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METROLOGIST

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Training

Quantification 5

Riverbank Reflections 2

History of Scottish W & M

From the Editor

This issue focuses on the topic "Training" and a number of *advertorials* are featured. Jane's report looks at this aspect of metrology and offers some thoughts for us to ponder.

The conference to be held in Canberra later this year - *Smart measurements: Metrologists Advancing Industry* is getting close now. Enclosed with TAM is a Registration Brochure for your use.

In this issue we continue our popular series - Jeff Tapping's *Quantification* and Ron Cook's - *Riverbank Reflections*. Both are entertaining and thought provoking.

We welcome Julian Holland back as a contributor, with his book review on the history of Scottish Weights and Measures. The cover photo shows a set of standard weights.

- *Maurie Hooper*

Cover: Set of troy nesting weights, 1687. See the Book Review on page 15.

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:

The Editor
The Australian Metrologist
11 Richland Road
NEWTON SA 5074
Phone: (08) 8365 2451
E-mail: maurieh@ozemail.com.au

The deadline for the next issue is 31st August 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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Insert one brochure in each TAM = $300

Contact the TAM editor for further details.

Please note: **Camera ready artwork is to be supplied. Size and specifications are available from the editor. If extra typesetting etc is required an extra charge will apply. MSA members receive a 10% discount when they place advertisements in TAM.**

MSA Membership Enquiries

Contact either your State Coordinators or the Secretary, Mr Mehrdad Ghaffari (02) 8467 3508, e-mail address mehrdad.ghaffari@measurement.gov.au or write to:

The Secretary, Metrology Society of Australia
c/o National Measurement Institute
PO Box 264
LINDFIELD NSW 2070

The **MSA website** address is www.metrology.asn.au

Webmaster: Mark Thomas (03) 9244 4042 (wk)

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 - July 2005

Ever since MSA2004 the topic of **Training and Education** has been high on the National Committee's agenda.

For more than twenty years there has been a shortage of teachers, particularly for the sciences and math. When you look at such a situation it is also not surprising that there is a shortage of Metrologists. Over the past ten years there has been a significant reduction in the number of government and semi-government laboratories. As a result, there has been a reduction in the numbers of trained metrologists. Few if any private organizations can afford to run and or develop training courses for their staff. As in all other areas of training they are looking to the education community and government to provide the skilled labour. As the tenure of staff within organisations shortens business is less inclined to invest the time in staff to train them and allow them to develop skills on the job. Consequently there is also a shift to reliance by employers on paper qualification over experience. Employers are looking for people who have a qualification as insurance that the person has the skills and knowledge to step straight into a job. There is also a related reluctance to risk that a person's experience will be enough. Whether this is sound management or not, it is clear that in the short term it is unlikely to change. This places the metrology community in an interesting and difficult situation.

It is clear that the Federal Government has recognized that there is a general shortage of skilled labour in Australia. There are talks at a variety of Government levels about the shortage of apprentices and the need to import skilled labour. However metrology does not even make it onto the official list of skills, so how will it be catered for?

There have been a variety of attempts to raise the profile of metrology and the training issues however typically these have been less than successful. TAFE courses have been developed but have tended to be short-term ventures. The small numbers of students available at any one time makes the running of courses unviable. The Swinburne IRIS course - Graduate Certificate of Engineering (Metrology and Quality) - as a distance education course has been somewhat more successful, but is only really staying afloat at this stage because of the students it is getting from Defence.

Historically, government has indirectly played a big role in the development of these types of skills bases, acting as a training ground. This worked in the past because there were more government organisations and arguably more resources. This meant that leakage of trained personnel into the private workforce did not cripple government agencies. But in these days of tighter budgets and significantly less freedom to recruit, government agencies cannot afford to act as the default training ground for industry.

What is the answer? To be honest I don't know. However in part it is going to need a cultural change within industry to recognize that training is a necessary investment of business. It is also going to need a heavy push from Federal and State Governments. Recognition on their part that among many other training shortages, metrology is a key one to the development and growth of smart industries.

To this end we have a unique opportunity from the 19th to 21st October; the 6th Biennial Conference of the Metrology Society of Australia is to be held in Canberra. To paraphrase a famous quote, "If the politicians won't come to us then we must go to the politicians." This is our opportunity to show that metrology is both important to industry and to the Australian economy at large. But to demonstrate this YOU need to be there, showing WE have a voice and that what we have to say and share is important. So I encourage you think seriously about attending the conference. The topic this year is "Smart Industry". As always I know it will be an enjoyable and educative event but it needs YOU.

As an introduction, this issue of TAM is slightly different to some others you may have seen. It is a series of "advertorials" to inform you of what training is out there. We want to start a robust conversation among the membership to identify ways we can reverse the "brain drain" from metrology.

I hope you enjoy this edition of TAM and look forward to seeing to in Canberra in October. The annual meeting for MSA will be held in Canberra as part of the conference and I would like to see some new people stepping forward to lead the MSA. So please if you believe that metrology is important (and I assume you do if you are reading this) then you have something offer. Step forward, nominate for the National Committee or contact your state coordinator, and offer a hand!

- Dr Jane Warne

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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

From the Conference Committee

Enclosed with this issue of TAM is a registration brochure for **the Metrology Society of Australia's 6th Biennial Conference**. The conference will commence with a "NATA Starter" cocktail party from 1900 to 2100 on Wednesday 19 October 2005. The Hon Warren Entsch MP, Parliamentary Secretary to the Minister for Industry, Science and Resources, will officially open the conference on Thursday 20 October. This will be a start for the two days of an exciting program comprised of over 40 presentations covering various areas of measurement, as well as workshops and trade displays. With its theme "Smart Measurements: Metrologists Advancing Industry" the Conference will be a showcase of metrology and its relevance to industry and to a wide range of stakeholders, including Government.

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. The conference will conclude on Friday 21 October with a closing barbecue.

The MSA 2005 Conference Committee looks forward to seeing you again at what promises to be a most exciting conference. Please use the enclosed brochure to register early, taking advantage of the discounted rate that is offered until 15 August 2005. As the conference will immediately follow the famous Canberra Floriade, accommodation may be difficult to find at a short notice. The committee has negotiated with ANU an excellent accommodation package, however the number of rooms is limited, so early registration would be advantageous.

Ilya Budovsky,
Chair, MSA2005 Conference Committee

TRAINING - Advertorials

Training Services from the National Measurement Institute

The National Measurement Institute (NMI) was formed in July 2004 following the amalgamation of the National Measurement Laboratory, the National Standards Commission and the Australian Government Analytical Laboratories.

The new organisation has a broad spectrum of measurement expertise and offers training in physical, legal, and chemical metrology. The training is mainly in the form of short courses (1 to 3 days) in specific areas of measurement developed to meet industry needs. NMI also provides in-house training or consultancy, tailored to suit a particular organisation's requirements. NMI also provides training to developing economies in the Asia-Pacific region.

Courses focus on giving participants an understanding of the key factors that affect their measurements and include practical sessions. Comprehensive course materials are also provided.

Courses on the verification of legal measuring instruments such as weighing instruments and fuel dispensers are carried out in cooperation with the state and territory trade measurement agencies.

Courses are run at intervals to suit current demand from industry, for example, the estimating measurement uncertainty and the analytical method validation courses are currently run every few months whilst the specialist calibration courses are run at one or two yearly intervals. NMI has the following courses scheduled :-

Physical metrology

Estimating measurement uncertainty (1 day)
Melbourne, 12 September 2005
Sydney, 22 September 2005
Melbourne, 1 December 2005
Sydney, 8 December 2005

Pressure measurement (2 days) Melbourne, 13-14 September 2005

Temperature measurement (3 days) Sydney, 9-11 November 2005

Radiometry (2 days) Sydney, 15-16 February 2006

Electrical measurement (2 days) Sydney, 15-16 March 2006

Time and frequency measurement (2 days) Sydney, 19-20 April 2006

Calibration of weights and balances (2 days) Sydney, 10-11 May 2006

Chemical metrology

Analytical method validation (2 days)
Sydney, 20-21 June 2005
Brisbane, 9-10 August 2005
Melbourne, 18-19 October 2005

Estimating measurement uncertainty (2 days)
Brisbane, 23-24 June 2005
Sydney, 11-12 August 2005
Melbourne, 20-21 October 2005

Legal metrology

Legal metrology officers course (3 days) Sydney, 17-19 August 2005

Non-LPG fuel dispensers (1 day) Sydney, 23 August 2005

Non-automatic weighing instruments (1 day) Sydney, 21 September 2005

Full details of all courses offered are available on the NMI website at www.measurement.gov.au or by contacting contact NMI's Training Section on (02) 8467 3796.

The future

NMI seeks input from industry on areas where additional measurement training is required. A proposal has been submitted to the Department of Education, Science and Technology (with the support of NATA, MSA and Manufacturing Skills Australia) for funding to develop entry level training for calibration technicians. If funded this training will also enhance the measurement training aspects of currently available mainstream technical courses.

NATA Training Services

NATA's Training Services Group was established in 1987 to fill the need within Australia for training courses related specifically to laboratory management. Since that time, NATA Training Services has become a well-respected training organisation within the Asia-Pacific region and is actively conducting training courses throughout Australia and the Asia-Pacific region on topics related to laboratory management systems.

NATA Training Services' courses cover the interpretation and application of the relevant national and international standards to support NATA's accreditation activities in laboratory, inspection, OECD Good Laboratory Practice and medical imaging, accreditation. Our courses cover the establishment and implementation of effective management systems, as well as internal and external auditing of such systems.

All courses are presented by experienced trainers who retain the currency of their experience through involvement in NATA's laboratory accreditation assessments.

NATA's Training Services Group provides regular public and in-company sessions across Australia in the following topics:

- Documenting and Implementing your Laboratory Management System

- Understanding NATA's ISO/IEC 17025 Requirements
- Understanding ISO 15189 – Accreditation Requirements for Medical Laboratories
- Internal Audits
- OECD Principles of Good Laboratory Practice
- Quality Control in the Microbiological Laboratory
- Quality Management in the Laboratory

NATA's Training Services Group can also provide training in ISO9001:2000 as part of any in-company laboratory training, if required.

Who should I contact at NATA?

NATA's Training Services Group is based in the Sydney Office. All inquiries regarding laboratory-related training can be directed to trainingservices@nata.asn.au or telephone 02 9736 8222 or freecall 1800 621 666 and ask to speak to one of the members of the Training Services Group.

Alternatively you can visit the NATA website at www.nata.asn.au for updated course information and our latest training schedule or to simply register on-line.

Learning that's practical and enjoyable!

MTI
METROLOGY TRAINING INTERNATIONAL PTY LTD

PRACTICAL MEASUREMENT UNCERTAINTY COURSES

Metrology Training International is a specialised training company that offers both one and three day training courses in Measurement Uncertainty. These courses present an overview of the ISO "Guide to the Expression of Uncertainty in Measurement" and provide a practical approach to calculation of measurement uncertainty. Not just a lecture, but "hands on" experience in calculations and uncertainty estimation.

The one day course is suitable for managers who need an overview of measurement uncertainty or testing officers who are involved in a limited range of tests. The three day course covers the same basic information as is in the one-day course but extends this to cover almost every need of the practising metrology and provides invaluable training for calibration and testing staff.

While public courses are run in Australian capital cities annually, MTI specialises in in-house courses with worked examples based on the client's activities. Courses are also run overseas for various organisations.

The three day course is normally run at graduate level, but is presented in a manner so that attendees with experience and a good understanding of at least one field of testing and basic skills in algebra and numerical calculation will be able to complete the course. Courses pitched at the technician level are available.

OVERVIEW

The ISO Guide to the Expression of Uncertainty in Measurement, first published in 1993, was the first internationally recognised statement of the methodology of metrological specification and evaluation of measurement uncertainty. It resulted from over a decade of work by the leading international organisations in legal and technical metrology and measurement science.

The courses cover the basic estimation process from specification of the measurement model through to evaluation of the final figure of measurement uncertainty. The course material is regularly updated and new examples added. Course notes, a text and a certificate are provided to all attendees. The three day course incorporates a written test and those who achieve a pass mark receive a Certificate of Completion. It therefore attracts double points for the IE Aust CPD program.

CONTENT

This includes: Introductory comments and background information covering the ISO Guide and its applications, review of nomenclature and definitions, sources of uncertainty, the prime sources of uncertainty and their nature, statistics for the metrologist, worked examples using a calculator or notebook computer, creating simple measurement models, calculation of standard uncertainties, combined and expanded uncertainties, class exercises in uncertainty estimation and reporting uncertainty.
It also covers: More advanced concepts, including degrees of freedom, Student's t distribution and its application, correlation, higher order terms, asymmetric distributions, illustrative examples and more complex exercises, revision exercises, numeric methods vs analytical methods, Monte Carlo calculations, more class exercises and worked examples, and finally the proficiency appraisal test.

The courses are presented by Mr Ron Cook, an experienced metrologist with extensive practical experience in applying the Guide to many fields of precision measurement.

Contact Metrology Training International for more details at:

7 Dallas Ave.
HUGHESDALE,
AUSTRALIA,
3166.
Ph 613 9504 3479 Fax 613 9504 3479
Mob 0438512045
E-mail mettrain@optusnet.com.au

Manufacturing Learning Australia

Laboratory Operations
Training Package PML04

What is a Training Package?

Training Packages provide the basis for development of essential skills and nationally recognised qualifications related directly to work roles. Training Packages have three components which have been developed with industry and endorsed by the National Training Quality Council (NTQC):

- the competency standards which reflect real workplace skills and knowledge
- a framework showing how the competencies combine to make up qualifications agreed by industry as relevant to real workplace requirements
- guidelines that define the requirements for consistency in assessing competencies

These are designed to enable nationally consistent qualifications with appropriate skills and at appropriate levels for your industry. Registered Training Organisations (RTOs) base their training, assessment and awarding of qualifications on Training Packages.

Who is the Laboratory Operations Training Package for?

This nationally endorsed Training Package (PML04) has been developed to reflect the skills and knowledge required by current and prospective employees in scientific and technical occupations across many industries.

Does this Training Package apply to your industry?

PML04 has been designed for use in many different industries and the skills embedded in the qualifications are relevant to employees in all laboratory settings or technical occupations. The qualifications are portable across industries and are based on a logical skills progression used in workplaces. As required by industry, specialisations are available at diploma level. PML04 directly addresses the training needs of technical staff working in a wide range of industries. For example:
- people working in manufacturing and field based sampling and testing
- laboratory assistants testing materials and products in industries such as food manufacturing, construction materials, mining, biomedical, biotechnical, environmental monitoring etc
- technicians and technical officers working in laboratories that serve a range of industries
- senior technicians and laboratory supervisors overseeing operations

What does it do for me?

Some enterprises use Training Packages to provide training and assessment that leads to qualifications for their workers. If you decide to offer training for qualifications, you may be eligible for Commonwealth and State training subsidies previously provided only for training in the traditional trades. You do not have to train towards qualifications. There are other ways you can use an industry Training Package. The competencies in this Training Package provide a comprehensive map of workplace skills and knowledge, defined in consultation with Public RTOs (ie the TAFE system), private RTOs and large and small enterprises.

For example, you can use this Training Package to:
- identify training needs and develop a training plan
- develop role and job descriptions for your employees by choosing particular combinations of units of competency
- create competency profiles for your workers by mixing and matching units of competency from various levels
- develop quality assurance systems
- work in partnership with an RTO to train and assess towards qualifications
- recognise the current competencies of your employees by assessing them against the units of competency
- support your safety and risk management systems
- plan career pathways
- recruit or classify staff

Statements of Attainment can be issued to those who have completed one or more units of competency but have not met the requirements of a qualification.

Frequenty asked questions

Is this a new Training Package?

No. Additional qualifications and units of competency required
re-endorsement by industry and the NTQC resulting in the revised Training Package PML04.

Do I need to buy a new version?

Yes. In order to deliver qualifications you are required to have the current version. Also to ensure that you have the latest industry standards.

Will this be the last version?

Training Packages are designed to be 'living documents' and need to be kept current with input from industry and training providers who do, or who want to, provide training using the package. Manufacturing Learning Australia and your local industry training body are keen to have your comments so that we can present up-to-date feedback into the continuous improvement process. Watch the MLA website for the latest on revisions to the Training Package.

What about support materials?

There are support materials available, some of which have been developed specifically for this Training Package. Some are available via Australian Training Products, some from other sources. Manufacturing Learning Australia keeps an up-to-date audit of resources that support the Training Package. This audit is available from www.mlaust.com.

What are the changes to the Laboratory Operations Training Package?

The Laboratory Operations Training Package (PML04) has been reviewed extensively. The Package now covers additional sectors and reflects up to date industry requirements.

Existing units

Although many of the existing units have been carried forward into PML04, all units have been updated for changes that have occurred in the workplace since development of PML99.

Existing units of competency have been updated with respect to:

- size, coverage, currency and titles
- clarity of elements, performance criteria, range of variables and evidence guides
- underpinning knowledge
- language, access and equity issues identified by the Equity Consultant
- prerequisites

The OHS units have all been reviewed and updated with input from the National Occupational Health and Safety Commission (NOHSC).

New units

New units of competency have been developed in close cooperation with expert groups to cover additional industry sectors. PML04 now provides better coverage for a wider range of industries, providing access to national qualifications and pathways for more technicians in areas such as mineral assay, construction materials testing, environmental monitoring, biotechnology, manufacturing testing, food testing and specialist calibration, in recognition of the growing importance of these fields.

Packaging rules

The Qualifications Framework has been reviewed to increase flexibility by reducing the number of core units and increasing the pool of electives to choose from.

New qualification

A Certificate II in Sampling and Measurement PML20104 has been introduced to the Training Package to meet the training needs of people working in production and field-based sampling and measurement. The new certificate will also facilitate VET in schools programs and provide a pathway for New Apprenticeships.

Assessment guidelines

The assessment guidelines have been reviewed to align with ANTA guidelines and to include issues identified by the Equity Consultant. Implementation of these guidelines will be similar to the existing assessment guidelines. These model guidelines have been customised by the addition of a section on assessment in the laboratory and testing industries.

Transition

People with existing qualifications from PML99 will still have those qualifications recognised. People who have some units of competency recognised (while not having a full qualification) should have the equivalent units of competency in PML04 granted and then be assessed for the relevant qualification under PML04.

Certificate II in Sampling and Measurement PML20104

In the construction, manufacturing, mining and environmental industry sectors, there is a clear vocational outcome at Certificate II for people working as sampler/testers in production or field operations including, for example, samplers and testers, production personnel, plant operators, production operators, field assistants, drivers and sample couriers. The Certificate II in Sampling and Measurement PML20104 provides a flexible package of competencies which meets the needs of workers in these roles.

Certificate III in Laboratory Skills PML30104

This qualification provides a broad and flexible package of competencies which meets the needs of laboratory assistants, instrument operators and similar personnel. The core and wide range of electives is designed to maximise the portability of this qualification, which is the entry level required for laboratory personnel.

Workers in these roles can be found in all industry sectors and will perform straightforward sampling and testing. They follow set procedures and recipes, and apply well developed technical skills and basic scientific knowledge. They generally work inside a laboratory but may also perform technical tasks in the field or within production plants. They may also perform a range of laboratory maintenance and office tasks.

Certificate IV in Laboratory Techniques PML40104

The Certificate IV in Laboratory Techniques provides a broad and flexible package of competencies which meets the needs of technical assistants, instrument operators and similar personnel.

There is a laboratory role at this level in some industry sectors. For example, some enterprises in the food and manufacturing sectors employ personnel who conduct a wider range of basic tests than do laboratory assistants and who generally have a more enhanced quality role. They may also conduct a limited number of specialised tests. While they generally work in a laboratory, they often work closely with other personnel throughout the workplace and with suppliers. They may assist other personnel to solve technical problems and to adjust formulations and production mixes; they may also train them to collect samples and conduct basic tests.

Diploma of Laboratory Technology PML50104

This qualification provides broad and flexible packages of competencies which meet the needs of technical officers, technical specialists and similar personnel.

Workers in these roles conduct a wide range of sampling and testing that requires the application of broad scientific/ technical knowledge and skills, with substantial depth in some areas. Although technical officers generally work in a laboratory, they often work closely with personnel in other teams within a section of the workplace. They may liaise with suppliers to troubleshoot product non-conformance at the direction of laboratory supervisors or managers. The work of technical officers involves frequent peak periods and interruptions. Industry sector/specialisations could include (but are not limited to):

- Biological testing
- Biological and environmental testing
- Biotechnology
- Calibration
- Chemical testing
- Construction materials testing
- Environmental monitoring
- Food testing
- Manufacturing testing
- Mineral assay
- Pathology testing
- Scientific glassblowing

Advanced Diploma of Laboratory Operations PML60104

This qualification provides a broad and flexible package of competencies which meets the needs of laboratory supervisors, senior technical officers and similar personnel.

Workers in these roles are generally responsible for the planning, allocation of tasks, coordination, quality assurance, recording and reporting of laboratory outputs within their work area or project team. This requires significant judgement about work sequences, choice of appropriate technology and procedures to ensure that products and services meet customer expectations and are provided safely and efficiently in keeping with enterprise business plan.

Under broad direction from scientists/medical staff/engineers the senior technician/supervisor accepts responsibility for the day to day operation of his/her work/functional area. They are often responsible for the effective implementation of operational policies and the technical training of personnel in their work area. They also contribute significantly to the development of these policies through the application of specialised technical knowledge.

The work of laboratory supervisors involves frequent peak periods, multiple and competing demands and frequent interruptions. Immediate decisions are often required.

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Recognition of current competency

Some existing workers may have gained the skills and knowledge outlined in the units of competency through their work experience. This can be established by the RCC assessment process.

Competency groupings

There are 94 units of competency in PML04. The units are not grouped, other than as core and electives. The core is different for each qualification.

The numerical portion of the unit code indicates at which AQF certificate level the unit might be packaged, and the alpha portion indicates the focus of the unit of competency. For example:

PMLDATA200A	Certificate II	Scientific calculations, data skills
PMLSAMP200A	Certificate II	Sampling skills
PMLCOM300B	Certificate III	Communication skills
PMLMAIN300B	Certificate III	Maintenance
PMLORG400A	Certificate IV	Organisational skills
PMLOHS400A	Certificate IV	Health and safety skills
PMLCAL500A	Diploma	Calibration skills
PMLTEST503B	Diploma	Testing/technical skills
PMLSCIG501B	Diploma	Scientific glassblowing
PMLTEAM600B	Advanced Diploma	Working with teams
PMLQUAL601B	Advanced Diploma	Quality system focus

Dr Ivan Johnstone
CIT Solutions *wrote the reviewed package.*

"Most people think science is only about white coats and PhDs. But laboratory work, such as testing the quality of manufactured products or ensuring the quality of sampling and testing services, is critically dependent on having highly skilled technicians. Calibration is so fundamental to all science and engineering – it ensures that an incredibly wide range of instruments and equipment produce precise results – everything from petrol pumps and aircraft navigation systems to pregnancy tests."

Common job roles

Sampler/Tester
working in manufacturing or a field environment

Samplers and testers conduct limited sampling and measurement as part of their duties. In areas such as mineral assay, for example, this work forms a whole job role. They apply a restricted range of skills and operational knowledge to perform these tasks and do not generally work inside a laboratory.

Laboratory Assistants

Laboratory assistants perform straightforward sampling and testing. They follow set procedures and recipes, and apply well developed technical skills and basic scientific knowledge. The majority of their work involves a predictable flow of parallel or similar tasks within one scientific discipline. For example:
- a laboratory assistant working in construction materials testing receives and prepares soil samples for classification testing.
- a laboratory assistant working at a dairy factory gathers samples from the milk tankers, vats and the processing line, and performs routine chemical and bacteriological tests on the samples.

Technical Assistants

Technical assistants undertake a wide range of sampling and testing that requires the application of a broad range of technical skills and some scientific knowledge. Although technicians generally work in a laboratory, they often work closely with other personnel throughout the workplace. For example, a technician who works in a mineral preparation plant receives and logs incoming ore samples and operates handling equipment to move samples to treatment points. In the laboratory, the technician conducts routine chemical and physical tests and redirects other subsamples for specialised analyses.

Technical Officers

Technical officers conduct a wide range of sampling and testing that requires the application of broad scientific-technical knowledge and skills, with substantial depth in some areas. Although technical officers generally work in a laboratory, they often work closely with personnel in other teams within a section of the workplace. Technical officers play an important role in laboratories in industries such as biotechnology, calibration, pathology, food manufacturing and manufacturing in general.

Manufacturing Learning Australia
PO Box 124
Camperdown BC, NSW 1450
T: 02 9518 7785
E: info@mlaust.com
W:www.mlaust.com

Quantification - Number 5

Jeffrey Tapping

I have received hundreds of emails following the last edition. Unfortunately all of the senders seemed to have difficulty addressing the measurement topics I discussed, and instead wanted to engage me in dialogue on the dimensions of anatomical components, or wanted to offer me cheap pharmaceuticals. So let's ignore them and get to the questions I posed.

Thermie is an artefact of early attempts to formulate a comprehensive system of units. It is the basic unit of heat in a metre-tonne-second system, and is the amount required to raise one tonne of water by one degree Celsius. It is therefore equal to one million calories. The cosy sounding name is derived from the Greek word for warm, *therm–*.

Frigorie is another obsolete unit concerned with heat, this time the rate of heat extraction. It is equal to an extraction rate of one kilocalorie per hour, and was used to rate refrigeration units. The less than cosy-sounding name was intended to imply the inverse of *calorie*.

Pieze is another relic of the metre-tonne-second units system. It was a unit of pressure equal to one *sthene* per square metre, and you all remember what a *sthene* is, don't you?

Poiseuille was a French physician and physiologist who was interested in blood flow, and developed a formula to describe the laminar flow of fluids in narrow tubes. His full name was Jean-Louis-Marie Poiseuille, (1799 - 1869). The unit of viscosity in the cgs (centimetre-gram-second) system, the *poise*, was named in his honour. But in France his full surname has also been used for a unit of dynamic viscosity in SI units, with the symbol Pl. The units of the *poiseuille* are 'newton second per metre squared'. Incidentally the man Poiseuille is credited with being the first to use a manometer to measure blood pressure. And to be even-handed, Poiseuille's formula was simultaneously developed by a German engineer, Gotthilf Hagen.

Cubit opens up the wider topic of ancient measurement systems, because its use goes back at least 3000 years and was widespread. Similar units were used in the ancient civilisations of Egypt, Israel, Rome, Greece and Babylon. The length of one cubit was based on the distance from the point of an elbow to the tip of the middle finger, but was standardised in each region. Egypt and Israel had an additional similar unit known the Royal cubit (see below). The dimensions were as follows:

Babylon	528 mm
Greece	462 mm
Rome	444 mm
Israel	450 mm
Egypt	451 mm
Royal cubit	524 mm

I think that the Ancient Egyptians are a wonderful demonstration of how necessity drives technology and innovation. Much of their system of measurement units was probably messy, but the cubit was carefully controlled. The Pharaoh maintained a granite standard and all cubit sticks were required to be checked against it once each year. Perhaps they even had an ancient NATA, but no relics have yet been unearthed. But as a demonstration of the efficacy of the system, the sides of the Great Pyramid vary no more than 0.05 percent from the mean length of 230.364 metres.

I will have more to say about ancient measurement systems in the future.

Degree Rankine and Degree Sikes

The only connection between these two units is the use of the word *degree* in its more general sense of "extent". The *Rankine scale* is the Fahrenheit version of the Kelvin temperature scale, that is, it is the Fahrenheit temperature plus the absolute temperature of the freezing temperature of water, 491.67°R. It was named after the British physicist and engineer, William Rankine (1820-1870).

The *degree Sikes* on the other hand, is a measure of specific gravity, used in measuring the composition of alcohol-water mixtures in U.K. It is based on the ratio of a specific gravity to that of water at 60°F (15.65°C). This temperature was probably that of the cellars in which the wine was stored.

Density and densité

The first is, of course, the mass per unit volume. The second is a French term for relative density, that is, what we would call specific gravity.

Atmospheres

You were asked in the last issue, what is the difference between a *standard atmosphere* and a *technical atmosphere*? The short answer to the question is a ratio of 1.01325. You have probably twigged that these are two versions of a standard atmospheric pressure, but where does this ratio come from? My source gave the magnitudes as 14.6959 lb/in^2 for the *standard atmosphere*, and 14.2233 lb/in^2 for the *technical atmosphere*. The Imperial units threw me for a bit, but then I realised that *standard atmosphere* in SI units is 101.325 kPa, so the *technical atmosphere* is exactly 100 kPa. The *standard atmosphere* is equal to 760 mm of mercury column, an adaption of the old Imperial standard of 30 inches (762 mm), but I do not know what the *technical atmosphere* was used for or who used it? Does anyone out there know?

The Foot

Last issue's Tricky Question asked the question of the origin of the unit of length, the foot. Firstly it must be made clear that matters surrounding old units must necessarily be murky, and we must go on fragments of information and some detective work. So here we go.

Many early length measurements were taken from things at hand, and what could be more at hand than a palm, a digit, or in the case of the cubit, the length from an elbow to the finger-tip. So it might be seen to be natural that short distances on the ground would be measured out using the lengths of feet. But a doubt arises when we look at the magnitudes assigned to the unit.

In historical times there have been many length units named with the word for foot in the local language, and although they varied in magnitude, they were all similar in size to the British foot which was an official unit here until recently.

Examples are:

British Imperial system	1 foot = 304.8 mm
Ancient Babylon	1 'foot' = 354 mm
Ancient Greece	1 'foot' = 309 mm
Ancient Rome	1 pes = 297 mm
Austria	1 fusz = 316.1 mm
Denmark	1 fod = 314.1 mm
Norway	1 fot = 296.9 mm
Portugal	1 pé = 333.2 mm
France	1 pied de roi = 324.9 mm
Italy	1 pie = 297.9 mm
Spain	1 pie = 278.6 mm

Now when you look at these values you may see that they are all at the very top or above the normal range of human foot-lengths. If, like me, you have sons whose feet are much bigger than yours, you are still most unlikely to have to buy size 14 shoes (for a foot 300 mm long). Is it likely that any Babylonian man had feet a few sizes bigger than this? Hmm, I think not! So where did the unit come from? One suggestion is that it was simply a convenient multiple of a smaller unit such as the inch (length of a thumb-joint), or a fraction of a larger unit such as the yard (a pace). The name was applied simply because it then turned out to be close to the length of a foot.

You will see in the table that two countries had a unit called a *pie*. I could have included that in my list of units that are English common words. And the French unit, the *pied de roi*, merits a mention. The name means "royal foot", and was a unit made deliberately larger than the Roman foot, with the name implying something like "grand foot". This sort of practice may have started with the ancient Egyptians, who had a Royal cubit which was larger than the usual one mentioned above. There is also some suggestion that they had a "royal foot" as well as a more modest version.

The size of the U.S. gallon

The size of the *U.S. gallon* versus the *Imperial gallon* is a lesson in the momentum of events. In mediaeval Britain standards of measurement were messy, to put it mildly. At various times monarchs tidied things up but even in the eighteenth century there were different official gallon measures for wine, ale and corn. In 1824 the Weights and Measures Act decreed a single gallon,

continued on page 14

Riverbank Reflections 2

Ron Cook

G'day.

The weather has been unusually mild and with less water in the rivers the density of fish ought to be higher. While laboratory experiments with bowls of water and small golden fish might seem to prove the theory it doesn't seem to be confirmed by my recent experiences.

While continuing to accumulate experimental evidence to test the hypothesis, I'm reading – there's not much else to do. I'm reading the most recent edition of "The Science of Discworld" by Terry Pratchett, Ian Stewart and Jack Cohen. The early chapters talk about lies-to-children, that is in an effort to impart some understanding the explanations of science and the Way the World Works are simplified to an extent that what is said it isn't true. This is a concept I'm very familiar with.

At the Moorabool Street Technical School we were told, in a very serious tone, that gases were compressible but solids and liquids were not. Very important information if you were about to become a motor mechanic and needed to understand inflated tyres and hydraulic brakes. When I moved on to the Gordon Institute of Technology I was told, in the same serious tone, that not only could you compress gases but liquids and solids as well. And if you compressed them enough strange things happened. Gases became liquid, liquids became solid and solids, having nowhere to go, broke. I did manage to break a few solids, not to mention a few bits of laboratory hardware and an occasional instrument during my time in the Institute, but it is best we draw a veil over that. What I learned was that if you adopt a suitably serious tone you can tell some pretty large fibs. Just ask a politician, a used car salesman or anyone explaining uncertainty of measurement.

I and some of my colleagues have become liars-to-metrologists, a quite satisfying activity. In explaining uncertainty of measurement we start out by either not mentioning things like Degrees of Freedom, Correlation, Higher Order Terms and Asymmetric Distributions or claiming they don't exist. I have heard my fellow liars-to-metrologists tell some whoppers. All in a good cause mind you. Being told everything all at once is overwhelming. Once we have grasped the basics then we can be told some more of the truth (as it appears to be) and given some guidance on handling degrees of freedom etc.

Some lies-to-metrologists have been spread about with the intention of making the calculations simpler. In the good old days BC, Before Calculators of the electronic kind and long before Personal Computers were common, all kinds of otherwise sober and worthy members of the community devised approximate solutions to problems such as calculating a standard deviation and finding the value of Students t. Some neat solutions were even devised for problems that didn't exist! That these approximate methods are still in circulation is cause for a little sadness. Why not use the current tools and do the job properly? It takes no more effort and the procedures are available in the software Help file. If it's not in the GUM then it is suspect.

These sorts of lies-to-metrologists ultimately cause grief. People who have been given these "short cuts" are going to forget it is only a rough calculation and will try to base important decisions on the result and even worse are likely to use the procedure when it is totally inappropriate to do so.

There is another common lie-to-metrologists, namely that the basic ISO GUM formulas are to be completely trusted. They are approximations and have embedded assumptions that sometimes aren't completely justified. In particular GUM equation 10,

$u_c(y)=\sqrt{\sum_{i=1}^{n}(c_i u_i)^2}$, for the combined standard uncertainty applies only if there is no correlation and no significant higher order term. I tell this lie regularly to test officers. Actually for most of the time it isn't a lie and even when it is a lie it generally doesn't do any harm as long as the model equation is adequate, that is it is modified to minimize the effects of correlation or higher order terms. For example the effect of varying temperature can give rise to correlated uncertainties in at least one pair of inputs. Incorporating temperature coefficients into the model removes the problem and equation 10 is valid once more.

I have found some metrologists even lie to themselves. While self delusion isn't the sole prerogative of metrologists as a group most of us feel more comfortable about our estimates if we have some numbers with which we can calculate an average and an ESDM. Some metrologists believe that a set of 5 measured values gives a really good uncertainty estimate but an estimate based on experience is pretty wobbly. What they overlook is that even with about 50 measured values our estimate of the ESDM is uncertain to about 10%. You can test this out by using the equation that links degrees of freedom and relative uncertainty. A little manipulation gives the relative uncertainty,

$$\frac{\Delta u}{u} \approx \frac{1}{\sqrt{2n-1}}$$

for n measurements. Try this for n = 5!

Another related lie-to oneself is that a coverage factor of 2 is OK for all testing. Just bear in mind that while we assume a Normal type distribution, in fact even with 50 measurements a histogram of the measured values looks pretty chunky and there are often one or two apparent outliers. It gets worse for fewer measurements. Unless we have a very good argument we should accept the outliers as legitimate. So with a practical number of measurements, say 5, if the ESDM is a large contributor to the overall uncertainty we should not use the nominal coverage factor of 2 but use the Welch-Satterwaite equation to find the effective degrees of freedom for the combined standard uncertainty and hence Students t and a better value for the coverage factor. Not using Students t for k could result in underestimating the expanded uncertainty by as much as 50%. Remember that the number of degrees of freedom is a quality estimator for the associated uncertainty.

Incidentally the procedure in the Eurachem Guide to Quantifying Uncertainty in Analytical Measurement while acknowledging and describing the problem of a major uncertainty component with 5 degrees of freedom or less does not put much emphasis on this. As sampling errors are often dominant in analytical chemical work (so I'm told) I wonder if more attention should be given to degrees of freedom.

The largest proportion of uncertainty calculations are made without regard to degrees of freedom and use a nominal coverage factor of 2, the "don't you worry about that" lie. I don't have a problem with this, providing someone is watching out for those calculations for which such a process gives significant errors.

Another lie-to-metrologists is that the combined standard uncertainty will, because of the Central Limit Theorem have a Normal distribution. The theorem works well providing there is no dominant non-normal distribution in the mix. If we ignore the effect of a dominant uncertainty with a rectangular distribution we will overestimate the expanded uncertainty by up to 15%. This is a direct outcome of applying rules for Normal distributions to a non-normal distribution. We can either accept the overestimate as a consequence of sticking to the same procedure each time or we can use a more appropriate coverage facto. For a dominant rectangular distribution k would be about 1.69. "Dominant" means three or more times greater than any other term.

Lies-to-metrologists have their place and are a consequence of the human tendency to want simple stories to explain the world. So long as we make our estimates as best we can and are open about how we have made our calculations we should keep out of trouble.

In the meantime I'm starting to think that Terry Pratchett has produced another good read and the evidence clearly shows that the fish density theorem is flawed. Talk to you again later.

Ron Cook ©2005 ■

from page 11

defined as the volume occupied by "10 imperial pounds weight of distilled water weighed in air against brass weights with the water and the air at a temperature of 62 degrees of Fahrenheit's thermometer and with the barometer at 30 inches.". Around this time the U.S. was trying to get its measurement system in order, and decided in favour of bringing their system in close harmony with their major trading partner, Britain. But the U.S. had already been using the *wine gallon*, also known as *Queen Anne's gallon*, and so continued to use it even though it had been discarded in Britain. The metric system was then being adopted in France

Question 2: It has been pointed out previously that SI units are (with one exception), designated by two letters, the first a multiplier which is a power of ten, the second indicating a unique measurement unit. What are the longest designations for *non*-SI quantities?

Question 3: In spite of SI units the calorie is still used very widely to refer to food energy intake, and often as a loose term for the equivalent body fat or weight. But if you do lose a calorie of energy from your body or elsewhere, exactly how much would you lose?

Question 4: what are these measurement units?

Therblig
Kati
Fanega
Erlang
Amagat
eotvos unit

Question 5: What was the basis for the strange values in the Fahrenheit temperature scale?

And finally, the **Trick Question.** Who invented the Celsius scale of temperature that we now use?

■

BOOK REVIEW

Of bolls and charities: the tangled history of Scottish weights and measures

Julian Holland

Macleay Museum,
University of Sydney
julian@macleay.usyd.edu.au

R.D. Connor and A.D.C. Simpson, edited by A. Morrison-Low, ***"Weights and Measures in Scotland: A European Perspective"*** (Edinburgh: National Museums of Scotland and Tuckwell Press, 2004), 842pp, ISBN 1 901663 88 4, £50

Australia's metrological history is relatively short and straightforward. It can be accounted for in three phases, each derived from an external source. The first European settlers brought with them the muddled and unsatisfactory system prevailing in England in the late eighteenth century. This was superseded from the 1830s by the Imperial System introduced by an Act of the British Parliament in 1824. This simplified framework of measurement was a great improvement on its predecessor and lasted for a century and a half before the introduction of the metric system in the 1970s brought Australia into conformity with the majority of commercial and scientific practice in the world.

Trying to trace the metrological history of a much older nation presents greater difficulties. Measurement practice predates written and material records. In the case of Scotland, the task is to make sense of the fragmentary evidence and find an underlying logic to the metrological complexity which existed in the centuries before the Imperial System was promulgated in Britain in the 1820s.

Robin Connor and Allen Simpson have devoted many years to the careful analysis of the evidence to produce this major study of metrological history with a relevance reaching well beyond Scotland. Connor has previously published the standard account of *The Weights and Measures of England* (1987).

Scotland's use of weights and measures did not develop in isolation. The early history of measurement relates particularly to trade and taxes. Complexities arise where existing local practices are joined by measurement units governed by dominant trading partners. Scotland had important trading links with England from an early date, but was also connected with Continental trade networks, particularly through the sale of wool to Flanders.

The evidence is such that it is not possible to give a simple account of what standards of measures were used when in Scotland. Analysis and inference is required to find logical connections between the various standards apparently operating over time. The evidence consists of two kinds, the legislative record and surviving physical embodiments of measurement. Revisions were given to standard measures in various assizes over the centuries from the high middle ages. The interpretation of these is by no means straightforward.

The earliest framework of measurement was given in the David's Assize supposedly dating from the time of King David I who came to the throne in 1124. Brought up in England, David reformed much legislation on the English pattern. But the manuscript records which attribute laws to David I date from the following century and so may incorporate many silent amendments. This may not seem to matter for so early a period but in fact this remains a problem for interpreting later legislation.

Very little from the Scottish parliamentary record survives from before the early fifteenth century, with the record of acts being fairly complete and continuous from 1466. Scottish parliamentary acts were first produced in printed form in 1566, and several times subsequently, most comprehensively in the 'Record Edition' in the nineteenth century. The early collations of the acts were not produced as authentic historical documents but as a statement of the range of law as it was then operating. This presents problems of interpreting the metrological force of successive assizes in their own time.

The other principal source of evidence is the array of surviving physical artifacts of metrology. The physical evidence provides a valuable check on the legislative history. One of the most fascinating aspects of this study is the variety of ways in which a unit can vary depending on the context.

I am old enough to remember feet and inches, pounds and ounces, and so on, in daily use: sixteen ounces in a pound, fourteen pounds in a stone. Well, this was the tidied up arrangement in the Imperial system, and these were avoirdupois pounds. But there were also troy weights. Going back in time one finds there were parallel units depending on the commodity: ale gallons were not the same as wine gallons, and these could each vary over time.

There were several reasons why a given unit could vary, even for a particular commodity. A legal unit of volume could be defined in several ways. Firstly, it could be determined by the mass of its contents or its dimensional volume. The mass of the contents could be defined by water, either 'diuers watters' – a mixture of fresh and sea water – or fresh water of the river Tay. So long as a consistent type of water was used, determination by mass or linear dimension should give consistent results. This is fine for liquid measures but cannot be translated to the hierarchy of dry measures.

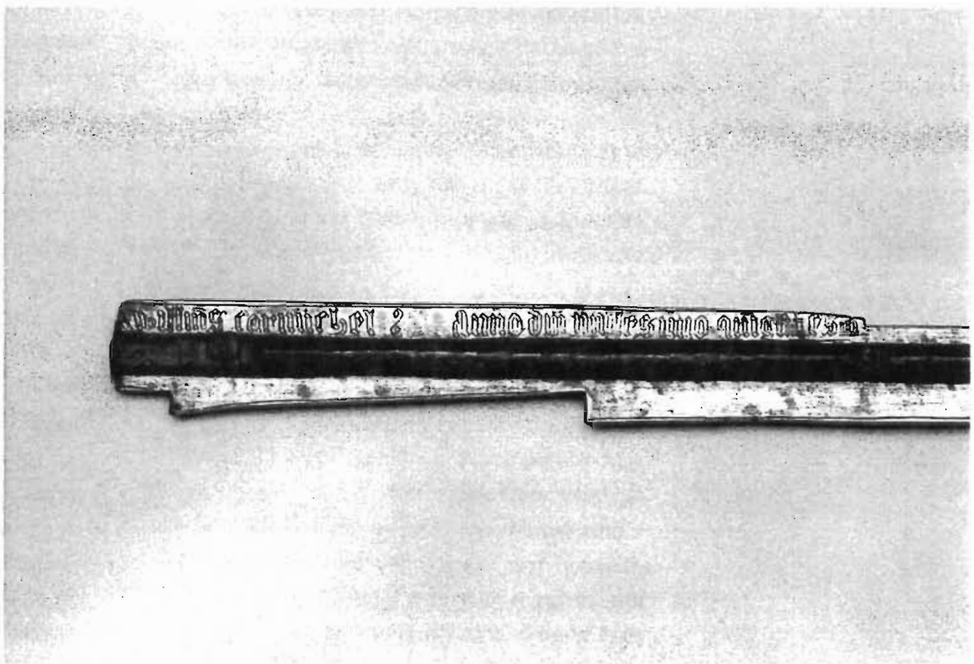
There is an apparent inconsistency in the definitions of the pint (dry measure) and the wheat firlot (the forth part of a boll) in the 1618 Assize. The firlot was a cylindrical vessel 19 1/16 inches diameter and 7 1/3 inches deep. Its capacity was 21 ¼ fills of the pint. These do not represent the same volume (if tested by liquid measure). The firlot contains 2110 cubic inches while 21 ¼ pints represents 2205 cubic inches. However, taking into account the physical characteristics of the material being measured (small seeds with rough surfaces), the shape of the vessels the seeds are poured into, the manner of pouring and the resultant stacking pattern, it turns out by experiment that the seeds are more tightly packed by about 4 ½ percent when poured into a broad vessel than into a narrow one. So, in fact, for measuring wheat, the firlot does represent 21 ¼ fills of the pint.

This is only one example of the need to understand the relation between the legal basis of metrology and the reality of commercial practice. The legal units were not necessarily given a physical embodiment because a system of allowances and 'charities' was applied in commercial practice which meant that an extra quantity was included in the transaction, often one sixteenth. In the case of 'water measures' this was usually one eighth. These were not liquid quantities but goods transported by sea. These various allowances for bulk goods protected the recipient against loss due to retail subdivision or spoilage in transport. Clearly it also favoured the buyer and landlords receiving feudal dues in kind. Connor and Simpson have carefully analysed the record of assizes and surviving early measures to show how the application of allowances seems to have driven a cycle of expansion of the dimensions of actual measures which were then incorporated into successive legal measures.

Weights and Measures in Scotland is a detailed and meticulous study which seeks to show an underlying logic to the development of Scotland's legal metrology. It is divided into three parts, the main text, an inventory of surviving standards, and a series of appendices. The inventory is an impressive collation of information with 261 entries covering individual items or groups of related items. These are discussed in detail and many are illustrated. Given that metrological legislation often sought to eliminate irregular or outdated measures, it is remarkable that such a large quantity of physical evidence remains, although some have been modified over time. The unique Inverkeithing firlot gauge dating from 1500 seems to have survived despite successive enlargements of the firlot due to its also being a gauge for the Scottish ell (37 inches) – see Figures 1 and 2.

Careful measurements of a number the early weights and measures underpin the close and intricate arguments of Part I. Just as the reader of a Russian novel needs a card of *dramatis personae* to keep track of the various characters' names, so the various relationships of weights

Figure 1. *Inverkeithing firlot gauge and ell bed made in 1500. This detail shows the inscription giving the name of William Carmichael and the date. In 1500 Carmichael was the Treasurer of the burgh of Edinburgh and his name thus indicates the authority of the gauge. No other such gauge is known. This one seems to have survived the successive increases in the firlot because of its dual use as a bed for testing ells, which remained 37 inches. (Item 1 in the Inventory)*



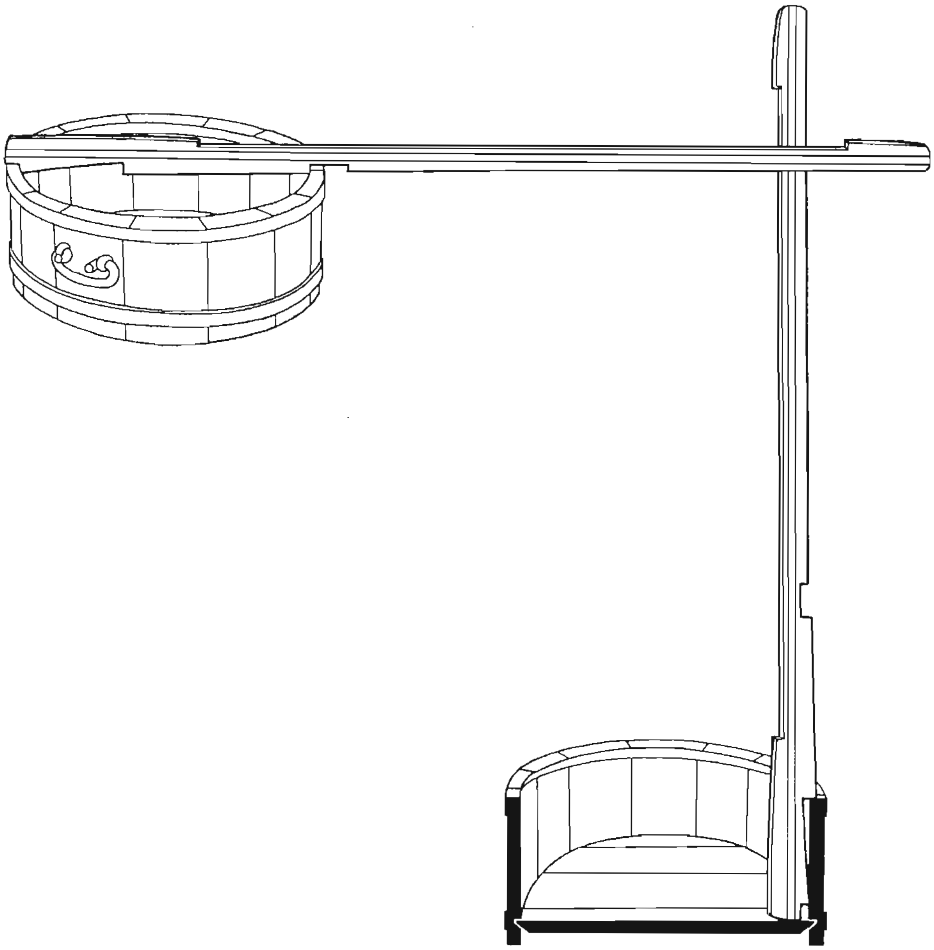


Figure 2. *Diagram showing the use of the Inverkeithing gauge to check the depth and diameter of a firlot measure.*

particularly require the reader to maintain at least a mental tabulation. We find stones with varying numbers of pounds, and pounds with varying numbers ofounces. And the ounces themselves are defined by a number of grains – which were slightly different from the grains used in recent centuries! This particularly applies to troy weights.

Troy weights have a very long history in relation to the trade in fine goods such as precious metals and spices. These were the sort of goods transported over long distances and worth weighing very accurately. Such trading means that measurement systems stretch beyond the local market. Troy weights derive their name from the French town of Troyes where seasonal trading fairs were held in the high middle ages, bringing together traders from the Low Countries to the north and Italy to the south.

Variants of the troy ounce affected Scotland from several trading relationships, so at different times the relevant ounce means a different quantity, given in grains: 471 (bullion), 472½ (Paris), ~474.5 (Flemish), 476.8 (Dutch or Amsterdam), 480 (English troy). The original Scottish ounce was 450 grains and was equivalent to the Cologne or English 'tower' ounce. This indicates the close relationship between weight systems and the minting of coinage. There is also a definable relationship between several of the ounces, showing that they do not merely represent arbitrary changes due to poor metrological precision. For example, the Cologne and Paris ounces are in the ratio 20:21. As a peripheral contributor to the European economy, Scotland was influenced by the usages of its major trading partners as well as the state of its political relations with England.

The nine chapters of the principal text are largely concerned with understanding the legal changes to Scottish metrology between the David Assize of the twelfth century and the Assize of 1618, the last Scottish framework of measurement, and how these were applied in practice with allowances. The Act of Union with England in 1707 meant that English weights and measures were intended to be adopted. In fact Scottish practice continued to a considerable extent, and even with the introduction of the Imperial System in the 1820s, existing measures continued to be used for some time.

The appendices provide the main Scottish metrological acts, considerations of regional variants and special usages, including land measure and the assizes of bread and ale, a glossary of measures, and a directory of Scottish scale, weight and measure makers to 1900.

In addition to the points already discussed it is full of interesting insights into the history of measurement. For example, weighing was not always undertaken with a horizontal beam. Inclined-beam weighing seems to have been widespread for bulk goods in European markets in the later middle ages. This produced a slight excess over the nominal weight by four percent. This was known as a cloffe allowance as a benefit to the purchaser or alternatively as a tare allowance to take account of the packaging material containing the bulk goods.

And in the eighteenth century the quest for numerical precision led to inappropriately precise measurements of surviving early standards with some spurious interpretations. For example, the length of standard bed measures - with a recessed portion representing the length of the 37-inch ell - was taken literally, but this gave rise to the idea of oversized Scots inches because of a failure to make allowance for a tolerance for placing scales in the bed. Another variant ell of 37.2 inches, which emerged from the cloth trade in about 1700, apparently demonstrated to later observers that the Scots inch (at 37 to the ell) was even longer. Although this ell became widely used, it had been applied out of context, and the English and Scots inches were actually identical.

Both these examples indicate the caution required in the use of historical evidence.

Weights and Measures in Scotland is thoroughly referenced and profusely illustrated. This very substantial book provides a careful and detailed analysis of the fragmentary evidence of the legal basis of weights and measures in Scotland since the middle ages and its relationship with trade practice. In doing so it sheds new light on the history of English metrology and indeed the relations of Scottish and English metrology with Continental practice.

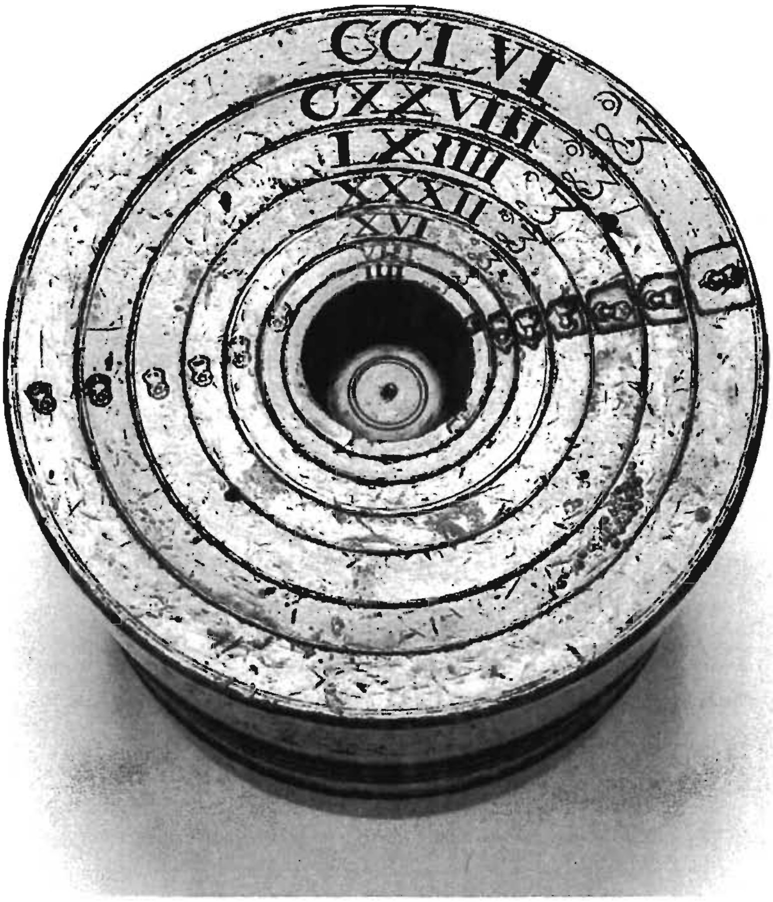


Figure 3. *Set of troy nesting weights, 1687. This set of cup weights makes up a pile of 512 bullion ounces and illustrates the principal of binary division. While the metric system with its decimal divisions superseded the old fashioned units of weights and measures, the spread of digital computing has made such binary multiples familiar once again. The two innermost weights, each of 2 ounces, are missing. (Item 41 in the Inventory)*

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