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Copyright contact:

Mr Steve Sidney

Physical Address

NLA BUILDING
Corner of Gen. Van Ryneveld Street & De Havilland Crescent
Persequor Park
Meiring Naude Road
Lynnwood, Pretoria

Postal Address

NATIONAL LABORATORY ASSOCIATION (NLA)
PO Box 914-2142
Wingate Park
0153
Pretoria

Telephone: +27(12) 349 1500
Fax: +27 (12) 349 1501

Email: **maggier@nla.org.za**
Internet: http://www.nla.org.za

Case Studies on the Impact of Poor Traceability in Testing and Measurement

Speaker / Author: E.L. Marais
Co-authors: E.P. Tarnow, S.B. Sidney

CSIR National Metrology Laboratory
PO Box 395, Pretoria, 0001, South Africa
Email: elmarais@csir.co.za
Phone: 012 841 3013 Fax: 012 841 2131

Abstract

The importance of traceability for every measurement that is made cannot be over-emphasised. For calibration and testing laboratories, traceability is normally imported through calibration of the standards and equipment used in the laboratory. When this is done, the discussion can be closed. Or can it?

Obtaining a traceable calibration for your standards and equipment can unfortunately lead to a false sense of security. What if the uncertainty assigned to the measurements performed on your standard is not small enough to satisfy the requirements of your subsequent measurements or tests? Are there any correction factors to be applied? Or is the certificate simply filed and forgotten?

This paper investigates a few examples where poor traceability caused invalid tests and measurements to leave the door of accredited calibration and testing laboratories.

1. Introduction

During 2002 a course on uncertainty of measurement was developed and presented to staff at the National Metrology Laboratory. Using some of the material prepared for this course, a course was held for all SANAS technical assessors at the end of that year. In 2003 a more general course was developed for SANAS accredited laboratory staff members [1].

Since May 2003 this course has been presented more than twelve times, with the frequency of presentation growing increasingly rapidly. On the last day of this course participants are given the opportunity to bring examples from their field of testing and measurement and these examples are then discussed. A number of these examples were presented at the 2005 conference [2].

From some of these examples it is clear that the issue of traceability is not always handled correctly by both calibration service providers and testing laboratories alike. Three such examples will be dealt with here.

2. Examples

2.1 Force

An automotive testing laboratory uses a loadcell to measure the force that is exerted onto safety critical fixture in a motor vehicle. The loadcell is calibrated by an accredited force laboratory.

The automotive testing laboratory performs the test to an international specification, and is certified by several motor manufacturers to perform this test. The test results provided by the laboratory are accepted overseas for the importation of automotive parts and complete vehicles from South Africa. This means that the test need not be repeated for automotive components and complete vehicles manufactured and tested in South Africa before being exported.

The certificate issued for the calibration of the loadcell used to provide traceability to the test result contains the data shown in Table 1 below.

Table 1: Loadcell calibration data from accredited certificate.

LOADCELL CALIBRATION CERTIFICATE	
FORCE APPLIED (kN)	**UUT DISPLAYED (kN)**
10	10,5
20	20,1
30	30,2
40	40,0
50	50,2
60	60,1
70	70,3
80	80,0
90	90,1
100	100,3
Uncertainty of Measurement: ± (0,5 % of reading + 2 kN)	

In the testing standard it is stated that the test must be performed at a force of 15 kN, and that the test requires an accuracy of ± 1 %. Can you spot the problem?

15 kN is not a calibration point on the loadcell, and the uncertainty as quoted on the calibration certificate is only applicable at the calibrated points. In this situation so-called “indirect” traceability is applicable, in other words the uncertainty at 15 kN must be calculated from the uncertainties at the closest calibration points, these being 10 kN and 20 kN.

Given the data in the certificate, the uncertainty that applied to the points immediately preceding and following the 15 kN point, these being 10 kN and 20 kN, must be calculated using the uncertainty statement on the certificate. The uncertainty is stated as ± (0,5 % of reading + 2 kN). This gives an uncertainty at the 10 kN point of ± (0,5 % of 10 kN + 2 kN) = 2,05 kN, and an uncertainty of ± (0,5 % of 20 kN + 2 kN) = 2,1 kN at the 20 kN point. If these values are stated as a percentage of the measured values, we obtain a 20,5 % uncertainty at the 10 kN point, and a 10,5 % uncertainty at the 20 kN point. It is very clear that the test limit requirement of 1% accuracy at t force of 15 kN cannot be met using the data supplied in the certificate.

What did the laboratory do in this case?

The automotive testing laboratory assumed that the uncertainty of ± (0,5 % + 2 kN) applied at 15 kN and neglected to assess the impact of the floor uncertainty of 2 kN at 15 kN that was obviously much larger than the required ± 1 %. Using the laboratory's logic this gave an uncertainty of 0,5 % of reading at the 15 kN point, giving an absolute uncertainty of 0,075 kN. The laboratory also did not take the required correction into consideration, leading to an additional uncorrected error in their measurement.

The best case estimate for the actual uncertainty at the 15 kN point would have been 2,075 kN, much larger than that assumed by the laboratory (this assumes perfect linearity of the loadcell). The actual uncertainty for the data presented in the calibration certificate is shown in figure 1 below, assuming perfect linearity for the loadcell. The uncertainty assumed by the laboratory is also shown.

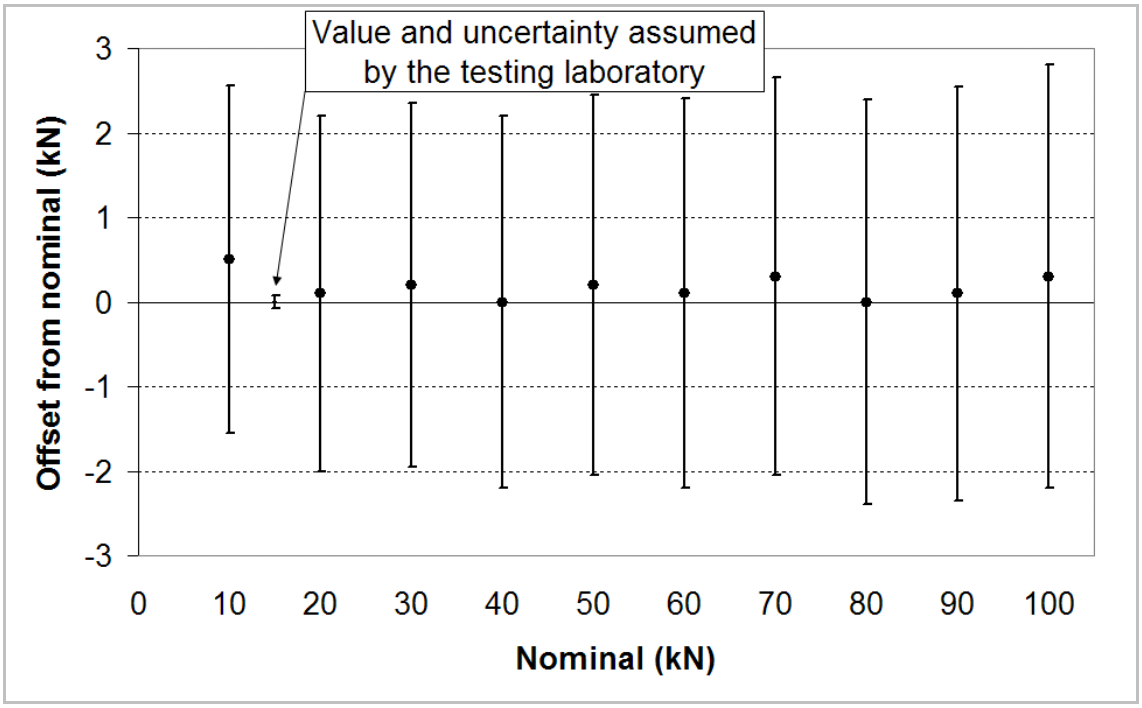

Figure 1: Visual representation of the problem.

The automotive testing laboratory was simply taking the certificate and filing it. They failed to notice that the uncertainty of their tests was larger than the specification limits! Needless to

say the laboratory personnel on the UoM course were shocked when this was pointed out to them.

How would you have handled the situation?

The problem in this example began with the imported traceability. The fact that the testing laboratory was quite happy to accept the calibration certificate that was provided to them makes it clear that proper contract review never took place. The calibration laboratory cannot be blamed for the service they provided since they were never actually sure of what the client required. Some blame should however fall on their shoulders for not finding out exactly what the client required. The exact circumstances of the negotiation between the two laboratories are not known, but it is very clear that it was not done properly.

Since the testing laboratory only uses the loadcell at 15 kN, it would have been far better to request a calibration that includes this point, and to make sure that the accuracy requirement was met at this point. If the current calibration laboratory cannot provide this, a laboratory with facilities that can provide it should be selected. It may even turn out that the selected loadcell cannot be used to the required accuracy, and in this case new equipment should be purchased.

2.2 Mass

In an analytical laboratory, a mass balance is used as the laboratory standard to import traceability from an accredited mass laboratory for the determination of concentrations in reference chemical solutions. The mass balance is only calibrated at fixed points in the scale. The test method calls for a measurement at a value that is between two of the calibration points.

In table 2 the results extracted from the calibration certificate are tabulated.

Table 2: Mass Balance calibration results.

MASS BALANCE CALIBRATION CERTIFICATE	
MASS APPLIED (g)	**UUT DISPLAYED (g)**
0	0,000
1	1,000
10	10,001
50	50,002
100	100,003
150	150,005
200	200,009
Uncertainty of Measurement: ± 0,003 g	

The measurement requirement in this case was to determine the concentration of a reference chemical solution gravimetrically by means of volume and mass measurements. The mass was to be measured at a nominal value of 180 g to an accuracy of ± 0,005 g.

On initial inspection, the calibration uncertainty of ± 0,003 g appears to be adequate to cover the accuracy requirement of ± 0,005 g. Using the data provided in the calibration certificate it is found that for an indication of between 150,002 g and 150,008 g, the true value of the mass being measured will be 150 g. For an indication of between 200,006 g and 200,012 g, the true value of the mass will be 200 g. This implies that an indication of 180 g on the balance will definitely not mean that a true mass of 180 g was placed on the balance.

Furthermore, neither of the uncertainties at 150 g or 200 g can directly be applied to the required measurement point of 180 g. Therefore the estimated uncertainty at this measurement point will be even worse as additional factors have to be taken into account.

What did the laboratory do in this case?

The laboratory used the calibration uncertainty of ± 0,003 g as the uncertainty applicable to the measurement at 180 g, without applying a correction to the indicated value. The problem is shown graphically in figure 2.

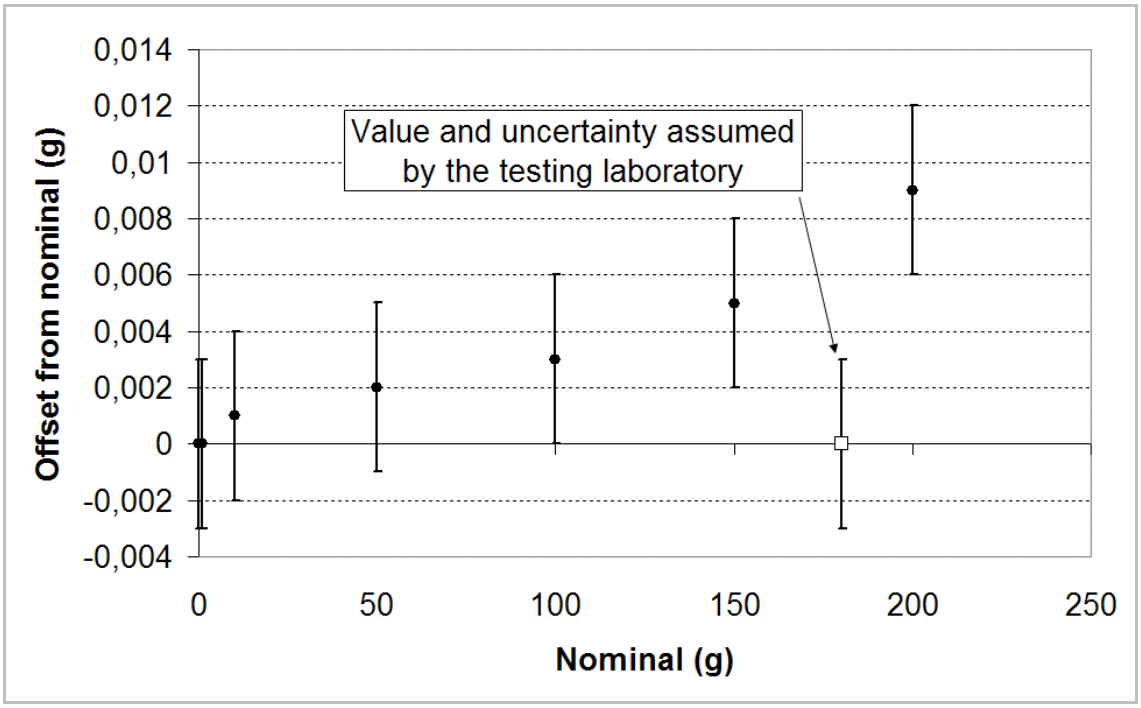

Figure 2: Visual representation of the problem.

What would you have done?

In this case the calibration laboratory is almost certainly not at fault. The measurement uncertainty that they issued for the calibration is acceptable, and with a little effort the data can be used by the testing laboratory to determine the appropriate indication and uncertainty for a true mass of 180 g.

Once again, proper contract review could have avoided the problem. The testing laboratory knows that it uses the balance at 180 g, and could have requested a calibration at this point.

2.3 Water testing

A water testing lab uses a balance in their routine work. They also have a set of weights which is used to perform regular verification checks on the balance. This is the normal practise in most analytical laboratories.

The calibrations of the balance and the mass pieces are performed by accredited calibration laboratories. The testing laboratory uses two different service providers for these calibrations. This is good practise since it removes any significant correlation between the calibration of the mass pieces and the balance.

So why is there a problem? The laboratory needs to set acceptance limits on the regular verifications done on the balance, using the calibrated mass pieces. They wanted to improve their process, and contacted one of the authors for assistance.

In table 3 the calibration data for the balance is shown, in table 4 the calibration data for the mass pieces is shown, and in table 5 the specification of the balance is shown. The manufacturer of the balance recommends that the regular verifications be performed using a check weight of 100 g with an uncertainty equal to or less than ± 0,1 mg. Now have a look at the data…

Table 3: Calibration data for balance.

Applied load (g)	Indication on balance (g)
0,100 01	0,100 0
1,000 00	1,000 0
10,000 03	10,000 0
49,999 98	50,000 1
100,000 0	99,999 9
200,000 1	199,999 9
The uncertainty of measurement was ± 0,000 6 g	

Table 4: Calibration data for mass pieces.

Nominal value (g)	Actual value (g)	Uncertainty of calibration (g)
1	0,999 8	0,000 5
20	20,000 9	0,001 0
40	29,997 8	0,002 0
100	99,999 4	0,005 0
200	199,996	0,010
2 000	2 000,05	0,10

Table 5: Specifications of the balance.

Specifications	**200 g balance**
Weighing range	220 g
Readability	0,1 mg
Taring range subtractive	220 g
Linearity	0,2 mg
Recommended calibration weight	100 g ± 0,1 mg

It is common practise to set verification limits at 75% of the specification of an instrument used within its specification. It is normal that the verification mass should have an uncertainty much smaller than the specification of the instrument being verified. From table 5 it can be seen that the accuracy specification of the balance is about ± 0,3 mg. The manufacturer recommends a calibration weight with an uncertainty of 0,1 mg, which is acceptable for the balance under consideration. Common practice will then be to have the balance recalibrated when the indication reaches either 100,000 2 g or 99,999 8 g.

With the data presented in table 3 and 4, it is clear that it is impossible to reliably verify the balance under consideration. This is shown visually in figure 3.

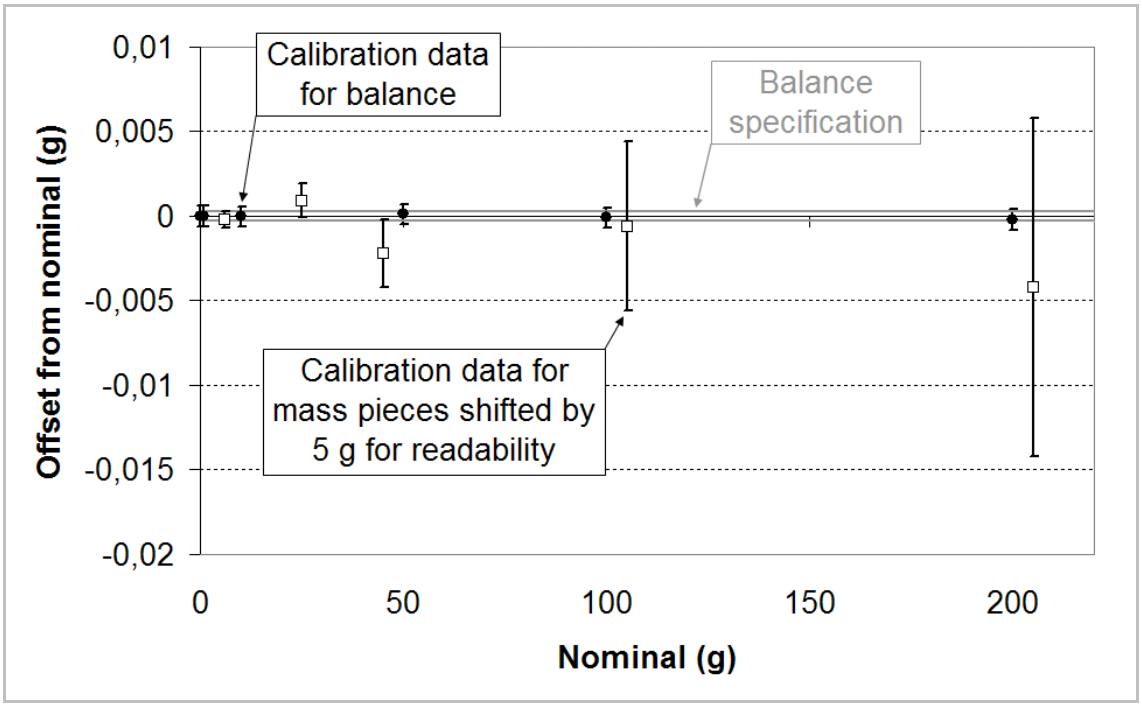

Figure 3: Mass piece calibration data, balance specification and calibration data.

The calibration uncertainty for the mass pieces overshadows the specification of the balance and the calibration uncertainty of the balance. To clarify the situation, the mass piece calibration data is removed, and the result is shown in figure 4.

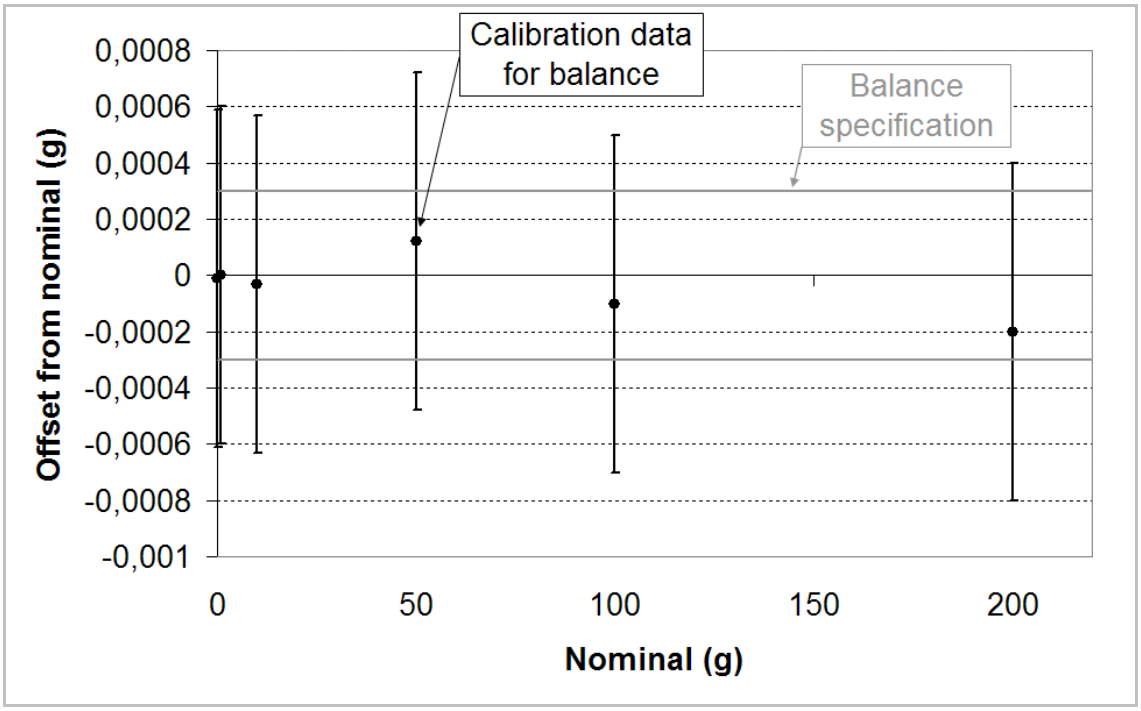

Figure 4: Balance specification versus balance calibration data.

Te testing laboratory wanted to do the best they could, but with the data available to them, this was impossible, as can be seen from figures 3 and 4.

The first problem is that the balance calibration did not prove that the balance met its accuracy specification. The second problem is that the calibration provided for the 100 g mass piece is completely inadequate. The uncertainty is 50 times larger than that required for verification of the balance.

This is another example where proper contract review was not conducted between the calibration and testing laboratory. This may have been due to the testing laboratory not being aware of what levels of uncertainty they required in the first place!

So what can the testing laboratory do to rectify this situation? The first step is to get the balance calibrated by a service provider that can provide an uncertainty small enough to prove the specification of the balance. The second step is to find a calibration laboratory that can calibrate the 100 g mass piece to an uncertainty of ± 0,1 mg or smaller. It is possible that the mass piece is of poor quality and therefore cannot be calibrated to the required uncertainty.

The mass pieces should be the highest level of traceability in the testing laboratory. Therefore the best option is to have the mass pieces calibrated to a much smaller uncertainty, and then use these mass pieces to calibrate the balance themselves. If the mass pieces that the laboratory currently own are not suitable, this will necessitate the purchase of a higher quality set.

3. Conclusion

It is clear that the issue of traceability is not clear to most testing laboratories. The problem is definitely due (at least in part) to poor contract review. Often the testing laboratory does not know what uncertainty they require. Interpretation of calibration certificate data is also questionable. Proper training in these aspects will definitely rectify the situation, but it is the responsibility of both the calibration and testing laboratories to work together to ensure proper contract review. Since most calibration laboratories have more experience working with calibration certificates, the responsibility should fall on them to help the testing laboratories with these issues.

Disclaimer

The names of the laboratories involved in the examples used in this paper are not mentioned to protect these laboratories. The examples are merely used to illustrate the problems typically encountered in the community. Some of the data points also differ from the actual data reported in the calibration certificates.

References

1. CMeTSA "Introduction to the Estimation of Uncertainty in Measurement" course, see http://www.nla.org.za/

2. E.P. Tarnow, "It can be a risky business assuming the calibration uncertainty applies to the points in between – Here's why", Proceedings of the 2005 Test and Measurement Conference, Emperors Palace Convention Resort, 5 to 7 September 2005.