Understanding the Data and True Value of a Calibration Certificate

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Abstract

Many people see calibration as a service that costs a lot and that gives little in return, but if understood and used properly, a calibration certificate is a tool that can be used to give confidence to measurements; to better understand measurements that are made; and ultimately is an investment that adds value to the equipment far and above the cost of the calibration.

This paper will guide those users of calibration certificates through the myriad of text, tables and terms to reveal the useful data and to uncover the true value of a calibration certificate.

1. Introduction

In the past the calibration certificate was the "holy grail" to any auditor; if you had one, then the auditor was satisfied. More recently though, international standards have become more strict and auditors have become more cranky (just kidding) and more often than not, questions are being asked about the calibration certificate that the end user struggles to answer.

In this paper I hope to be able to show you where to find those answers, and along the way you may discover that the calibration certificate is not just a piece of paper to satisfy an auditor, but a useful tool that has much more value than its cost.

Along the way we'll look at ISO 17025 where it pertains to calibration certificates by studying a sample certificate to see how the requirements of ISO 17025 have been met.

Our journey will then continue with a more detailed explanation of some of the more misunderstood points on a calibration certificate and we'll end with a look at how a calibration certificate can be used to increase confidence in measurements and how it can save you money.

But first, let's take a brief look at why we have a calibration certificate in the first place.

2. The Pyramids – a Testament to Traceability.

Without looking too hard, we find evidence of a system of weights and measures in several places in the Biblical book of Proverbs. Chapter 11 verse 1 tells us that *"Dishonest scales are disgusting to the LORD, but accurate weights are pleasing to him."(GW)* And again in Proverbs 16:11, 20:10 and 20:23 reference is made to the use of dishonest scales. While God is mentioned in these passages as being “disgusted” by dishonest measures, we cannot know what kind of punishment would be metered out (pun intended) to those transgressors.

However, turning to ancient Egypt of about the same time period and we find a story regarding the building of the pyramids. Apparently the so-called “Royal Egyptian Cubit” was decreed to be equal to the length of the forearm from the bent elbow to the tip of the extended middle finger plus the width of the palm of the hand of the Pharaoh or King ruling at that time.

The “Royal Cubit Master” was carved out of a block of granite, and workers engaged in building tombs, temples, pyramids, etc. were supplied with cubits made of wood or granite. The Royal Architect or Foreman of the construction site was responsible for maintaining & transferring the unit of length to workers instruments. They were required to bring back their cubit sticks at each full moon to be compared to the Royal Cubit Master.

Failure to do so was punishable by death!

Though the punishment prescribed was severe, the Egyptians had anticipated the spirit of the present day system of legal metrology, standards, traceability and calibration recall. (One wonders how much busier calibration laboratories of today would be, if failure to re-calibrate was punishable by death.)

With this standardization and uniformity of length, the Egyptians achieved surprising accuracy. Thousands of workers were engaged in building the Great Pyramid of Giza. Through the use of cubit sticks, they achieved an accuracy of 0.05%. In roughly 220 m they were accurate to less than 2 cm. [2]

Traceability today of course, extends beyond the local national Ruler (another intended pun) and ends now in international agreements. Consequently the Egyptians could now have imported blocks of stone from the four corners of the earth and they would still have achieved similar accuracy. Of course the paperwork would have been mind-blowing, and that’s where the calibration certificate comes in.

Imagine if you will that the Egyptian foreman decides to order blocks from his Aztec cousin in South America. He specifies the size of the block in Royal Egyptian Cubits (REC) and even defines the REC for his cousin. But the Aztec king has shorter arms than the Egyptian Pharaoh and when the blocks arrive, none of them fit.

The foreman then decides to send a granite REC to his cousin, complete with a note telling the Aztecs that this granite rod is 1 REC in length and may be used to check the sizes of the ordered blocks. And what we call that note these days? You guessed it; a Calibration Certificate!

So now the Atzec cousin knows that blocks manufactured using the certified REC will be accepted by the Egyptians and everyone is happy.

(Everyone of course except the Egyptian auditor who is waiting for the Atzecs to submit their quality manual. Actually they did send it but it was 1345 pages carved on stone tablets, and the postal ship sank because of the sheer weight.)

3. ISO17025 and Calibration Certificates

Of course the note from the Egyptian to the Aztec explaining about the accuracy of the Royal Egyptian Cubit was probably just a few lines long. Today however, thanks to such glorious institutions as ISO, calibration certificates often run into several pages and are covered in tight printed fonts, although to the uninitiated, the information may just as well be written in Egyptian Hieroglyphics. So let's see if we can decode this information into something useful.

3.1 What, Who, When, Where and How?

Taking a look at the standard ISO17025, to which all internationally recognised calibration laboratories comply and are accredited, we find that there is much information that must be included on a calibration certificate issued by one of these accredited laboratories. We'll take a closer look at these requirements by inspecting a typical calibration certificate.

Certificate of Calibration

SANAS accredited laboratory no's 139/239/339/539/1439

The South African National Accreditation Service (SANAS) is a signatory to the multilateral agreement of the European co-operation for Accreditation of Laboratories (EA) and the bilateral agreement with the Chinese National Laboratory Accreditation (CNLA) organisations for the recognition of calibration certificates.

Certificate No	: MX990
Manufacturer	: Mettler
Description	: Electronic Balance
Model No	: AE 160
Serial No	: 38500-066-10
Plant No	: None
Calibrated for	: Pharma Co, Midrand
Temperature	: 22 °C
Relative humidity	: 32 %RH
Date of calibration	: 29 August 2006
Expiry date	: 29 August 2007
Calibrated by	: Guy Snelling

Issue date : 29 August 2006

Checked by

SANAS Authorised Signatory

G.Snelling

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Fig 1 Example of a SANAS calibration certificate – page 1

The first page of this certificate is designed to show the customer details about what was calibrated, when and under what conditions. Some of the requirements of ISO17025 are obvious on this page. These include the title “Calibration Certificate”, name and address of the laboratory, name and location of the customer, name of authorising signatory, date the calibration took place, the environmental conditions at the time, unique identification of the item calibrated and the unique identification number of the certificate.

One other item that is shown here is the so called expiry date. ISO17025 recommends that this be omitted unless requested by the customer or is a legal requirement. In the italicised paragraph near the bottom of the page, is a guide to the user about re-calibration intervals. In this case though, the client has requested that an expiry date also appear on the certificate.

SANAS also requires that the SANAS logo and accreditation numbers appear on the certificate. The statement about bilateral agreements is included to assist with the acceptance of the certificate by a foreign accreditation organisation. Also a copyright notice is included along with a declaration that the certificate should only be reproduced in full. This helps to avoid misleading information. In the same section is a statement about confidence levels. This statement is vitally important and to the uninitiated, a bit confusing, but we’ll cover it later on under Uncertainties of Measurement.

The page ends with the signature of the person that authorises the report as well as the page numbering.

Although it is not a requirement, either by SANAS or by ISO17025, this certificate also carries a “Checked by” signature. This is an in-house requirement for this particular laboratory that allows for checking of the certificate by an additional staff member.

So much for page 1. Now onto page 2.

Certificate of Calibration

Certificate No: : MX990

1. Standards and equipment

Fixed Asset ID	Make	Model	Description	Serial Number	Certificate No	Cal Due Date
14-01	Wis & Haigis	E1/E2	31 Mass Pieces	2457, 2458, 1, 2	MV/M-1985	Sep-2006

2. Procedure

The balance was calibrated by using standard mass pieces in terms of procedure 14/P/002-04

3. Results

All results are shown in " g"

3.1 Repeatability (g)

Applied Mass	Variation
20	0.0001
80	0.0001

3.2 Corner Load (g)

Applied Mass	Position	Display
50	Centre	49.9998
	Back	49.9998
	Right	50.0000
	Front	49.9999
	Left	49.9998
	Centre	49.9999

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Fig 2 Example of a SANAS calibration certificate – page 2

Once again, at the top of the page is the title and also the unique certificate number.

Below this is a section that covers the ISO requirement for evidence of traceability to national measuring standards. Sometimes this can simply take the form of a statement, but in this case there is a list of equipment that was used to perform the calibration, including calibration certificate numbers and calibration due dates.

The section is then followed by the identification of the procedure used to perform the calibration. These procedures can often run to several pages so are here referred to by procedure number. A lot of work goes into writing a complete and thorough procedure, so many laboratories are hesitant about releasing them to clients. But rest assured that the calibration procedures used in SANAS calibration laboratories are monitored by SANAS during initial and annual assessments.

3.2 And what did we find?

The next section of this certificate covers the results of the calibration

Certificate of Calibration

Certificate No: : MX990

3.3 **Linearity (g)**

Applied Mass	UUT Display As found	UUT Display As left	UUT Error As left
0.001100	0.0012	0.0012	0.0001
0.002100	0.0022	0.0022	0.0001
0.005000	0.0050	0.0050	0.0000
0.010000	0.0101	0.0101	0.0001
0.020100	0.0202	0.0202	0.0001
0.050000	0.0501	0.0501	0.0001
0.099900	0.1000	0.1000	0.0001
1.000100	1.0001	1.0001	0.0000
10.000300	10.0004	10.0004	0.0001
19.999900	20.0000	20.0000	0.0001
49.999900	50.0000	50.0000	0.0001
80.000100	80.0002	80.0002	0.0001
80.001200	80.0013	80.0013	0.0001
80.002200	80.0022	80.0022	0.0000
80.005100	80.0053	80.0053	0.0002
100.000000	100.0000	100.0000	0.0000
149.999900	149.9997	149.9997	-0.0002
160.000200	160.0000	160.0000	-0.0002

Uncertainty of Measurement: 0 to 160 g ± 0.0003 g

4. **Notes**

Calibration summary:

Function	Maximum Error
Linearity	0.0002
Repeatability	0.0001
Corner	0.0002

The calibration was performed onsite.

---- End of document ----

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Fig 3 Example of a SANAS calibration certificate – page 3

Due to the many types of instrumentation that are calibrated by calibration laboratories, the layout and actual results taken will vary from certificate to certificate. However there are some basic fundamentals that should be observed.

In accordance with ISO17025, the results must be accurate, clear unambiguous, objective and in accordance with the method or procedure used.

If available, calibration results obtained before and after adjustment and or repair must be included. We'll find out why this is important, a little later.

Measurement uncertainties must also be included, as well as an indication with compliance with a standard or specification, if applicable. Again, we'll cover uncertainties of measurement a little later.

The certificate may also include results obtained from a sub-contractor, and these results must be clearly marked as such.

3.3 Extra stuff

ISO 17025 also allows for amendments and supplements to calibration certificates as well as opinions and interpretations where necessary. The requirements for these would be dealt with on a case-by-case basis and so familiarity with ISO17025 is advised.

4. And All This Is Useful….How?

So we have our calibration certificate and we now have a bit more of an idea of what it all means. But what do we do with it?

Well there are several reasons for having an instrument calibrated in the first place, so let's deal with them one at a time.

4.1 Traceability

The measurements that you make with your instruments are most useful if they can be related to other, similar measurements. Thus the mass of a sample measured in one country should give the same mass when measured in another country. This helps companies to maintain manufacturing tolerances throughout the world so that end users can have confidence in the products that they buy. This is easily achieved when the measuring instruments in each country have both been calibrated using standards that are traceable to each other.

Calibration certificates must therefore indicate this traceability, either by listing the standards used in the calibration or by a statement to the affect that the measurements are traceable. In any case, records of standards used are kept by the calibration laboratory for inspection.

4.2 Uncertainty

In an ideal world, the measured mass of a sample measured in one country would be exactly the same as the measured mass of the same sample measured in another country.

Unfortunately there are many factors that can affect a measurement and therefore the two measurements will differ by a certain amount. The factors influencing the measurements are evaluated and an “uncertainty of measurement” is determined. Taking this uncertainty into account helps us to make decisions about the accuracy of our measurements and therefore, for example, the acceptance or rejection of a sample based on its specification.

One of the factors that is used in determining the uncertainty of the measurements is the uncertainty of measurement quoted on the calibration certificate. This should be used in your own calculations for the uncertainty of measurements you make with the instrument.

Another value to be used is the reference made to the “confidence level” that was quoted on the first page of our example certificate. This is used in the statistical calculations of the uncertainty of measurement.

Much literature has been written about the calculation of uncertainties of measurement, but one that is widely used is “Assessment of Uncertainties for Measurement for Calibration and Testing Laboratories”, by R.R. Cook and published by NATA, more affectionately known as “The Cook Book”. Reference should be made to such literature for further information about the calculations of uncertainties of measurement.

4.3 Reliability

When using an instrument you need to know that the readings can be trusted. Again, in an ideal world every instrument would read perfectly every time. Unfortunately the state of affairs is not so easy and readings on an instrument will vary even when measuring the same sample, and this variance with change over time. The degree of this variance should always be within the specification of the instrument since the specification is the basis on which the instrument was initially purchased, otherwise corrections must be made.

The results on the calibration certificate will indicate the degree of accuracy of the instrument, **but only at the time and conditions of the calibration**. The tendency of these results to drift can only be determined by historical data and thus the necessity for regular calibration. Previous calibration results can be graphed against more recent ones and the drift can then be determined and extrapolated (with care) to determine the current accuracy of an instrument.

Incidentally, if a system of validations is in place, whereby a few repeatable measurements are made regularly between calibrations and are monitored, then these values can be used to predict the values that the calibration laboratory will report. If the predicted values and the calibration values agree, then a high level of confidence is placed not only on the instruments but also on the validation system. This can often be used to extend calibration cycles and therefore to save money.

4.4 Accuracy

Of course the most important question to be asked is “How accurate are my measurements?” This can be determined by analyzing the results on the calibration certificate.

Again, the actual results given on the certificate may vary both in specific values and also in formats, but generally the value of a standard is shown and the result obtained when using the instrument to measure that standard is given. (Obviously this applies to measuring instruments. Certificates for instruments that source a value will give the nominal value of the instrument, along with the value measured by the standard measuring instrument.).

The actual error of the instrument may then have been calculated and shown or a correction value is given. ("Correction" is the algebraic opposite of "error" and by convention corrections are algebraically added to results)

At some point however, it may be tiresome to correct large errors of an instrument and the instrument will need to be adjusted. It is critical to maintaining a valid history that calibration values are determined **before** adjustments are made, and then those same values are measured again **after** the adjustments. These are often listed on certificates as "pre-cal" and "post cal" values or sometimes "As found" and "As left" values. However they are named, the use of these values can allow the continued determination of the drift to be maintained.

Of course, if an instrument becomes faulty and requires repair and re-adjustment, then "pre-cal" values cannot be determined.

5. What about re-calibration?

Even though an instrument may have been supplied with a calibration certificate from the manufacturer, as we have seen previously, unless this certificate indicates its traceability, then it's not worth very much. It is therefore important to have new equipment suitably calibrated at the time of purchase before putting them into use. This calibration will also form part of the commissioning of an instrument, and also gives useful evidence in a case for a warranty claim if an instrument is found to be out of specification.

But then how often should the instrument be recalibrated? The ISO standard 17025 firmly puts this decision into the hands of the user. A typical calibration certificate may carry a statement that a recalibration period must be chosen that will ensure that the accuracy of the instrument stays within predetermined limits, but again those limits are to be determined by the user. Generally speaking though, recalibration should be performed when you no longer have confidence in the measurements made by the instruments, or can no longer prove traceability of the measurements. [1]

Factors that may be used to determine the re-calibration period, or calibration cycle, would be the amount of use, the way it is handled, and the degree of required accuracy. Regular validation measurements can be used to monitor the drift of an instrument and to then determine its current accuracy. Using statistical analysis of calibration results and also of validation measurements, expected calibration intervals can be chosen and either shortened or extended as required. It is therefore important that records be maintained of calibration, validation and maintenance work, and it may also be useful to restrict the use of the instrument only to suitably qualified persons.

By the way, ISO17025 discourages the calibration laboratories from including a "recalibration date" on a certificate. ISO does however realise that such a date may be a requirement for the customer for quality system or legal purposes, and so does make allowances for it, but only under specific instruction from the customer. It is important then to liase with the calibration laboratory about a recalibration date, and to instruct them in writing of your requirement. Most calibration laboratories have staff with many years experience with different types of instruments used under varying conditions, and their advise can usually be sought when determining calibration intervals.

6. Conclusions

And so we come to the end of our journey through the calibration certificate.

We have seen why calibration certificates are issued; what information appears on the certificate and why; how to use the results data to show the accuracy of your instrument; how to use the certificate to maintain calibration history and to determine drift; and how determine calibration cycles.

All of this information, if used correctly, adds value to your instrument; not only in the value obtained from being able to trust measurements taken by the instrument, but also an increase in the value of the instrument itself. Should you choose to sell the instrument at some point, the inclusion of a comprehensive calibration history file into the sale may actually increase the sell price past the initial purchase price.

So the next time you balk at the prospect of spending money on calibration, rather think of it in terms of investment rather than expense.

References

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3. R.R. Cook, Assessment of Uncertainties for Measurement for Calibration and Testing Laboratories", 2002, NATA, ISBN