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METROLOGIST
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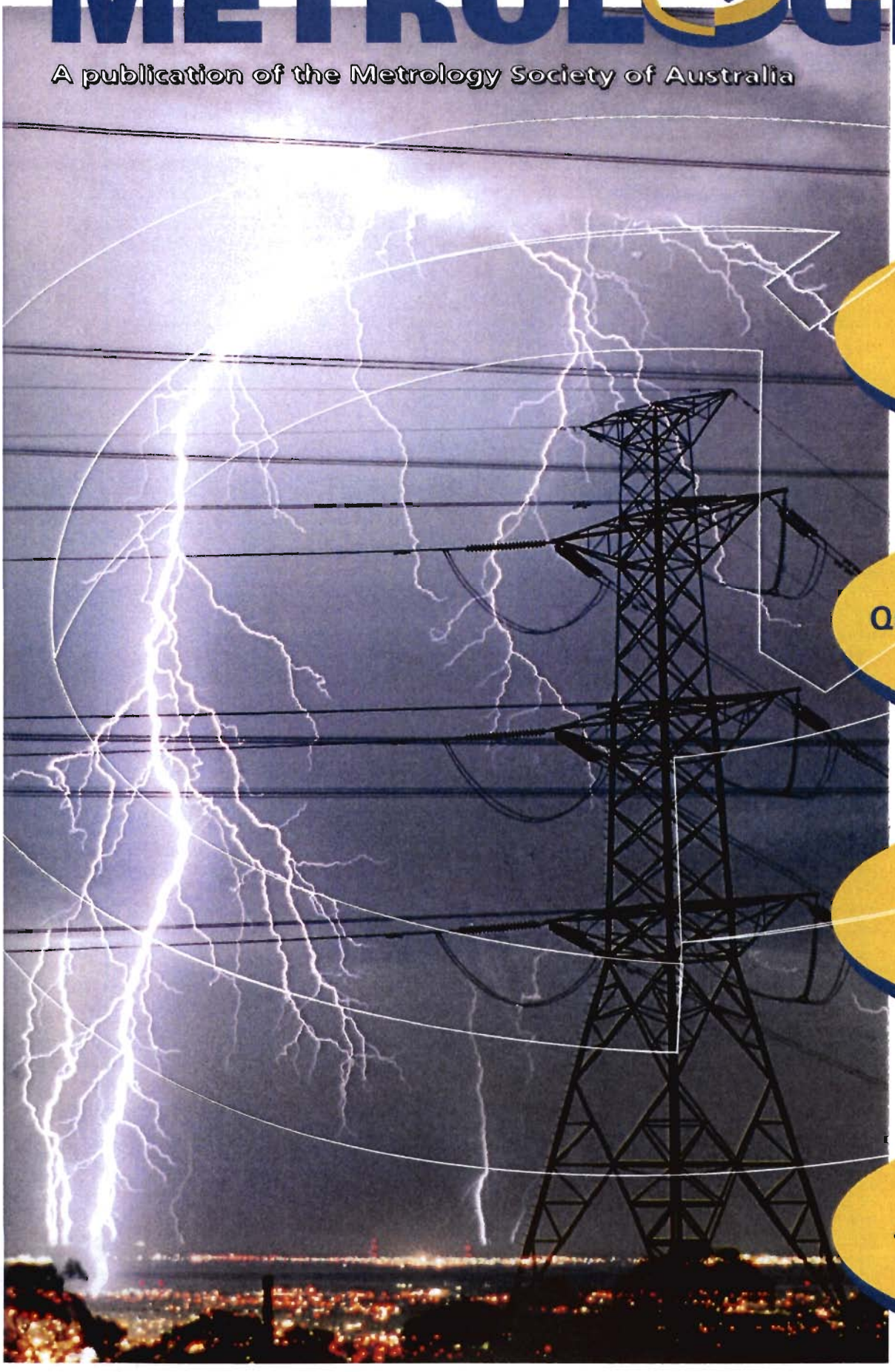

MSA AGM Papers

Quantification 9

Riverbank Reflections 6

Pt - Au Thermocouple

THE AUSTRALIAN METROLOGIST

From the Editor

To comply with our Constitution requirements, this issue contains a notice of the coming Annual General Meeting of the MSA, as well as nomination forms.

We continue our two popular series - Jeff Tapping's *Quantification* and Ron Cook's - *Riverbank Reflections*.

In addition there is a reprint from the MSA 2005 Conference Proceedings of the paper on Pt-Au thermocouples by F. Jahan and M.J. Ballico of NMI.

Les Felix has provided information and a Call for Papers for the MSA Conference 2007 to be held in Adelaide at the Lakes Resort, West Lakes.

- Maurie Hooper

Cover photo - "Sparks" - Ross Felix

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: maurie@maurie.org

The deadline for the next issue is 31st October 2006.

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.

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.

Other Fees:	Web site	$150/hr (1 hr minimum)
	e-mail	$150/hr (1 hr minimum)

MSA Membership Enquiries

Contact either your State Coordinator or the Secretary, Neville Owen, e-mail address *thesecretary@metrology.asn.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

Fellow	$45 Annual Subscription
Member	$45 Annual Subscription
Associate	$45 Annual Subscription

President's Report - September 2006

Here we are again with the end of the year racing up very fast to wipe us out with Christmas and the New Year. While I may appear premature in my statement, the MSA Annual General Meeting always heralds the end of the year for me.

It has been an interesting and very intense year for me personally but also for the Society. On reflections there are as always high and low lights in every year, but this one for me has resulted in some dreams coming to fruition. From the beginning of my time as President I have believed that the state bodies are central to the on going health of the society. It appears that on this front at least we are making progress.

The Victorian Branch managed to have its first meeting for approximately a year earlier this month. While it was not a huge affair, the meeting was well received but more importantly there is now a planned and reasonably fixed calendar of events for the next year or more with at least four get togethers. This is due to the hard work of John Widdowson and his team and I am very grateful to them. Please Victorian members come along to what they organize, it may not strictly be in your field of interest but you never know what you might pick up on. As a matter of fact this applies to all the states and their members.

The NSW Branch is going great guns under its new State Coordinator Daniel. They are orgainising a "Great Debate" or "Hypothetical" on Uncertainty in Chemistry later in the year. Once again Daniel and his team have shown great initiative and drive for this high profile event which!

SA and Queensland are still ticking over and I know that both Les and Brian would appreciate all the new blood you can encourage to come along. On a less up beat note Gary Want resigned recently from his membership on the national committee and State Coordinators role in NT. We were very disappointed, but I for one understand the pressure that come to bare when your work role increases. It becomes almost impossible to fit any more in. Thank-you Gary for your efforts and we wish you all the best for the future. I will also include a plug at this stage for anyone who feels they would like to take on the now vacant chair in Northern Territory. This is a national organisiation and if we are going to survive and contribute then we need representation from all walks of life and areas of the country.

This brings me to WA and Tasmania, both these states need your support. The membership is not big and can be very distributed. If you are visiting these states on Business, give the coordinator a call and they might invite you join or present to one of there meetings.

As to the broader picture and what is going on there are two big events planned; the AGM in Oct of this year and the Conference in Adelaide in July 2007. Neville has done a marvelous job of organizing video conferencing across the country. Our thanks go to NATA and NMI for supporting this. We are asking each state to run their own meeting coincidently with Melbourne one to join us all as one. Please also consider nominating for a position on the National committee, the work load is generally not too onerous. The people you work with are a great fun. We encourage membership from across the country via a teleconference. Think about it, new blood is good.

Lastly and most importantly there is the Conference next year. Les Felix and his team have planned a brilliant event. I can say planned, not planning because of the advanced stage the planning is at. This will be a great and smooth event, based on the idea that metrology is even more important these days because of the global nature of the world. A car made in one part of the world may have components from dozens of countries across the globe. No mean feat! The SA team have planned some really interesting speakers and visits, social events and treats. It is a big year in metrology for Australia next year with a number of international and regional meetings in Sydney. But the conference in Adelaide is not to be missed!

- Dr Jane Warne

Contents

Quantification - Number 9

Jeffrey Tapping

I hope that you have been busy since the last issue, pondering on the questions about measurement units that I posed to you in the last issue. Anyway, you can all join me by first pondering on pondering.

What is the connection between *pond* as a unit and *pondering* as an action?

To *ponder* means, according to my Macquarie Dictionary, "1. To consider deeply; meditate. 2. to weigh carefully in the mind, or consider carefully." I might have also included the word *ponderous*, because all derive from the Latin word for *weigh*. So the connection to the *pond* as a unit of weight is now obvious. Actually the weight unit arrived via the Roman expression, *pondo* meaning "by weight".

We have addressed the *Arpent* question, now how about the *Arshin*? A clue: it is definitely not a Chinese soup.

The only things in common between these two units is the first two letters of their names, and the fact that neither has anything to do with soup. *Arshin* was a linear measure used in Western Russia a little less than a *yard*, in fact exactly 28 inches compared to 36 inches in a *yard*. It was probably their version of a pace, but a little shorter because of the cold weather up there. Curiously the name *Arshin* is also used in Turkey as the name for a *metre*, perhaps supporting the proposition that all three of these units, *Arshin*, *yard* and *metre*, fill a natural tendency to have a length unit of about one pace long.

How long is a league? Anyone who says something like "four quarters of 25 minutes", or "too long" is in the wrong business.

Once again we have a length unit that was applied to different but similar distances in different places and times, but with a difference. The term has, at least in recent history, had very little practical use as a measurement, being mostly confined to poetic and romantic literature, particularly describing long sea journeys, where presumably something a bit bigger than a mile has some appeal. The magnitudes are all based on a length of *three miles*, but using different versions of the *mile*. In the U.S.A. it was equal to three U.S. *nautical miles*. In the U.K., to add extra confusion, it was equal to three *Imperial miles* on land, and three U.K. *nautical miles* at sea. Elsewhere the U.K. terrestrial *League* has been adopted in many places, but the French used a distance of 4 km. So values recently used, expressed in *kilometres*, are:

U.K. on land	4.828 km
U.K. at sea	5.561 km
U.S.A. on land and sea	5.555 km
France (*lieue*)	4 km

And you could say that this is a much travelled unit, because it said to have come from one used in Greece about 2000 years ago, which in turn came from one used in Gaul.

What is the difference between an Imperial mile and a Statute mile?

The answer is, nothing. The prefix "statute" simply refers to the fact that the value has been established by statute, that is, by a legislative enactment. So the term *Statute mile* has mostly been used to emphasise that the distances have formal legal status, for example in surveying.

In the ships bell system of time marking there is no "five bells". Why not?

First let's look at the timing system used on ships. The system of timing on board ships using bells has been essentially the same for many centuries and used by most countries in Europe and the Mediterranean. In this system the day is divided into six periods called *watches*, each of four hours. But the watch between 1600 hours (4 pm) and 1800 hours is divided into two "*dog*

watches" of two hours, the main reason being that this allows all of the crew to have their evening meal close together at an appropriate time of day. The progress of time through a *watch* is signalled by the ringing of a bell each half-hour, with one extra ring for each half-hour. So at the first half-hour into a *watch* the bell is struck once, at an hour it is struck twice, and so on up to eight rings. Rings are made in pairs with a short pause between, so four bells would be: ring, ring, pause, ring, ring. This means that to note time it is only necessary to count up to four rather than to eight which would be subject to errors, particularly on a noisy ship. Before the development of reliable chronometers, the timing was done with a 30 minute hour-glass, and so the bell was rung each time the sand in the glass ran through and the glass was inverted. The system of *watches*, and the name itself, originated on land where *watches* were kept in castles and military camps.

Now in my question I was negligent, because the absence of a signal of *five bells* occurs only in British ships, and only in the *dog watches*. The reason for this peculiarity is that the fifth bell in the second *dog watch* was the signal used to start a famous rebellion, known as the mutiny at the Nore. The Nore was a sandbank marked by a lighthouse ship in the Thames estuary at a spot where sailing ships waited for a favourable wind to take them in or out of the river. In 1797 the crew of the Nore lighthouse ship mutinied against their living conditions, alas to no avail because the mutiny was put down and its leader, Richard Parker, was hung from the yard arm. Thereafter the second *dog watch* on British ships began with one bell at 1830 hours, not five.

What sort of unit is a litre-atmosphere?

Surprisingly, it is an obsolete unit of work used in physics, equal to 101.325 joules. So how does this come about? Well first, work is equal to force times distance. Now think about the individual units of the *litre* and the *atmosphere*. The *atmosphere* is a pressure which is force per unit area. And the *litre* is a volume which can be thought of as area times height. So using the symbols F for force, A for area and L for distance (length or height), we have:

atmosphere = F / A

litre = A . L

lire-atmosphere = A . L . F / A = L . F

Expressed this way you can see that the area units cancel out, leaving force times distance. Now only a physicist with Asperger's Syndrome would think that this is a sensible way to go about the problem.

What are zoll and zak? Another clue: they are not cartoon characters.

A *zoll* is an old Swiss measure of length, and their equivalent of an inch (25.4 mm). It is apparently still in occasional use, but is rounded up to 30 mm. The *zak* is another old measure, this time for the volume of dry-goods such as corn. The exact original magnitude is not known but again it has been incorporated into the metric system, with a size of 100 litres. And some of our very old members might have answered that a *zak* was sixpence in Aussie slang, but that was usually spelled *zack* if I remember correctly.

What is measured using a tonometer?

What do most people do when they have invented a new kind of measuring instrument and want to find an appropriate name for it? They scurry off to the library to find a Greek or Latin word that might describe what they measure, and probably don't check if anyone else has used a particular name. The name of the *tonometer* derives from the Greek *tonos* for tension, and of course there are many different kinds of tension, consequently there have been quite a few *tonometers* for different purposes. So a tonometer could be something used to measure eyeball pressure, or for measuring vapour pressure, or more interestingly, a device for determining the tone of a musical note, consisting of a series of tuning forks.

What unit is described as a traffic factor?

The basic quantity called a *traffic factor* is the *ton-mil*e. This was used in estimating and comparing the cost of transporting freight by different methods. It is the cost per *mile* of transporting one *ton* of freight between to locations. I have also found a reference to another unit, the *ton-mile per gallon*, which is also called a *traffic factor*. There was no explanation of exactly what it represented, but seems to be

equivalent to the distance that one *ton* of freight could be transported per *gallon* of fuel.

What is unusual about the shaku as a unit?

We have had quite a few unit names that were applied to two types of quantity, for example both length and area, but this one goes one further. It was used for length, area and volume. The reason is simply that the word actually meant something like "measure", and if a person said "A *shaku* of rope and a *shaku* of corn", they were actually saying "A measure of rope and a measure of corn", and the respective meanings were obvious from the context.

Free Bonus Topic

At absolutely no extra charge we bring you this fabulous additional topic, containing not one but three action-packed paragraphs! (Hmm, I think I have been watching too much of the spruiker on the Chaser TV program).

From time to time the Feedback page of New Scientist magazine has anecdotes on the use of unusual units of the "contains enough water to fill ten million swimming pools" kind. The edition of 27 May 2006 had the grandfather of them all, reprinted from a serious article about the new large Airbus in The Times newspaper:

"Fully laden, the Airbus A380 holds 310,000 litres of fuel, enough to fill 21 road tankers...The aircraft's interior volume is 1570 cubic metres, the equivalent of 44 million ping-pong balls...Removing all the seats from both decks would provide enough space for 10 squash courts...A freighter version, the A380F, will carry 150 tonnes of cargo - about the same as a herd of 57 fully grown Asian elephants... The temperature in the engines reaches 2800°C, half that of the sun's surface...The take-off thrust is the equivalent of about 2500 family cars."

But a later issue had an example where a unit of this sort actually has a useful purpose. In efforts to improve the productivity of village farms in Africa, the farmers in some areas are being given supplies of trace elements that are missing from their soil. They have to add quite small quantities to the fertilizer they use, but of course they have no conventional means of measuring appropriate amounts. So the measuring containers they are instructed to use are beer bottle caps, which they have plenty of.

Topics in the next issue

In the next issue will discuss the following measurement terms and units. If you are trying to get ahead of me be careful, because there are a couple tricky ones in the bunch.

16mo

tola

CHU

International unit

International candle

Line

kienböck unit

poncelet

pud and funte

dollar and cents

gowpen

rH

Sunday letter

IQ

■

Riverbank Reflections 6

Ron Cook

I'm heading home after three days trying to ski at Mt Buller and the banks of the Delatite River provide an ideal vista for cogitating while munching on my lunch. It has been the worst snow season in living memory and if it weren't for the technology of snow making the skiing season would have barely lasted a week.

The snow is manufactured by mixing pressurised water and air and expelling it from a nozzle. The cooling caused by the expansion of the air freezes the water and the crystals coalesce into small pieces of snow. It works providing the ambient temperature is near 0 °C and is further facilitated by the introduction into the water of a bacterium that is common in Alpine areas. In past years the man-made snow has mixed with natural snow and been used as a top-up. This year it made up virtually the whole of the skiable snow. I suspect the manufactured snow has more air in it and something, perhaps the bacteria, prevents the usual growth of the ice crystals as the weather warms up.

A day of skiing in Spring usually starts with a firm icy surface due to any free water in the snow freezing overnight. As the morning progresses each run is done on progressively softening snow. By early afternoon the snow has become heaped into wet piles of soft snow on the turns making it heavy going. Around 3 PM as shadows spread across the slopes the snow starts freezing up. The skiing is then over bumpy ground but without the earlier slush. Finally after the lifts close the grooming machines appear and level out the runs, dragging in a little stockpiled snow to make up for evaporation and melt loss.

The lift company did not make as much snow as they would have liked as they had only limited water available. There is talk of taking the effluent from the sewage treatment plant and using that for snow making. I believe this is done in other places, but each mountain has its own problems and at the very least some experimentation based on an existing system will be required.

This year, I noticed that the snow did not become very wet and soggy, although the usual piling up of soft shaven snow did occur during the day and the slight softening did reverse in the mid afternoon. Hence my supposition that the physical make-up of the manufactured snow differs from the natural snow. The technique of snow making has been the subject of considerable research overseas, yet in Australia where it is of major econonic importance to the skiing industry only a little local theoretical work seems to have been done. Perhaps someone out there could undertake a PhD to look at optimizing the use of recycled water for snow making. There is a lot to be done even in just characterizing the physical properties of manufactured snow – a job for a metrologist. Any developments in technology could be exported as Australia is not alone in experiencing changed weather patterns.

Monash University has an established campus in the village at Mt Buller and has had researchers working out of these facilities since it was established. The main theme is, not surprisingly, sport.

Sponsorship of a PhD with a strong metrology theme is something our society should consider as an appropriate activity. Monash has had a long

history of research with a measurement theme so they should be interested in any MSA proposal.

The MSA need not provide all the funding. Indeed the lift companies in the Australian Alpine resorts could make what would be for them a very modest contribution to fund a suitable candidate for a 5 year term.

The usual plan for the research would need to be written up and presented to various parties but it would be something worth a little effort.

There are multitudinous opportunities for measurement related research in the Australian Alps. It is the habitat of several endangered species, a consequence of the activities of timber loggers and skiers impinging on the flora and fauna. The logging aspect is pretty obvious but trees and large rocks can be incompatible with the desires of skiers. I have seen a chain saw used to remove a snow gum within an hour of a skier colliding with the tree, a tree that had stood there for decades and could only be considered a hazard for the careless or foolhardy. And tens of thousands of visitors daily leave their effluent and other impacts from their visit.

Management of these issues is being tackled by the local resort management, but often they do not have reliable data. They have more than enough opinion and assertions.

There would be half a dozen potential master's degrees available in gathering and cataloguing more completely the flora and fauna at the seven major ski resorts in Victoria and a similar number in New South Wales, let alone the statistics of other issues.

While peeling my orange I notice that the level of the river is closer to that expected in February rather than in early September amply illustrating the low winter precipitation levels this year. The Delatite is one of the rivers that feed Lake Eildon. The lake presently remains a tiny water-filled gutter way below the bridge at Bonnie Doon, at least 20 metres lower than was considered normal a decade back. It is currently at about 25% of capacity. The lake is primarily an irrigation pondage and feeds the Goulburn River which flows into the Murray. Thus snow melt from Mt Buller thus finishes up in the kitchens of Adelaide residents. Incidentally the Goulburn River is home to 19 species of native fish and 10 species of introduced fish.

When a new dam wall was completed in 1955 it was expected to take some 5 years to fill but, if my memory serves me correctly, it was overflowing less than two years later. The prediction was presumably based on the then current 30 year average rainfall. I remember many occasions in the 1960's and 1970's when it was literally brim full but the lake has not filled since 1996.

Any 30 year average rainfall figure must change, and this is an intentional outcome. Of course when the average rainfall, based on the current 30 year period, is quoted the uncertainty is not given. Perhaps we should expect to at least see a standard deviation quoted as well. Maybe it is in some private chambers reserved for metrological meteorologists.

The predictions for the effects of greenhouse gases and global warming usually give an expected value and upper and lower limits. This is an area of research that certainly relies on good measurement of the gas concentrations and parameters such as rainfall, sea level and air temperature.

Could this also be an area where the MSA could sponsor research? Global warming and man's impact on the environment is a problem we collectively are trying to shrug off, but our grandchildren will have to deal with our legacy. It's not too early to look for some of the solutions now. Eventually the short term fixes such as man made snow and ethanol in petrol will seen to be seen as failing to face up to the real issues.

I'm sure you could suggest many areas of useful research that relate to the interests of the MSA. It would be too ambitious to sponsor more than one project per year, but having a large choice would help in picking appropriate topics.

Well, I think I should get back on the road and head for the Delatite Winery. I hear there is a new winemaker there so I'm curious to see if there have been any changes. Of course I'll have to make a few olfactory and flavour measurements as part of my self-funded research.

■

Announcement and Invitation to the Annual General Meeting for the MSA 2006 to be held at the NATA State Offices.

Wednesday 18th October, 2006 at 6:30 pm EST

Formal AGM including a Talk on the Development of Australia's Tsunami Early Warning Systems, followed by State Functions

The agenda for the meeting is as follows:

- Apologies
- Minutes of the previous AGM
- President's and Treasurer's Reports
- Election of Office bearers and Committee members
- Consideration of listed motion
- Close of meeting

Nominations for the National Committee of Management are sought and should be with the Secretary no later than close of business on the 11th October 2006.

Motion:

1. That Marianne Philips be elected to the position of auditor for the MSA.

Speaker: Dr Jane Warne
Supervising Metrologist
Observations Network Design and Management
Australian Tsunami Warning System Project.

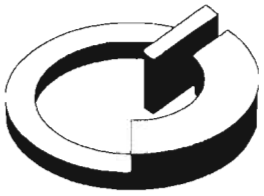
Title
Waves of Understanding
(*or* How do you Measure a Tsunami?)

This will be followed by light refreshments/supper. For catering purposes please indicate your intention to attend the evenings activities to the secretary by e-mail at thesecretary@metrology.asn.au or phone (03) 9452 4007 or directly to your State Coordinator as noted in TAM.

Please take careful note of the time of this meeting. This meeting is planned to cover as many members as possible and will start promptly at 6:30 pm Eastern Standard Time.

NATA State Offices

Location	Address	Time
New South Wales	7 Leeds Street, Rhodes	6:30 pm
Victoria	71-73 Flemington Rd, North Melbourne	6:30 pm
Queensland	628 Ipswich Road, Annerley	6:30 pm
Western Australia	Suite 7 Business Centre Technology Park 2A Brodie Hall Drive, Bentley	4:30 pm
South Australia	Unit 1 13 King William Road, Unley	6:00 pm



METROLOGY SOCIETY OF AUSTRALIA

NOMINATION FORM

To the Secretary
Metrology Society of Australia

We,

_____, Member No _____

and

_____, Member No _____

hereby nominate

_____, Member No _____

for election to the position of (circle one)
President
Vice-President
Secretary
Treasurer
Ordinary committee member

of the Society at the MSA's Annual General Meeting of 2006.

Signatures

Nominator _____

Seconder _____

I affirm that I am willing to stand as a candidate

Nominee _____

Date _____

METROLOGY SOCIETY OF AUSTRALIA

APPOINTMENT OF PROXY

To the Secretary
Metrology Society of Australia

I, _____,

Member No _____

Hereby appoint

_____,

being a member of the Metrology Society of Australia, as my proxy to vote for me on my behalf at the 2006 AGM of the Society and at any adjournment of that meeting.

Signed:_____

Date: _____

Note: This Proxy form must reach the Secretary 24 hours before the AGM.

SECOND CALL FOR PAPERS
FOR THE
MSA 7th Biennial Conference

Time has a habit of passing, bringing the deadline for papers closer. As a reminder of the time lines, the following information is reprinted to assist in keeping you on schedule. The web site www.metrology.asn.au contains the paper template. The template will also be available upon request from the Conference Chairman.

Contact the Conference Chairman for further details (details below).

SCOPE OF THE CONFERENCE

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

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

CONFERENCE TIMELINE

o 31 January 2007	*Submission of short abstracts by authors*
o 15 February 2007	*Notification sent to successful authors*
o 31 March 2007	*Submission of full papers to conference convenor*
o 15 April 2007	*Discount Registration Deadline*
o 25-27 July 2007	*7th Biennial Conference of the MSA*

SUBMISSION GUIDELINES

Authors are required to submit abstracts (maximum half a page) before **31 January 2007**.

The abstract should clearly describe the work and also indicate the preferred from of presentation (oral paper, poster paper or workshop). Submissions will be reviewed on the basis of their relevance to the theme and aims of the conference and to the development of metrology skills.

Successful applicants will be notified by **15 February 2007**, at which time they will receive guidelines on the preparation of the full papers to be published in the conference proceedings.

Submit the abstract, either electronically or in hard copy to the Conference Chairman.

Additional information can also be obtained by contacting the Conference Chairman by any of the following media.

Post
Mr Leslie Felix
Conference Chairman
42 Light Terrace,
Thebarton
SA 5031

Email
les.felix@abstec-calibrations.com.au

Phone/Fax
Phone 61 8 8354 1355
Fax 61 8 8354 1377

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

Stability study of a simple design of high precision Pt-Au thermocouple

F. Jahan and M J Ballico

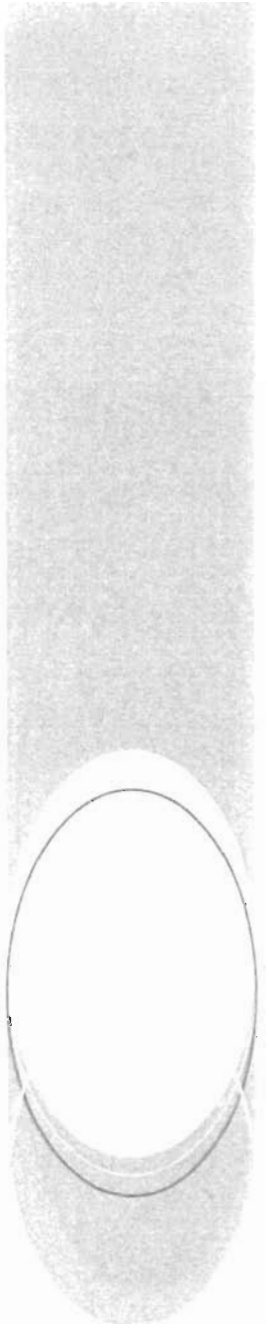
National Measurement Institute, Lindfield, NSW 2070, Australia

Reprinted from the Proceedings of the Sixth Biennial Conference of the MSA, October 2005

Abstract

Platinum-Rhodium (Pt-Rh) thermocouples are widely used as both secondary reference standards and as precision industrial sensors for temperature measurement in the range of 0 -1600°C. The accuracy of temperature measurements made by these thermocouples is limited by the stability and inhomogeneity of the thermoelements, which is mainly due to the effects of preferential oxidation in the alloyed thermoelement. Thermocouples made from pure elements do not suffer from this instability. Various precision versions of the Pt-Au thermocouple, usable up to 1000°C are now available with accuracies of a few mK, however, they are expensive, complex and fragile. In this paper, we present some stability testing results on a simple Pt-Au thermocouple, similar in design and cost to the familiar and commonly used Pt-Rh thermocouple. Studies of the calibration and inhomogeneity of these thermocouples, after exposure to 450 hours at 600°C and 50 rapid quench cycles to 600°C, show them to be far more stable than conventional Pt-Rh thermocouples, comparable to that of Platinum resistance thermometers.

Keywords: Pt-Rh thermocouple, Pt-Au thermocouple, annealing, high stability



1. Introduction

Thermocouples constructed from Platinum (Pt) and Platinum-Rhodium (Pt-Rh) alloys are currently used as secondary reference standards in the temperature range of 0 to 1600°C. The best achievable uncertainty obtained from these thermocouples is 0.25°C at 1100°C. The main disadvantage of these thermocouples is the thermoelectric inhomogeneity of the thermoelement which arises from the preferential oxidation of rhodium at a temperature range of 500°C to 900°C [1].

Thermocouples constructed from pure elements do not suffer from this preferential oxidation problem. Being pure elements, these thermocouples are inherently more thermoelectrically homogeneous and their stability is not limited by shifts in alloy composition caused by preferential oxidation. The performance of Au-Pd, Pt-Pd and Au-Pt elemental thermocouples has been investigated by a number of laboratories [2, 3, 4, 5]. The Au-Pt thermocouple is the most accurate (10mK at 900°C), but limited to 1000°C, whereas the Pt-Pd thermocouple can be used up to 1500°C. In most of these studies of Pt-Au thermocouples, a stress relieving coil or bridge was used at the tip to minimize the deformation stress due to the different thermal expansion of Pt and Au wires [4, 5]. As a result, these thermocouples need a special and complicated manufacturing technique. They are also not as robust as conventional type R or S thermocouples and require a fragile protective quartz tube.

In the present study a simple design of Pt-Au thermocouple was developed using a special head assembly to relieve mechanical strain, rather than an expansion coil. The calibration stability of the thermocouple after 450 hours exposure to temperatures of 600°C was assessed. Additionally, the thermal cycling 50 times between ambient and 600°C tested the mechanical stability of the thermocouple.

2. Construction of Thermocouples

Two Platinum-Gold (Pt-Au) thermocouples were constructed from 0.5 mm diameter of gold and platinum wire of the highest purity (99.999%) from Sigmund-Cohn Corp., US. The insulator used was high purity recrystallized alumina of length 750 mm and diameter 4.75 mm with two 1.57 mm diameter bores. The relatively large bore diameter allows the thermoelements to move easily through the bores as they expand with heating.

To reduce the mechanical strain in the wires and also to oxidize and remove impurities from the wires, high temperature annealing of the thermoelements is essential. This was achieved using the following procedure: the platinum wires (1450 mm long) were firstly electrically annealed at 1400°C by passing electric current (approximately 12 A) through the wire for 6 hours and then quenched by switching off the current. As the gold wire does not have sufficient mechanical strength for electrical annealing, it was annealed only in a furnace. To ensure that the full length of the Au wire was annealed uniformly, a different method was used: two 750 mm long pieces of Au wire were cut from the reel. They were fed into the two bores of a long alumina insulator. The alumina insulator had been pre annealed at 1100°C for 6 hours and dedicated to Au wire annealing. The alumina insulator holding the Au wires was then placed inside a protective quartz tube, in a long horizontal furnace such that the full length of the Au wires were in the uniform temperature zone of the furnace. A horizontal Kanthal-on-alumina tube furnace with a quartz tube liner was used for this purpose. The temperature of the furnace was uniform to ± 8°C at 1000°C over the central 750 mm region. The Au wires were annealed at 1000°C for 6 hours and then 16 hours at 450°C.

Because the annealed gold wire is very soft, it is difficult to insert the wire into the insulator without mechanically damaging it. We used a "pull-wire technique" to overcome this problem. After annealing, one Au wire was removed from the annealing-insulator and inserted into the thermocouple-insulator. The two gold wires were then butt-welded using a small hydrogen-oxygen torch. Pulling the gold wire in the thermocouple insulator then drags the other wire from the annealing insulator to the thermocouple insulator. The gold wire in thermocouple insulator is thus strain free and homogeneous.

The annealed Pt wire was inserted into the other bore of the insulator. The tip was made by welding the Au and Pt wires using an oxygen-hydrogen torch. The assembled thermocouples were then given a final 4 hour anneal at 1000°C and an overnight anneal at 450°C.

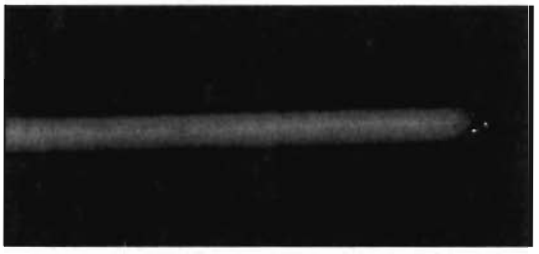
The wires emerging from the alumina insulator were insulated with relatively stiff Teflon tube of bore diameter 1.37 mm. This (i) avoids cold-working the soft, annealed thermocouple wire and thus introducing inhomogeneity and (ii) ensures the wire can move freely within the insulator. A pair of insulated Cu wires was soldered to the open ends of the thermoelements to form reference junctions. The reference junctions of the thermocouples were mounted in a single stainless steel tube of length 220 mm, closed at one end. A special head assembly (Figure 1C), was designed to secure the TC insulator and the Teflon insulation tubes without restricting the ability of the thermocouple wires to move freely, as they expand when heated.

The cost of this type of Pt-Au thermocouple is similar to the conventional Pt-alloy thermocouples, as the insulator and Pt thermoelement are the same, and the Au thermoelement is similar in cost to Pt/Rh.

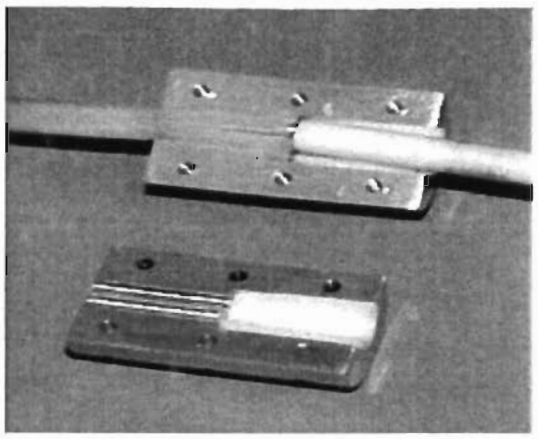
3. Experimental Procedure

The thermocouples were thermoelectrically scanned [6,7] in an oil bath at 200°C to determine their thermoelectric signature up to a length of 550 mm from the tip. The thermocouples were then calibrated [11] up to 550°C in a salt bath against a Standard Platinum Resistance Thermometer (SPRT). The thermocouple emf was measured using an Agilent 34420A Nanovoltmeter. During calibration and scanning the reference junctions were immersed in a crushed ice point.

(A)



(B)



(C)

Figure 1. A simple design Pt-Au Thermocouple, (A), conventional welded tip (B), special head (C)

After the initial scanning and calibration, the thermocouples were given several heat treatments (in the annealing furnace) at a temperature of 600°C for a cumulative period of 450 hours. Between heat-treatments they were calibrated and scanned (a total of 7 salt bath calibrations and 10 oil bath scans at 200°C were performed).

To assess the mechanical stability of these Pt-Au thermocouples, they were subjected to 50 thermal cycles. For each cycle the thermocouples were put into a horizontal tube furnace set at 600°C for 30 minutes, removed from the furnace and kept at ambient temperature for 20 minutes before being put back into the furnace.

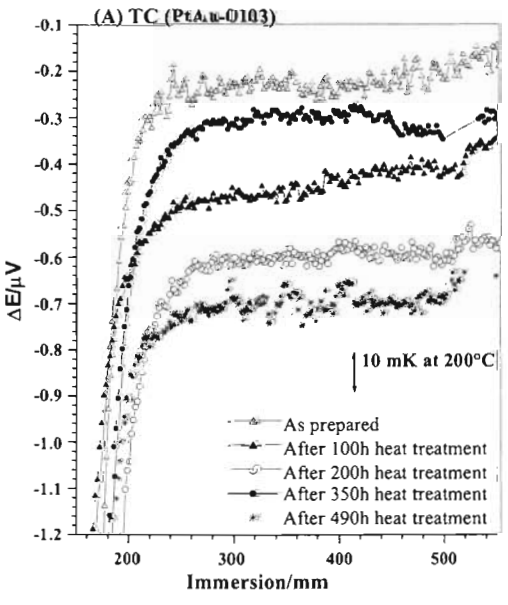
4. Results & Discussion

Thermoelectric Inhomogeneity:

The thermoelectric scan of two Pt-Au thermocouples is shown in figure 2. The inhomogeneity of the thermocouple is the relative difference in thermocouple EMF at different immersions. Note that the curves have been shifted for clarity, it is only the shape that is important. The inhomogeneity from 200 mm to 550 mm is 0.1μV, which is equivalent to ±0.003% (±5mK at 200°C). The temperature dependence of thermoelectric inhomogeneity is not presently known, however, for Pt-Rh alloy thermocouples, it is relatively independent of temperature [7]. Assuming Pt-Au thermocouples behave similarly, ±5mK at 200°C should correspond to ±15mK at 600°C. Due to thermal conduction along the thermocouple, inhomogeneity can't be measured at an immersion less than 200 mm (although this can be reduced using an appropriate convolution [12]). Figure 2 shows the scan of the thermocouples 'as prepared' and after annealing at 600°C for different period of times.

Figure 2A shows that the inhomogeneity of the TC does not change significantly after heat treatment at 600°C. It is well known that the pure element thermocouples are more homogeneous than the Pt-Rh alloy thermocouples (Type S or R) [2, 10]. Due to the different thermal expansion of Pt and Au, some workers [3, 4] have used a stress relieving coil of thin Pt wire at the hot junction to reduce the strain on the wires. Kim et. al. [9] used a 0.1 mm diameter of Au wire as a bridge across the Au and Pt wires at the tip. In the present design, there was no expansion coil or bridge at the tip, and the tip was formed by simple conventional welding as in a conventional Type R or S thermocouple. The scan results show no change in the thermoelectric signature, indicating no additional strain or stress was introduced into the thermoelements by this thermal expansion. In an isothermal heat treatment at 600°C for a length of 500 mm, the thermal expansion of Pt and Au, wires relative to alumina insulator is about 1.1 and 3.5 mm, and the difference in expansion between the wires is 2.4 mm. Due to the large bore size of the insulator and the special head, the wire could easily move longitudinally to accommodate this expansion.

For one of the thermocouples (PtAu-0203), it was observed that initially the inhomogeneity was



about ± 0.1μV, (Figure 2(B)) but after annealing at 600°C for longer period, the thermocouple becomes more homogeneous, about ± 0.05μV ~ (±0.003%). This could be due to the reduction of lattice vacancies which was introduced when annealed at high temperature (during preparation) and quenched [10].

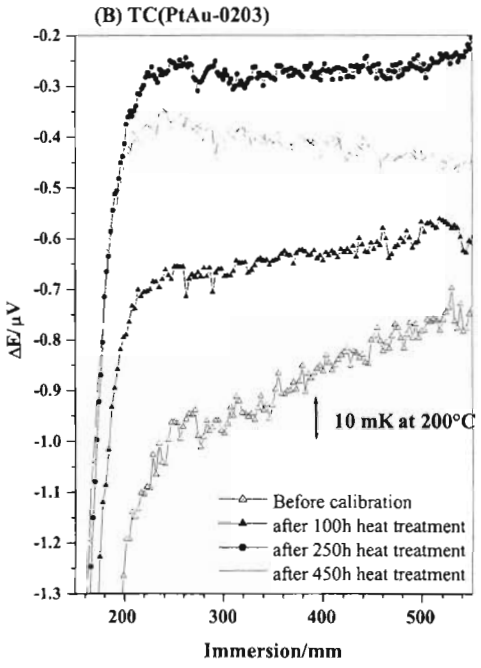


Figure 2. Thermoelectric scans of two Pt-Au thermocouples after different cumulative periods of heat treatment at 600°C. Note that the curves have been shifted vertically for clarity: only the shape of the curves is important.

For comparison, conventional (Pt-Rh) type R thermocouples were also assessed after similar heat treatment. Figure 3 shows the inhomogeneity scans of two Type R thermocouples after several heat treatments at 600°C together with the scan of the 'as prepared thermocouples (1100°C quenched state). The inhomogeneity of both thermocouples increased significantly, for example the inhomogeneity of thermocouple 13-0495 increased from 0.020% to 0.035% (± 0.2μV to ± 0.4μV) in 100 hours of heat treatment.

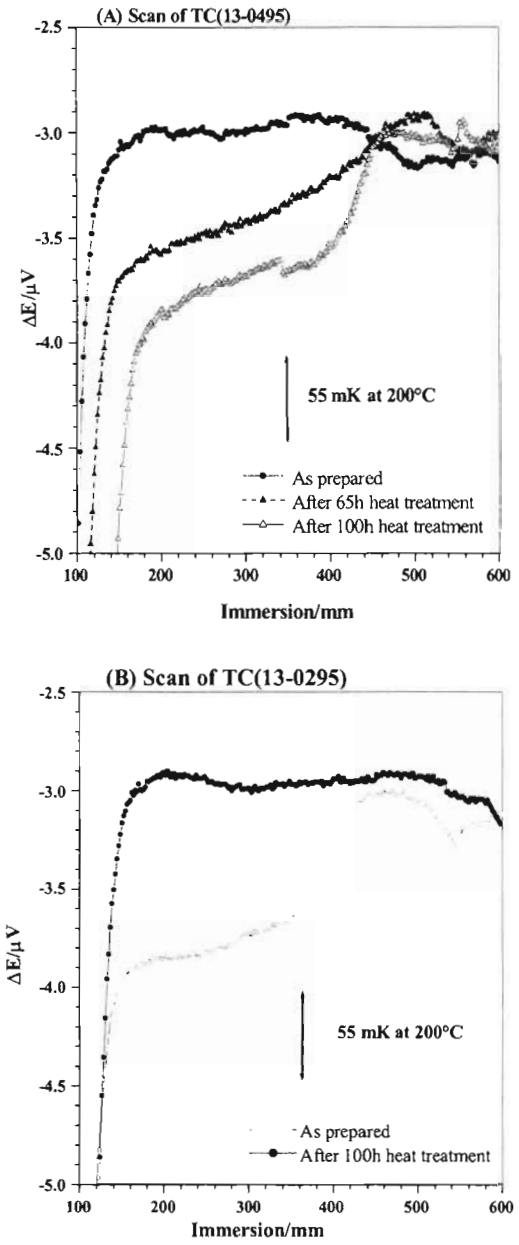


Figure 3. . Thermoelectric scans of two Pt-Rh thermocouples after different cumulative periods of heat treatment at 600°C. Note that the curves have been shifted vertically for clarity: only the shape of the curves is important.

In a thermocouple the voltage is generated in the segment of wire exposed to a temperature gradient. Due to this inhomogeneity the calibration at an immersion of 250 mm, will be significantly different to that measured at an immersion of 500 mm.

This result clearly indicates one of the main disadvantages of using the Pt-Rh thermocouple as

a reference standard, especially for the standard laboratories. If reduced to a homogeneous state by appropriate thermal treatment, these thermocouples can initially be calibrated accurately. However, depending on the temperatures they experience, oxidation of the Rh in the Pt-Rh thermoelement during use makes them inhomogeneous. For pure single elements (Au, Pt), there is no oxidation effect, resulting in a more homogenous thermocouple.

Calibration Stability:

The Pt-Au thermocouples were calibrated in a salt bath from 200 to 550 °C against an SPRT [11]. During calibration the thermocouples were in the salt bath for 6 to 7 hours. Figure 4 shows the calibration of the thermocouples 'as prepared' and also after different periods of heat treatment at 600°C. No shifts in calibration were observed over a cumulative 450 hours of heat treatment. An earlier study by Bentley [8] also showed no reversible or irreversible changes in the Seebeck coefficient in Pt and Au wires for temperature up to 550°C.

The scatter in data in Figure 4, between different calibration sets at 550°C is ≤ ± 0.1μV (~ ±5mK) which is within the calibration uncertainty of ± 10 mK. The calibration uncertainty comprises the 3 mK calibration uncertainty of the SPRT and F17 AC bridge used as a reference standard and the measured 5 mK temperature uniformity and stability of the salt bath. The measured nanovoltmeter drift rate of 11ppm/year is equivalent to 0.11μV (or 5 mK). The standard deviation of thermocouple emf measured at the highest temperature of the salt bath is about 0.12μV (~ 5 mK).

Considering the above uncertainty factors, it is remarkable that results from the different calibrations on a given thermocouple agree within ± 5 mK, showing not only that there is no shift in calibration after 450 hours of heat treatment at 600°C, but also the good reproducibility of this simple design of Pt-Au thermocouple and also of the calibration system.

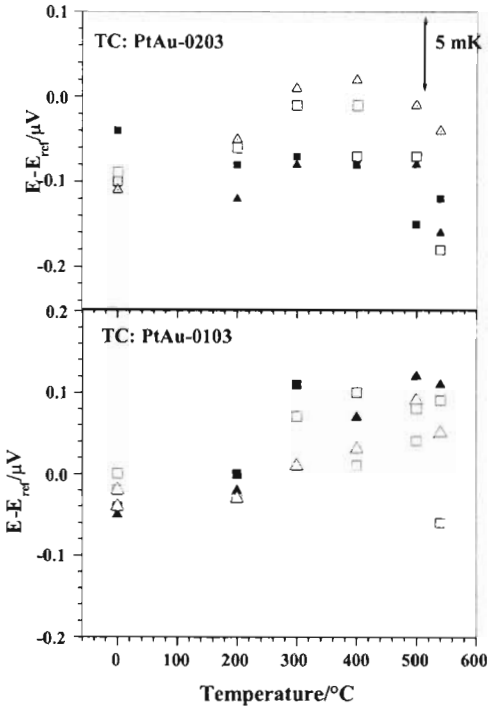


Figure 4. Calibration data of two Pt-Au thermocouples. ▲ - First calibration, ■ - calibration after 100h of annealing, □ - calibration after 350h of annealing, △ - calibration after 450h of annealing

Thermal Cycling:

In the present design of the thermocouples, there is no stress relieving coil, so the thermoelements must slide in the insulator as they expand, otherwise strain in the wires and thermocouple junction will lead to its failure. We tested the design by repeatedly thermally cycling the thermocouples.

The thermal cycling test was carrying out with the same thermocouples which had been heat treated at 600°C for 450 hours and calibrated 7 times in the salt bath up to 550°C. Figure 5 shows the inhomogeneity scans of the two thermocouples 'as prepared', and after a cumulative 50 thermal cycles at 600°C and 450 hours at 600°C. There is no significant difference in the thermoelectric signatures indicating good thermal and mechanical stability. There was no sign of mechanical failure of either of the two thermocouples.

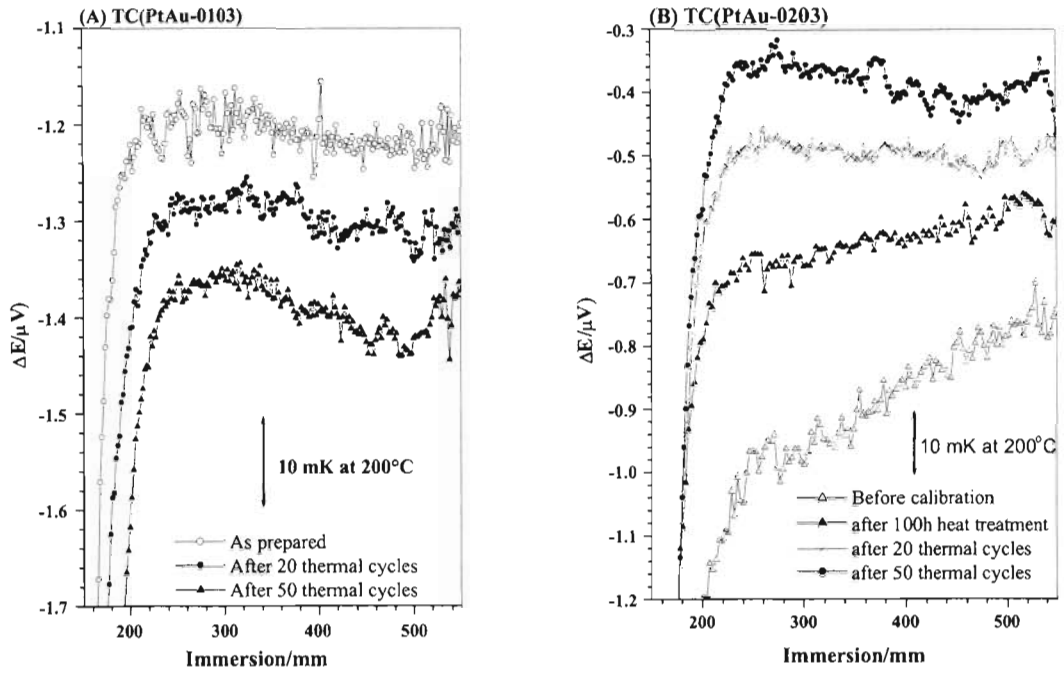


Figure 5. Thermoelectric scan of two Pt-Au thermocouples after thermal cycling at 600°C for 50 times.

5. Conclusion

A simple Pt-Au thermocouple design was developed, similar to the conventional type R or S thermocouple, but far better in performance. This thermocouple can be calibrated with an uncertainty of 10 mK up to 550°C. The present work showed that this simple design Pt-Au thermocouple has good thermal and mechanical stability up to 600°C. It is reproducible to ±5 mK, which is comparable to the very best industrial design PRT (IPRT) under ideal conditions and more than an order of magnitude better in high precision temperature measurements than the conventional type R or S thermocouples.

References

[1] B E Bentley, "Changes in Seebeck coefficient of Pt and Pt10% Rh after use to 1700°C in high purity polycrystalline alumina", Int. J. Thermophysics, 6, 83-99, 1985.

[2] E H McLaren and E G Murdock, "The Pt/Au Thermocouple" Report NRCC 27703, National Research Council Canada, Orrawa, 1987.

[3] G W Burns, G F Strouse, B M Liu and B W Mangum, "Gold versus Platinum Thermocouples: Performance Data and an ITS-90 Based Reference Function", Temperature: its measurement and Control in science and industry, Vol. 6 531 – 536, 1992.

[4] M Gotoh, K D Hill and E G Murdock, "A gold/platinum thermocouple reference table" Rev. Sci. Instrum. 62 (11), 2778 – 2791, 1991.

[5] Y G Kim, K S Gam and C Rhee, "1000H stability test of the Au/Pd thermocouple at 1000°C", Metrologia, 33, 337-339, 1996.

[6] R E Bentley , "A thermoelectric scanning facility for the study of elemental thermocouples," Meas. Sci.Technol. 11, 538-546, 2000.

[7] F Jahan and M Ballico, "A Study of the Temperature Dependence of Inhomogeneity in Platinum-Based Thermocouples", Temperature: its measurement and Control in science and industry, vol. 7, 469-474, 2002.

[8] R E Bentley, "Thermoelectric changes in Au and Pt: metals used in elemental thermocouples", Meas. Sci. Technol. 12, 627-634, 2001.

[9] Y G Kim, K S Gam and K H Kang, "Thermoelectric properties of the Au/Pt thermocouple" Rev. Sci. Instrum. 69, 10, 3577-3582, 1998.

[10] D Ripple, G Burns and M Battuello, "Highly accurate temperature measurements with pure element thermocouples", the International Journal of Metrology, 37-41, 1998.

[11] M Ballico "Intercomparison Calibration Procedure for Platinum Resistance Thermometer (PRT) and Digital Thermometers (DT)" NMI Quality System PM – EADA - 8.2.26.

[12] M Ballico, "Numerical Post correction of thermocouple inhomogeneity scan data to improve spatial resolution and reduce conduction errors", Tempmeko 2005, Dubrovnik, 2005

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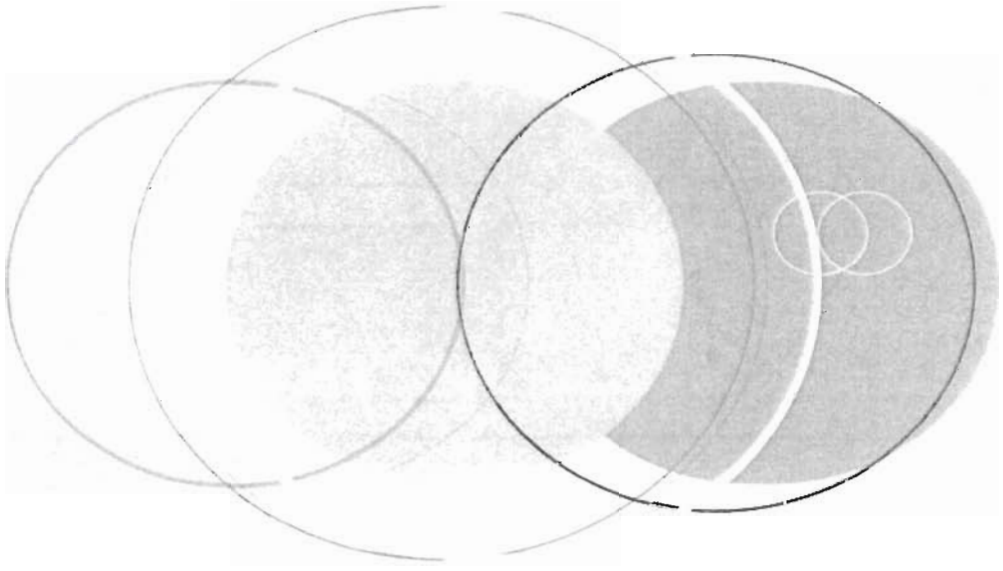

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