepting them as 'seconds' at a reduced price. i.e. fail in the purchase weight of goods.

Rule 3

Pass all items that fall within the limits including those within 1 TUR of the limits and fail all outside limits. This is the same rule used by a hypothesis test with the benefit of doubt in favour of the supplier.

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Use the above rules, but retest all items falling in zone 2 and use the average of the test results for the pass or fail according to one of the options above. This is, in effect, an increase in the TUR by $1/\sqrt{n}$ where n is the number of test repeats. This uses additional testing to reduce the number of items that fall into the new zone 2.

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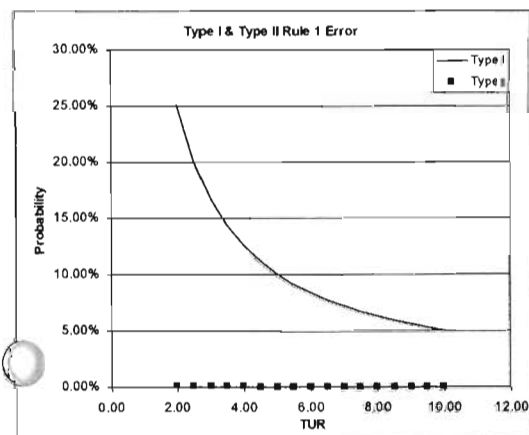


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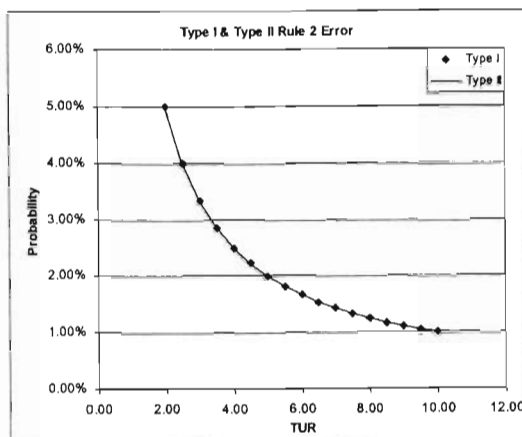


Figure 5 Rules group 2 chance of Type I or Type II error

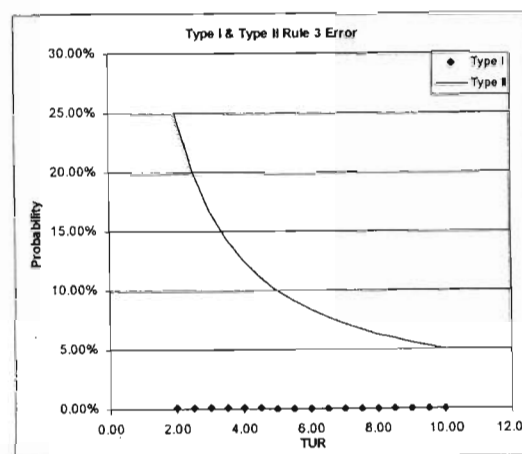


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News from NML

Update on the National Measurement Institute

The National Measurement Institute of Australia will come into operation on 1 July 2004. It is being formed by the amalgamation of the National Measurement Laboratory (NML), the National Standards Commission and the Australian Government Analytical Laboratories, as reported in TAM No. 30 (July 2003). The necessary changes to legislation have now been completed with the National Measurement Amendment Act 2004 receiving Royal Assent on 25 March 2004. Aside from tidying the language, the legislation covers the appointment of a Chief Metrologist to oversee the scientific business of the institute. Clients may be assured that any business with a constituent body will continue unimpeded through the changeover. From an NML perspective it is hoped that being under the umbrella of the Department of Industry, Tourism and Resources will facilitate even closer relations with industry. Further information may be found on the website www.measurement.gov.au.

Metrology Society of Australia (MSA)

NML staff members were involved in the presentation of thirteen papers, while a further four chaired special interest group workshops, at the recent MSA conference, held in Melbourne. NML is pleased to

be a principal supporter of the MSA and is a major sponsor of the associated biennial conferences.

Training Courses and Publications

In March NML conducted a two-day training course in introductory radiometry, which was very well received by the participants. Approximately twenty attendees enthusiastically embraced the subjects of photometry and radiometry and many valuable discussion sessions were held, complementing the theory and demonstrations delivered by members of staff.

The next one-day course on the measurement of uncertainty, referencing the ISO 'Guide to the Expression of Uncertainty in Measurement' (GUM), will be conducted in June. Further training courses to be held this year include "Electrical Measurement" in September and the evergreen "Temperature Measurement" course in October. In all these courses the lectures are presented by staff members with extensive experience (research and practical) in their particular field. Participants are invited to bring individual problems for discussion as well requests for explanation of general concepts.

As an adjunct to the training courses, NML publishes monographs that are available for purchase separately, covering the above topics as well as humidity and pressure measurement and balances & weighing. Further information about these publications and the upcoming training courses can be found on NML's web site www.nml.csiro.au or contacting Robin Bentley (Robin.Bentley@csiro.au, tel: 02 9413 7764).

The Redefinition of the Kilogram

As detailed in an earlier issue of TAM (No. 30), interest in the redefinition of the kilogram has been reported in the popular press. The kilogram stands alone as an artefact in the International System of Units and the drive to find a new definition for the kilogram, based on a fundamental constant, stems from the instability of the platinum-iridium artefact that is the current standard. Over the last 100+ years there has been a drift of almost 100 μg between this standard and the six official copies, all platinum-iridium and all kept in Paris. The extent of any absolute drift is not known but it may be up to



Presenters Brad Ward and Neil Lukins, between sessions at MSA2004

10 μg per year.

The National Measurement Laboratory (NML) has been involved in the research project using X-ray crystal diffraction of the single-crystal silicon sphere to determine the molar mass and hence the Avogadro constant which, it is hoped, will lead to a redefinition of the kilogram in terms of a specific number of ^{12}C atoms (reported in TAM No.28, Sept. 2002).

NML is part of CSIRO's Telecommunications and Industrial Physics (CTIP) and it is CTIP's optical workshop that has fabricated the five precise single crystal silicon spheres, from cylinders of 10 cm diameter, which have been used in this research in laboratories around the world. The sphere has been chosen for its smooth surface with no edges or corners to be damaged and a particular form of silicon chosen, with very small impurities and defects. The CTIP optical workshop has an enviable reputation for its ability to manufacture to very exacting tolerances that cannot be matched elsewhere and the manufacture of one sphere alone includes 200 hours of manual polishing.

NML's involvement in this project has been two-part. On the research side precise measurements, such as the initial mass, temperature effects, out-of-roundness and diameter, have been made that have assisted in determining the surface characteristics and absolute density. The extent of the surface oxide layer has been measured using optical ellipsometry.

As well as this NML Fellow Dr Mike Kenny has been building and collating a web-based database that contains all relevant data and information regarding this project. With his impending departure, the management of the database is being handed to Dr Atsushi Waseda at the National Measurement Institute in Japan. This database is maintained by the International Bureau of Weights and Measures, in Paris.



Achim Leistner setting up sphere for roundness measurement

Training Courses

The National Measurement Laboratory (which will become part of the National Measurement Institute on July 1) will be conducting courses in Measurement Uncertainty, Electrical Measurement and Temperature Measurement later this year at its Lindfield, Sydney, laboratory.

These courses are suitable for technicians, scientists and engineers who require a better understanding of theory and practise in the particular subject area. The courses are presented by staff with extensive knowledge and experience in calibration, research and industrial consultation and consist of lectures, demonstrations and laboratory tours.

Informative and relevant monographs are supplied at each course.

15 September 2004

Measurement Uncertainty

A full one-day course designed to give you a better understanding of the use and application of the ISO Guide to the Expression of Uncertainty in Measurement.

16 – 17 September 2004

Electrical Quantities

This course deals with the theory and practice of electrical measurement using digital multimeters (DMMs) and calibrators, with special attention given to important practical issues such as grounding, interference, thermal effects, etc.

6 – 8 October 2004

Temperature Measurement

General principles of measurement as well as specific techniques in thermometry are covered in this three-day course, with emphasis placed on traditional techniques involving thermocouples and resistance & radiation thermometers.

Further information may be obtained by contacting Mr Robin Bentley.

Phone: 02 9413 7764

Fax: 02 9413 7383

Email: Robin.Bentley@csiro.au





Behind the Scenes – The MSA Conference 2004

Steve Jenkins,
Convenor of the Organising Committee

If the delegates heard a sound of rushing wind at the end of the Conference, it was probably the loud and joint sigh of relief from the Organising Committee. There can be many views of a conference - the view from the presenters, from the delegate participant, from the delegate networker, the delegate spectator, and the trade representative. Our view is that it went well and that the inevitable hiccups were barely noticed.

The Organising Committee was Carol Sieker, Randall Anderson, Neville Owen, Leigh Mackinnon and Steve Jenkins and started work in early 2003.

First let me give some of the basic statistics for the Conference:

- There were just over 100 delegates of which 8 were from overseas.
- There were 31 papers and six Special Interest Groups. Of the papers, 13 came from CSIRO, 8 were from government-sponsored institutions, 3 from Universities and 7 from private companies.
- The Conference dinner hosted 100 guests.
- The Conference returned a small profit.

Organising conferences seems to involve a few major decisions and a multitude of detail; the finer the detail the more likely it is to slip through the mental net. We decided early on that the conference should be two days of three streams and held at the Hemisphere/ Edmund Barton Centre. These major decisions turned out to work well. The venue was an ideal size, providing some intimacy between delegates and trade reps with sufficient rooms for the SIGs.

Minimising the Conference costs to delegates was always a driving force in the decision-making, as we wanted as many delegates as possible. While the venue was not in the lively part of Melbourne, it allowed us to bring the costs down to what we considered an attractive level.

The disciplines within the metrology community are wide-ranging and so having the Conference concentrated into two days and three streams had the advantage of encouraging the time-constrained to attend without having too many topics that overlapped. Feedback from the SIGs suggested that they worked well, being less formal than a Workshop and more participatory. For example, the Pressure SIG had 18 people attend with a healthy discussion

of issues facing the pressure measurement community. The salient issues identified were training and test procedures for modern calibrators. The outcome will lead to action and the highlighted issue of training, which affects so many areas, is seen as an issue requiring a broad response. By contrast the Colour Uncertainty SIG had four people attend but Jim Gardner put to rest the thorny problem of uncertainty calculations for colour using spectral data. This has long been a problem without a solution; the dissemination of Jim's work to the measurement laboratories is now the issue.

Some of the decisions that were not solved easily were: who should be the keynote speakers, are they available, and what should be the topics? The forming of the NMI was an obvious topic of interest for all metrologists so that rather selected itself. For the other keynote speaker, we tried to get someone from the technical side of Formula One racing that was on the weekend before the Conference. We thought that a presentation on data collection at 300 km/h, how they use it to diagnose problems and formulate tactics would interest most metrologists, especially the Committee (there has to be some benefits!). However, it wasn't to be as no one was available. Then we had the realization that we had a multi-million dollar scientific endeavour on our doorstep and this was too much to ignore. Contacting the Synchrotron Project, they provided a speaker for the opening day. We had everything covered.

Of course, there was a parade of anxious moments. In between the "Call for Papers" and the "Registration Brochure", the Edmund Barton Centre changed its name to Hemisphere. Would this create confusion? An anxious moment. We were very well served by the Hemisphere conference staff and struck up a good rapport with our contact. Three days before the Conference, she went on maternity leave. An anxious moment, but her replacement was great. On the first day of the Conference, the committee was on edge waiting for the first calamity. It came from where we least expected it. Five minutes before the keynote speaker was due to start, he hadn't arrived and we had no mobile communication. An anxious moment. Do we go to an early tea break? Just as we were writing the announcement, he drove into the car park. The relief felt was almost worth the anxiety.

The next Conference will be in September/October 2005. What would be invaluable to the organizers

Continued next page

Vale - Philip Heskett

Philip Heskett was the manager of the Australian Defence Forces Calibration (ADFCAL) Measurement Standards Laboratory situated at the RAAF Base Richmond NSW. He sadly passed away on 13 November 2003 after a long illness. A funeral service was held at Parkway Funerals & Chapel Dee Why on 18 November 2003 and was attended by a large number of family and work colleagues, many more than could fit in the chapel. Many had only heard through the grapevine but travelled all across Sydney to pay their respects.

The following eulogy was delivered by Phil's brother, Ray Heskett.

Phil was born on the Isle of Wight in the UK on the 7th August 1942 at the height of the Second World War. He was the eldest of the three children born to Sidney and Betty Heskett. His childhood was spent on the Isle of Wight and in Portsmouth. During this time it was evident to all that knew him that he had an artistic side to his personality. He spent many hours doing pencil drawings and also making puppets, which he used for putting on shows for the neighbourhood kids...**for which I must add he charged a small fee.**

During his teenage years, Phil also developed a keen interest in electronics, spending many hours making radios, amplifiers and other electronic bits and pieces

Behind the Scenes (from previous page)

What Conference is to have some feedback about this one. If you would like to assist in this way please send comments to Ilya.Budovsky@csiro.au who will be pleased to receive them. We do feel we need to encourage participation from a broader range of metrologists. While it is vital that, as a professional organization, we maintain the contribution of NML to the Conference, contributions from the wider metrology community are invaluable for the organization to gauge its well-being. Perhaps. In the next Conference, we should have a stream entitled "A day in the life of....."

Ultimately, the enjoyment of organizing the Conference far outweighs the anxieties. The Committee had a good time and we ended up satisfied with the Conference. Would I do it again? Fortunately, at my age, by the time it comes round again I would have completely forgotten this one. ■

that lead to his life long love of music. Phil was also an avid reader. At the age of 16 Phil left school to join the Royal Air Force and after training became an aircraft radio technician. Having signed up for ten years he served at many air force bases around the UK and also in Singapore. The RAF also gave Phil a love for rugby, which he played for many years. **An offshoot of this was his knowledge of and love for rugby songs, which he performed with gusto after a few ales.**

On completion of his time with the RAF Phil set off for Australia to join his family who were now living in Sydney. In 1969 he married Sandra Mercer and it was not long before they had renovated a VW combi van and were setting out on a big adventure to explore Europe and the UK. Returning to Australia, Phil started his career as a metrologist at Garden Island Dockyard. Phil and Sandra were later blessed with two wonderful children...a daughter Corinne and a son Myles. During his children's early years Phil interrupted his career to stay at home to care for the children full time. He was optimistic that during this time he would be able to further develop his artistic talents... **he soon found that looking after two young children did not allow much time for such endeavours.**

On returning to the workforce Phil once again devoted his talents to metrology.... an exact science requiring infinite patience and meticulous record keeping. He continued in this field until he became ill just over twelve months ago.

During his life Phil continued to develop his artistic skills... always experimenting, always seeking new boundaries. His body of work is outstanding and is a legacy his family will, I am sure, cherish.

Phil had many roles in his life.... he was a devoted son.... a much loved brother to Jayne and myself....an exceptional loving father to Corinne and Myles....a loving partner to Rosemary.... a loving friend to Sandra....cherished brother in law to Elaine and Ian.... loving uncle to Andrew, Brendan, Stephen, Lyndsay and Jessica....A great mate to all his friends....and a workmate and colleague to many....but to all of us who had the privilege of knowing him he was a kind and gentle man who enriched all our lives.

I would like to make special mention of his recent partner Rosemary. Phil himself told me only recently that he had found a soul mate in Rosemary who he deeply loved and cherished and who had given him great happiness over the few short years they were together. ■

QUANTIFICATION - Number 2

Jeffrey Tapping

In the first edition of this column I asked about some old measurement units that have a name that is an English word. The answers are:

Bar is a pressure measurement, with one bar approximately equal to atmospheric pressure. Actually, one bar is equal to 100,000 Pascals, while a standard atmosphere is 101,325 Pascals.

Cord is a measure of cut timber equal to about 3.6 m^3 (128 cubic feet). I first came across this unit when I heard it being used in the U.S.A. about 20 years ago to express the size of a man's winter firewood stack. So perhaps it still survives.

Nit is a unit of luminance, and is an alternative for a candela per square metre.

Perch, rod and pole are in fact the same quantity. It is a measure of length equal to $5 \frac{1}{2}$ yards, used for land measurements.

Chain is another land measurement equal to 22 yards. A chant heard in school rooms in the middle of last century was "From wicket to wicket in cricket, is 22 yards or one chain!", so that will give you a feel for it.

Gill is a liquid volume measure, equal to a quarter of a pint (0.142 L), but one of my dictionaries adds "in some parts a half pint".

Peck is a volume measurement used mainly for dry materials such as grain, equal to about 9.1 litres.

Slug is a unit of mass in the imperial system, with units (pounds seconds-squared per foot). It is further discussed in the answer to the final question.

The final question was, what part does the unit the pound play in the FPS (foot-pound-second) system of units, and it is tricky because there is no single answer. Prior to the SI system there was often no distinction made between weight, mass and force. A "weight" was a lump of metal that you checked scales with, what we would now call a mass. And the weight produced a force, and this led to units like psi (pounds per square inch), which still hang around today. Towards the end of the Imperial system in the enlightened world, there was an effort to tidy things by using pounds-force (abbreviation lbf), to try to avoid confusion. The formal unit of force

was the poundal (abbreviation pdl), which was equal to a mass of one pound divided by g (the acceleration due to gravity), so the two quantities conformed with Newton's equation, $\text{force} = \text{mass} \times \text{acceleration}$. The problem then was that g varies from place to place, so they had to define a standard g . You can see that it got quite messy!

Now enter the U.S.A.-ians, who rejected the royal rulers but keep their measurement system. In a training manual dated 1978 from the U.S. navy on measurement and calibration it is explained that in the FPS system they use, the basic metrology units are:

Force unit is the Pound,
Mass unit is the slug,
Length unit is the foot,
Time unit is the second.

Further, the slug is designated as the derived unit. That is, force, length and time are the basic units, and mass is obtained from them! Then, using Newton's equation a pound is defined as one slug times g .

Now do not ask me why they chose to go that way. It would make more sense to me to define the pound in terms of the kilogram, and then have the same structure as the SI system. I wonder whether NIST agrees with the U.S. Navy?

So now a new batch of questions - here are a few more units with names that have other meanings, plus a couple of strange ones, for you to ponder on:

Stone	Iron
Grade	Grain
Cental	Sthene
Nail	Link
Knot	Minim

And do you know of a unit that applies to two entirely different kinds of quantity?

To finish, what quantities are represented by:

1 am
1 pm
1 dam

See you next issue with the answers.

Effective Degrees of Freedom and Coverage Factors

In the July issue of *The Australian Metrologist* it was stated that NATA favours the use of effective degrees of freedom (v_{eff}) and that this was not consistent with ISO 14253-2. This article looks at national and international policies and guidance on this subject and then discusses the actual NATA policy for Metrology laboratories, the ISO 14253-2 approach and different options that have been suggested for dealing with dominant repeatability components that can lead to low effective degrees of freedom and consequently coverage factors significantly larger than 2.

ISO Guide to the Expression of Uncertainty in Measurement (ISO GUM)

Section 5.4.6.3 of ISO/IEC 17025 refers to the ISO GUM. Sections 6.3.3 and G.6.4 of the ISO GUM state that the preferred method for calculating an expanded uncertainty is to use the Welch-Satterthwaite formula. Section G.6.6 covers the simpler approach of assuming $k = 2$ but contains the rider that although this approach should be suitable for many practical measurements, its applicability will depend on how close you must be to 95% and provided that v_{eff} is greater than 10. A v_{eff} of 11 will lead to an underestimate of 10%.

Australia's Legal Metrology Policy

In June 1994 the National Standards Commission determined pursuant to sub-regulation 80(9) of the National Measurement Regulations that "the accuracy of a reference standard of measurement shall be ascertained on the basis that there are not more than 5 chances in 100 that the verified value of the standard of measurement differ from the true value by more than the calculated uncertainty" i.e. not less than a 95% confidence level.

A May 2002 determination pursuant to sub-regulation 19(2) of the National Measurement Regulations 1999 revoked the previous determination and added that the uncertainty had to be ascertained in accordance with the principles of the ISO GUM with a confidence interval estimated to have a 95% confidence level at the time of verification.

Australia's National Measurement Laboratory

In 1994 the CSIRO's National Measurement Laboratory made the policy decision that they would follow the methodology of the ISO GUM. Stating that

"In general, the value $k = 2.0$ will yield an approximation to a 95% level of confidence for the interval $y - U$ to $y + U$. However if this approximation is not valid for a particular application, the value of k which has been used to calculate U will be stated in the NML report".

European co-operation for Accreditation (EA)

Section 5.1 of EA-4/02 states that "In cases where a normal (Gaussian) distribution can be attributed to the measurand and the standard uncertainty associated with the output estimate has sufficient reliability, the standard coverage factor $k = 2$ shall be used. The assigned expanded uncertainty corresponds to a coverage probability of approximately 95%."

However there is a rider in section 5.3 which states that "the reliability criterion is always met if none of the uncertainty contributions is obtained from a Type A evaluation based on less than ten repeated observations"

NIST Technical Note 1297, 1993

Section 6.5 states "To be consistent with current international practice, the value of k to be used at NIST for calculating U is, by convention, $k = 2$ "

However, this is later qualified in Appendix B where it states "if v_{eff} is less than about 11, simply assuming that the uncertainty of $u_c(y)$ is negligible and taking $k = 2$ may be inadequate if an expanded uncertainty $U = k u_c(y)$ that defines an interval having a level of confidence close to 95 percent is required".

The NATA Policy

The NATA *Supplementary Requirements for Accreditation in the Field of Metrology* state that "Unless otherwise required by a test or calibration specification, uncertainties shall be reported at a 95% confidence level" and that "An assumption that $k = 2$ is permitted provided that the laboratory has carried out an initial analysis to justify this (refer to Annex G of the ISO Guide to the Expression of Uncertainty in Measurement)".

This policy is consistent with the Australian legal requirements, that of the National Measurement Laboratory and the above-mentioned international guides on uncertainty.

Ian Bentley

Manager, Physical and Dimensional Metrology

NATA

So why are we not consistent with ISO 14253-2?

Section 5 of ISO 14253-2 states that "the expanded uncertainty U is calculated by the formula $U = kx_c$ where $k = 2$ ". There is no mention of "effective degrees of freedom", nor is there an explicit rider equivalent to those in ISO GUM, NIST 1297 or EA-4/02 outlined above. However, section 8.2.2 states "When the mean value or the standard deviation is based on very few repeated measurements the estimated standard deviation values may be wrong and possibly too small. For this reason a "safety" factor h is used".

It is claimed that this safety factor is based on the Student t -factor and ranges from 7.0 for 2 measurements to 1 for 10 measurements. So in effect it is achieving a similar outcome to that of a coverage factor derived from an effective degrees of freedom. The safety factor is applied earlier in the process and has no effect once you have 10 measurements. This is similar to the reliability criteria of EA-4/02 and the v_{eff} of at least 11 specified in ISO GUM and NIST 1297 for assuming $k = 2$.

The Welch-Satterthwaite formula

This formula has received some criticism about its appropriateness in some circumstances and the relevant ISO Committee will need to consider these criticisms when the ISO GUM is reviewed. However, there must be some means of "weighting" the expanded uncertainty to cater for a relatively large component with a low degrees of freedom rather than just root-sum-squaring all components and assuming k equals 2.

So how can the degrees of freedom be increased when only carrying out a low number of repeat measurements?

It may not be economically viable for a low grade instrument to carry out a sufficient number of repeat measurements to give a reasonable degrees of freedom. Or a limited number of sets of readings may be specified in a standard test method (e.g. AS 1349 specifies 2 sets of readings giving 1 degree of freedom and a student t of 12.7).

If the item being calibrated is an artefact such as a gauge block or mass, the laboratory can limit the repeatability component of their system by acceptance limits on their initial and final measurements and justify using a pre-characterisation of their measurement system to give higher degrees of freedom for the repeatability component (refer H.1.3.2 of ISO GUM).

The most common cause of a low v_{eff} is due to the repeatability component of an instrument being calibrated being relatively large. With the advent of cheaper high resolution digital indicators the resolution component (with infinite degrees of freedom) may no longer be a significant component so if the measuring system, environmental and other components are small the repeatability component can dominate. An option here is to do a more extensive repeatability examination at one or two points in the range and assume it applies to the whole range. Some examples of this are :-

- Chapter 6 of The Calibration of Weights and Balances by Morris and Fen for a balance (10 readings at full and half scale);
- B.3.5 from ISO/TS 14253-2 for a micrometer (15 readings at 1 point - which is probably not economically viable).

Another option is to take the largest difference between the repeat readings over its entire range as a rectangular distribution and halve it to get the semi-range. Then use the total number of differences minus one as the degrees of freedom. An example of this is given in Chapter 7 of NML's Pressure Measurement booklet.

Note that these approaches are not meant to cover up poor repeatability, they are only valid for instruments where the repeatability of the instrument appears to be of consistent character over its range. This may not be the case for low accuracy devices such as torque wrenches that may not wear evenly or force testing machines where the axial alignment effects and other characteristics may change throughout their ranges.

Conclusion

The NATA policy on calculating expanded uncertainties using effective degrees of freedom is consistent with international standards for achieving a 95% confidence level in line with Australian legal requirements. The coverage factor (k) cannot automatically be assumed to be equal to 2. There are valid assumptions that can be made to cope with individual components that have low degrees of freedom, however if the instrument actually exhibits poor repeatability then the results must have an uncertainty that reflects the instrument performance.

Metrology Society of Australia

ABN 802 123 257 48

Annual Financial Report 2002-03

Treasurer's Report

This financial report represents a period of 12 months from July 1, 2002 to June 30, 2003. The Balance Sheet reflects a healthy financial state showing the society has assets of \$ 76,350.65. The Statement of Receipts and Expenditure for the period shows a loss of \$ 695.10. The loss reflects the investment in an upgrade of the appearance of TAM.

Subscription fees increased slightly from the previous year. This is good to see especially as there was no annual conference in this period. This indicates a consistent and growing membership. IMEKO continues to be a concern as the fees are high and we appear to gain little from our membership. The society will only ever reap rewards if individual members agree to participate in IMEKO committees and are willing to share what they learn through this participation. The committee intends to evaluate the role of MSA and IMEKO in 2004.

I would like to thank the MSA executive committee for their support and especially Ilya Budovsky who as secretary has worked especially hard to ensure the reporting between the membership database and the treasurer is perfect. Special thanks to our honorary auditor Bryce Thornton, who is guiding the development of sound financial reporting systems that will stand the Society in good stead as it grows in strength. This will be the last annual audit that Bryce will carry out on behalf of MSA. As I approach the end of six years as Treasurer I am happy to be able to hand over the accounts to Randall Anderson. I feel the societies financial affairs are in good hands.

- Marian Haire

	2002-2003	2001-2002
ASSETS		
Current Assets		
Term Deposit 3	10,313.44	0.00
Cash Management	16,665.95	16,043.36
MSA Conference	0.00	5,832.82
MSA No.1	19,100.12	25,719.68
Term Deposit 1	18,462.33	18,038.85
Term Deposit 2	11,828.81	11,431.04
Total Current/Savings	76,370.65	77,065.75
Total Current Assets	76,370.65	77,065.75
TOTAL ASSETS	76,370.65	77,065.75
LIABILITIES & EQUITY		
Equity		
Opening Bal Equity	35,150.46	35,150.46
Retained Earnings	41,915.29	24,052.49
Net Income	-695.10	17,862.80
Total Equity	76,370.65	77,065.75
TOTAL LIABILITIES & EQUITY	76,370.65	77,065.75

Statement of Receipts and Expenditure for the year ended 30 June 2003

	Jul 02 - Jun 03	Jul 01 - Jun 02
Income		
Fees		
Annual	13,470.00	12,630.00
Debts	40.00	0.00
Nominating	625.00	785.00
Total Fees	<u>14,135.00</u>	<u>13,415.00</u>
Interest	1,847.89	1,704.72
MSA Conference income		
Merchandise	0.00	397.00
MSA Advert in proceedings	0.00	1,000.00
Grants	0.00	4,000.00
Registration	0.00	25,875.00
Trade Display Stand	0.00	6,000.00
Total Conference income	<u>0.00</u>	<u>37,272.00</u>
TAM income		
Advertising TAM	0.00	360.60
Subscriptions TAM	30.00	30.00
Total TAM income	<u>30.00</u>	<u>390.60</u>
Total Income	<u>16,012.89</u>	<u>52,782.32</u>
Expense		
MSA Conference		
Proceedings	0.00	7,080.79
Gifts	0.00	334.95
Satchels	0.00	1,797.40
Bank Fees	0.00	599.12
Venue Hire	0.00	12,474.52
Total MSA 2004	<u>0.00</u>	<u>22,286.78</u>
Society		
Fair Trading	33.00	66.00
Melbourne Workshop	0.00	2,414.28
Bank Fees	272.42	193.03
Disbursements	509.36	819.43
IMEKO	1,033.00	1,722.29
Meetings	22.70	0.00
Office	201.70	270.00
Web	668.50	511.50
Insurance	693.89	613.95
Total Society	<u>3,434.57</u>	<u>6,610.48</u>
TAM	13,273.42	6,022.26
Total Expense	<u>16,707.99</u>	<u>34,919.52</u>
Net Income (surplus or deficit)	<u>-695.10</u>	<u>17,862.80</u>

INDEPENDENT AUDIT REPORT

To the members of Metrology Society of Australia

Scope

I have audited the attached annual financial report comprising the Statement of Cash Balances and the Statement of Cash Payments and Cash Receipts of Metrology Society of Australia for the year ended 30 June 2003. The Committee of Management is responsible for the financial report and has determined that the accounting policies used are consistent with the financial reporting requirements of the Metrology Society's constitution and are appropriate to meet the needs of the members. I have conducted an independent audit of the financial report in order to express an opinion on it to the members of Metrology Society of Australia. No opinion is expressed as to whether the accounting policies used are appropriate to the needs of the members.

The financial report has been prepared for distribution to members for the purpose of fulfilling the Committee of Management's financial reporting requirements under the Society's constitution. I disclaim any assumption of responsibility for any reliance on this report or on the financial report to which it relates to any person other than the members, or for any purpose other than that for which it was prepared.

audit has been conducted in accordance with Australian Auditing Standards. My procedures included examination, on a test basis, of evidence supporting the amounts and other disclosures in the financial report. These procedures have been undertaken to form an opinion whether, in all material respects, the financial report is presented fairly in accordance with the cash basis of accounting whereby revenue is recorded when it is received, expenses are recorded when they are paid, and no assets or liabilities, other than cash and bank balances, are recorded. Accounting Standards and other professional reporting requirements (UIG Consensus Views) are not applicable to the cash basis of accounting adopted by Metrology Society of Australia.

The audit opinion expressed in this report has been formed on the above basis.

Audit Opinion

In my opinion the financial reports presents fairly in accordance with the cash basis of accounting, as described above, the payments and receipts of the Metrology Society of Australia for the year ended 30 June 2002 and its cash and bank balances as at that 30 June 2003.

BF Thornton CPA

26 Penrith Avenue, WHEELER HEIGHTS NSW 2097

MOTIONS

1. Fees for 2003/2004 remain as they are:

Associate member	\$35
Full member	\$40
Fellow	\$45
Joining fee is equal to 1 year's subscription	

2. That Marianne Philips be elected as the auditor for the financial year July 2003 to June 2004.

MSA Management Committee

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Next Issue

- The Australian Kilogramme
- Timed to Perfection

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