MAC - A Summary of Critical Decisions

This document has been created and reviewed by the A2LA Measurement Advisory Committee (MAC). It provides a summary of consensus decisions voted on and approved by the Measurement Advisory Committee and A2LA Criteria Council for use by laboratories and assessors. Dates in parentheses after each item indicate the date each was approved by the A2LA Criteria Council.

I. General

a. A2LA treats statements of conformance and uncertainty as a contract review issue. (1/13/11) (see Tab 1 for summary minutes)

b. Decision rules do not need to be provided on a calibration certificate if the provider (OEM) states the measured value, the uncertainty, and that it is within specifications. (1/13/11) (see Tab 1 for summary minutes)

c. It is never acceptable to accept manufacturer's specifications in lieu of uncertainty budget calculations. (1/13/11)

d. The acceptability of a single point calibration is determined on a case-by-case basis by the technical assessor. (1/13/11)

II. Gage Blocks

a. For cases where a gage block is damaged it is agreed that there is no "before" data available and the "as found" information is stated on the certificate. An A2LA assessor would not expect to see before data on a certificate if the received condition says damaged or in need of repair/replacement. (1/13/11)

III. Fluke 50 Turn Coils

a. For Fluke Coils an open-ended calibration interval is acceptable as further calibrations would not be needed, only visual checks. (1/13/11) (see Tab 2 for summary minutes)

b. A Conformance Assessment Body (CAB) is considered to meet section T9 of the A2LA Traceability Policy for Calibration of Fluke 50 turn coils in lieu of the calibration certificate for cases where the calibration certificate pre-dates the reverse traceability information provided from Fluke. The in-house calibration must be limited to the range from the initial original calibration certificate for the coil. (1/13/11) (see Tab 2 for summary minutes)

IV. Hardness

a. The minimum factors required for hardness uncertainty budgets are repeatability, resolution, and the uncertainty of the block. (1/13/11)

Note: this is applicable for hardness uncertainty budgets documented prior to the implementation of *P110 – Policy on Measurement Uncertainty in Calibration.*

V. Surface Plate Flatness

a. The “Moody Method” for flatness using the "Union Jack" pattern is accepted as a standard method. (See Tab 3 for documentation of the “Moody Method”) (1/13/11)

VI. Electrical and Microwave/RF Minimum Contributors

a. The required minimum contributors for Electrical and Microwave/RF uncertainty calculations used to support the Calibration and Measurement Capabilities for a scope of accreditation are those outlined in the document entitled “Uncertainty Budgets for Electrical Parameters”. (See Tab 4 for the referenced document) (1/13/11)

VII. Traceability of Environmental Chambers (see Tab 5 for Proposal: Consensus on Calibration of an Environmental Chamber) (5/5/2011)

a. That three approaches are deemed as acceptably meeting *P102 – A2LA Policy on Measurement Traceability for environmental chambers:*

1. An in-house calibration performed in accordance with the manufacturer instructions/recommendations and (T9) of P102, as long as the CAB, when using the environmental chamber, includes an accredited sensor with the load to measure the environment during the test; or

2. The CAB obtains an accredited calibration of the entire system; or

3. The CAB obtains an accredited calibration of the individual components of the entire system.

VIII. Making Statements of Compliance Without Taking Measurement Uncertainty Into Account (5/5/2011)

a. For accredited, endorsed, calibration certificates, it is agreed that as long as the CAB indicates in the contract with the client that the calibration results will be reported without factoring in the effect of uncertainty on the assessment of compliance, and the client agrees to the contract, then the uncertainty can be excluded when making that statement of compliance on the calibration certificate. In effect, both parties share the risk that the results may or may not meet the specification since the uncertainty was not included when the results were determined.

Note 1: as of December 1, 2011, for accredited, endorsed, calibration certificates, the actual measurement uncertainty shall be included on the calibration certificate, regardless of whether or not a statement of compliance is made, in order for the certificate to be in compliance with *P102 – A2LA Policy on Measurement Traceability.*

Note 2: A CAB cannot claim to meet a method in cases where the method requires the consideration of the uncertainty.

TAB 1

A2LA Measurement Advisory Committee Meeting Minutes
The Sheraton Columbia Hotel
Columbia, MD

Saturday, March 11, 2006
(8:00 AM– 3:00 PM)

Summary

Agenda Item 6d: Uncertainty and statements of compliance (T. Rasinski)

Discussion: (See attachment 3) Under contract review there are often problems including guard banding, but a part of contract review is to have a guard banding policy and how the laboratory or customer has approved it. In many instances the customers are the one who are determining what the guard banding is.

Calibration providers cannot dictate to the client what will be done. If laboratories do not define the limitation then anything may be acceptable. Laboratories have to have a record or mechanism to extract this information.

A2LA is looking for a recommendation to determine how to approach this issue.

Motion 20: **Motion to recommend to Criteria Council that A2LA deal with statements of conformance and uncertainty as a contract review issue which is sufficiently addressed by existing requirements and take actions to educate labs on this issue.**

Motion 20 passed**: against - 1**

A2LA Measurement Advisory Committee Meeting
The Sheraton Columbia Hotel
Columbia, MD

Saturday, March 24, 2007

SUMMARY

An OEM in attendance requested guidance regarding pass/fail criteria in relation to listing this on issued calibration certificates. In his particular case as a manufacturer, the criteria are proprietary information. In reports issued by his laboratory, the customer is provided with the data, the uncertainty, and a pass/fail decision. During the discussion, it was thought that the OEM did not have to tell a laboratory whether or not their instrument passed; however, if pass/fail is listed on the calibration certificate, the OEM is then required to provide their decision rules. The OEM does not have to make a statement of compliance. Production tolerances are proprietary, when a calibration is performed and the equipment meets specifications, it can be stated that the item meets specification and this would meet the requirements in ISO/IEC 17025.

It was pointed out that the A2LA Calibration Program does require accredited laboratories to have the decision rule defined. A laboratory can state that the statement on the certificate indicating that the measurement uncertainty is considered should suffice. It was also discussed that the internal decisions are irrelevant if the laboratory only wants to know, “Can I use this specification?”

The consensus was that no decision rules need to be provided if the provider (OEM) states the measured value, the uncertainty, and that it is within specifications.

TAB 2

A2LA Measurement Advisory Committee Meeting
The Sheraton Columbia Hotel
Columbia, MD

Saturday, March 24, 2007

SUMMARY

g. The Fluke 50 Turn Coil was discussed. In many cases, the Fluke 50 turn coil is calibrated once and only once as long as they are not damaged. The problem is that no one is currently accredited to perform the calibration. If the calibration was performed many years ago, the laboratory may not be able to obtain the traceability information from the OEM. The concern is whether or not A2LA should require the laboratory to obtain another calibration on the coil in order to achieve traceability.

Based on discussions, an open-ended calibration interval is acceptable as further calibrations would not be needed, only visual checks. Further discussion with A2LA management will be required regarding the traceability of the initial calibration.

Measurement Advisory Committee Meeting Summary
The Sheraton Columbia Hotel
Columbia, MD

Saturday, April 12, 2008
(08:00 AM – 5:00 PM)

Meeting Minutes

e. Previous Action Item: D. Leaman to discuss with A2LA management further guidance on traceability for the valid calibration on the coils.

D. Leaman indicated that there are no issues regarding traceability for these items because we have worked with Fluke to get their traceability documents. Since we have this on file now this is not an issue for most of our labs.

The MAC discussed how this is still a non-accredited calibration and it was noted that A2LA staff is aware of this but since we do have the traceability information from Fluke this is not a concern because the laboratories are able to meet our traceability requirements through the reverse traceability process. The concern was how to handle those laboratories whose calibration certificates pre-date the information provided by Fluke to A2LA.The MAC also discussed that the coils are stable and there is no reason to require a recalibration unless the laboratory cannot establish traceability (i.e. the laboratory has lost the certificates for the item).

MOTION 8 –To allow the laboratory to meet section T9 of the A2LA Traceability policy in lieu of the calibration certificate for cases where the calibration certificate pre-dates the information provided from Fluke. *Approved*.

Amendment to Motion 8 – To amend the motion to indicate when conducting an in-house calibration it should be limited to the range from the initial original calibration certificate for the coil. *Approved*

TAB 3

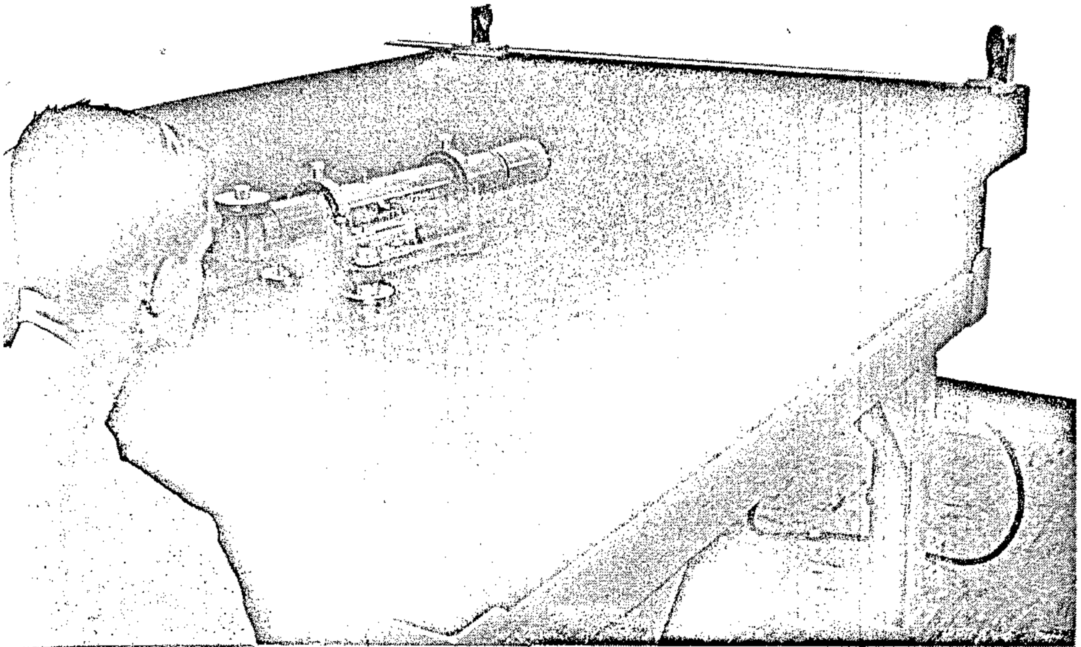


Fig. 1. Typical calibration setup showing the autocollimator, optical flat attached to mount on extreme left-hand corner, mirror mount on extreme right-hand corner and straight edge on end of surface plate.

how to calibrate surface plates in the plant

By J. C. Moody

Physical and Electrical Standards Dept.
Sandia Corp.
Albuquerque, N. M.

SINCE MEASUREMENTS are no more reliable than the surface plate on which they are referenced, it is important to know exactly the accuracy of the plate being used. Surface plates are manufactured to accuracies varying from 0.002 to 0.00005 inch of deviation from a true plane. The user should check each plate after it is installed to determine whether it meets specifications and from time to time thereafter to learn the effect of wear and environment. The check measurements must, for practical purposes, be done in the work environment.

Fortunately, a practicable method of accurately calibrating surface plates is available to industry. The method used in the metrology laboratory at Sandia Corp. is highly accurate yet can be performed by semiskilled personnel using instruments available to any industrial laboratory. This method is an application and extension of procedures developed by K. J. Hume (British metrologist) and involves no new principles.

Ideally, the calibration should be performed in a room in which the temperature of the plate can be kept in equilibrium and from which thermal currents can be excluded. However, industry uses

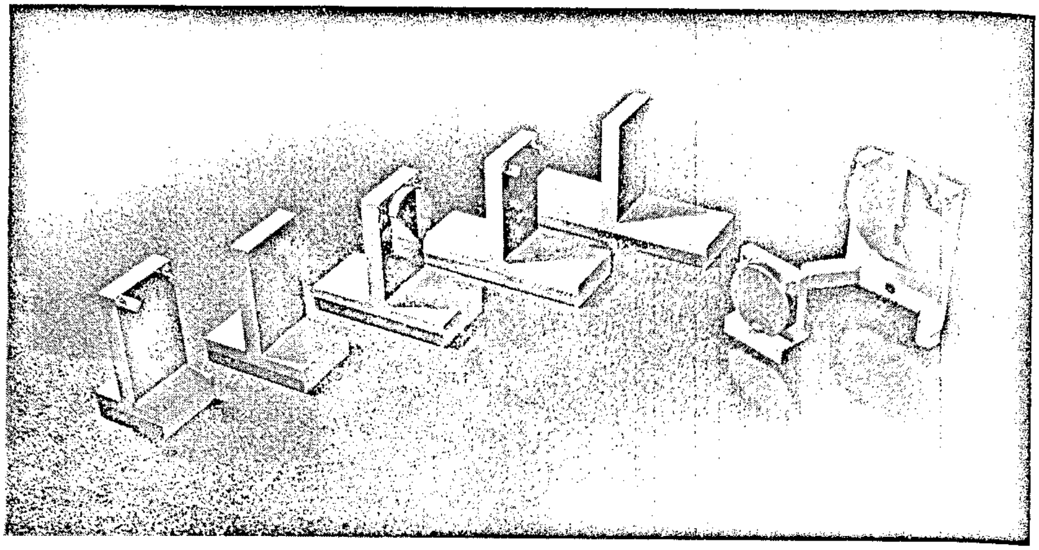


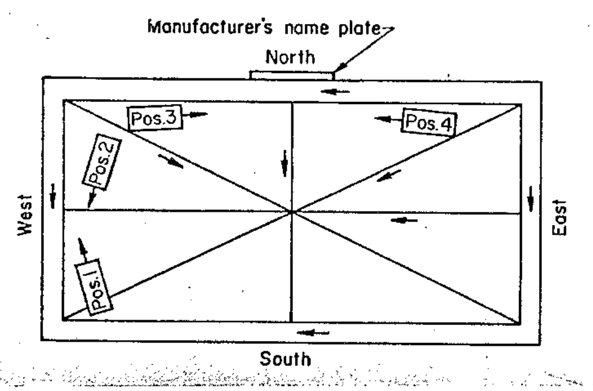
Fig. 2. Mirror mount, reflector mounts and optical flats used for calibrating surface plates.

surface plates under conditions that are less than ideal. These plates can be satisfactorily calibrated under the same conditions. Extremes of temperature changes, thermal currents, and vibration are obviously to be avoided.

Calibration Method: Equipment needed for this method is shown in *Fig.* 1. The autocollimator is essentially an optical lens system from which parallel rays are emitted. These rays strike the surface of a steel optical flat and are reflected back into the autocollimator. The reflected rays produce an image at the focal plane of the autocollimator from which angular displacements can be accurately determined.

The reflector is mounted on a bracket, the support pads of which are separated by a distance

Fig. 3. Positions of autocollimator during readings for the eight principal lines.

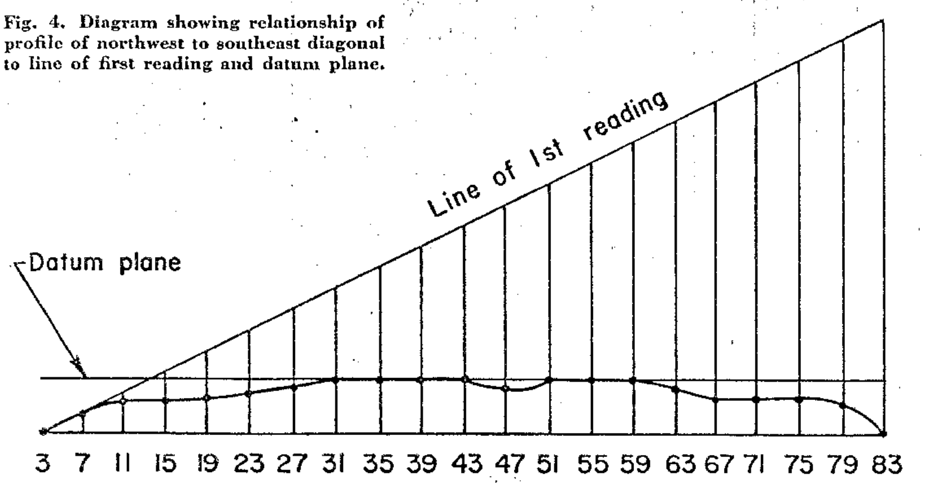


arbitrarily chosen so that it will divide evenly into the dimensions of the surface plate. This distance should be about 8 percent of the length of the short side of the plate. Various reflector mounts needed for different size plates are shown in *Fig.* 2. The mirror mounting bracket is so designed that the mirror mounting is normal to the surface plate. Steel optical flats, the faces of which do not deviate from a plane by more than 0.000003 inch, are used for both the mirror and reflector. In addition, a straight edge, graduated in increments equal to the distance between the support pads of the reflector stand, is used.

A total of eight lines of readings are taken: four perimeter lines, two diagonal lines, and two center lines, *Fig.* 3. The perimeter lines are laid out one increment from the edge of the plate. The precise stations at which readings along all eight lines are taken are measured off in steps equal to the increments on the straight edge. Many more readings could be taken, but a reasonable compromise between accuracy and economy is achieved by this method.

Detailed instructions for using an autocollimator are supplied with the instrument and should be studied carefully. The position of the autocollimator for each line of readings is shown in *Fig.* 3. The readings along the north perimeter line, for example, are taken with the autocollimator in the southwest corner of the plate. The reflector is moved along the line and readings are taken at each station. These readings are entered directly on the properly identified work sheet, *Fig.* 4. After each line is completed, the reflector is moved back to the first station on that line and another reading taken. If this does not agree within $\pm$ 0.3 sec. of

Fig. 4. Diagram showing relationship of profile of northwest to southeast diagonal to line of first reading and datum plane.



arc with the first reading taken at the same station, the operation must be repeated.

Autocollimator readings entered on the work sheet show only angular displacement in tenths of a second of arc in relation to the line of first reading. To be readily meaningful, these must be converted to linear deviations from a base plane. The procedure for these conversions and their presentation will be discussed in the following paragraphs.

Though care must be exercised in each step, the conversion is not a formidable task. Readings can be made in about two hours; an intelligent, properly instructed clerk can reduce the data to an accurate profile of the surface plate in an equal time.

Simplified Data Conversion Procedure: Directions for converting autocollimator readings into linear displacement in hundred-thousandths of an inch are given without any attempt at theoretical justification. One line of each class will be explained in detail. The reader who is interested in the theoretical considerations should read K. J. Hume's *Engineering Metrology* or the author's paper, *The Metrology of Surface Plates*, copies of which are available upon request.

The person who is to reduce the data is given a work sheet for each of the eight lines, TABLE 1. On these, the stations at which readings were taken are indicated in Column 1 in terms of inches from the edge of the plate in the direction in which the line was read. The autocollimator readings are entered in Column 2. No reading is entered for the first station on the line.

CONVERSION FOR DIAGONALS: To process the Northwest to Southeast diagonal line data, the following steps should be taken in order:

1. Convert the autocollimator readings into angular displacement by determining the amount by which each value in Column 2 is greater or less than the first value in Column 2. Do this at each station; enter the result in Column 3, paying attention to the sign.
2. Next, determine the algebraic sum of the angular displacement at each station and enter this value in Column 4. To do this, add the values in Column 3 down to and including each station.
3. Divide the last value in Column 4 by the total number minus one of the stations on the line to determine the correction factor. (In the example shown there are 21 stations. Hence, $-280/20 = -14$.)
4. Set up an arithmetic progression in Column 5. Reverse the sign of the value in Column 4 opposite the midstation and enter it opposite the same station in Column 5. Working up Column 5 from the midstation, add the correction factor cumulatively at each station. Return to the midstation and subtract the correction factor cumulatively at each station to the bottom of the column. The resulting arithmetical progression is the cumulative correction factor for each station.
5. At each station, add algebraically the values in Columns 4 and 5. Enter the sum which is the angular displacement from the datum plane in Column 6. (The datum plane, *Fig.* 4, is that plane in which the center point of the surface plate lies and is parallel to the lines containing the end points of each diagonal.) Proceed with the other diagonal in exactly the same way to this point. Before the last two columns for the diagonal can be completed, computations for the perimeter and center lines must be carried to this point. Do the perimeter lines next.

CONVERSION FOR NORTH PERIMETER LINE:

1. Proceed exactly as with the diagonals through Column 4 for each of the perimeter lines.
2. Prepare a chart of the surface plate as illustrated in *Fig.* 5. Enter the physical center, 0, and the values found for the ends of the diagonals from

Table 1—Work Sheets for Calibrating a 48 x 78-Inch Surface Plate*

1	2	3	4	5	6	7	8
Station (inches from edge) (No.)	Auto-collimator Readings (0.1″ arc)	Angular Displace-ments (0.1″ arc)	Sum of Displace-ments (0.1″ arc)	Cumulative Correction Factor (0.1″ arc)	Displace-ment from Datum Plane (0.1″ arc)	Displace-ment from Base Plane (0.1″ arc)	Displace-ment from Base Plane (0.00001 in.)
Diagonal, Northwest to Southeast							
3	—	—	—	—36	—36	32	6
7	65	0	0	—22	—22	46	9
11	60	—5	—5	—8	—13	55	11
15	50	—15	—20	+6	—14	54	11
19	52	—13	—33	+20	—13	55	11
23	55	—10	—43	+34	—9	59	12
27	56	—9	—52	+48	—4	64	13
31	55	—10	—62	+62	0	68	14
35	50	—15	—77	+76	—1	67	14
39	55	—10	—87	+90	+3	71	14
43	48	—17	—104	+104	0	68	14
47	50	—15	—119	+118	—1	67	13
51	52	—13	—132	+132	0	68	14
55	53	—12	—144	+146	+2	70	14
59	49	—16	—160	+160	0	68	14
63	46	—19	—179	+174	—5	63	13
67	42	—23	—202	+188	—14	54	11
71	53	—12	—214	+202	—12	56	11
75	49	—16	—230	+216	—14	54	11
79	45	—20	—250	+230	—20	48	10
83	35	—30	—280	+244	—36	32	6
Diagonal, Northeast to Southwest							
3	—	—	—	—53	—53	15	3
7	66	0	0	—35	—35	33	6
11	54	—12	—12	—18	—30	38	7
15	54	—12	—24	0	—24	44	8
19	52	—14	—38	+17	—21	47	9
23	55	—11	—49	+35	—14	54	11
27	57	—9	—58	+53	—5	63	12
31	50	—16	—74	+70	—4	64	13
35	50	—16	—90	+88	—2	66	13
39	54	—12	—102	+105	+3	71	14
43	45	—21	—123	+123	0	68	14
47	44	—22	—145	+141	—4	64	13
51	45	—21	—166	+158	—8	60	12
55	45	—21	—187	+176	—11	57	11
59	48	—18	—205	+193	—12	56	11
63	42	—24	—229	+211	—18	50	10
67	42	—24	—253	+229	—24	44	9
71	42	—24	—277	+246	—31	37	8
75	48	—18	—295	+264	—31	37	7
79	42	—23	—318	+281	—37	31	6
83	32	—34	—352	+299	—53	15	3
North Perimeter Line East to West							
4	—	—	—	—53	—53	15	3
8	205	0	0	—40	—40	28	6
12	197	—8	—8	—26	—34	34	7
16	205	0	—8	—13	—21	47	9
20	203	—2	—10	+1	—9	59	12
24	202	—3	—13	+14	+1	69	14
28	199	—6	—19	+28	+9	77	15
32	190	—15	—34	+41	+7	75	15
35	195	—10	—44	+55	+11	79	16
40	183	—17	—61	+69	+8	76	15
44	186	—19	—80	+82	+2	70	14
48	187	—18	—98	+96	—2	66	13
52	186	—19	—117	+109	—8	60	12
56	184	—21	—138	+123	—15	53	11
60	185	—20	—158	+136	—22	46	9
64	190	—15	—173	+150	—23	45	9
68	179	—26	—199	+163	—36	32	6
East Perimeter Line North to South							
4	—	—	—	—53	—53	15	3
8	35	0	0	—49	—49	19	4
12	21	—14	—14	—45	—60	8	2
16	25	—10	—24	—41	—65	3	1
20	28	—7	—31	—37	—68	0	0
24	34	—1	—32	—33	—65	3	1
28	32	—3	—35	—29	—64	4	1
32	35	0	—35	—25	—60	8	2
36	40	+5	—30	—21	—51	17	3
40	42	+7	—23	—17	—40	28	5
44	35	0	—23	—13	—36	32	6

*All values except Columns 1 & 8 are in tenths of a second of arc.

Table 1 (Continued)*

1	2	3	4	5	6	6a	7	8
Station (inches from edge) (No.)	Auto-collimator. Readings (0.1″ arc)	Angular Displacements (0.1″ arc)	Sum of Displacements (0.1″ arc)	Cumulative Correction Factor (0.1″ arc)	Displacement from Datum Plane (0.1″ arc)		Displacement from Base Plane (0.1″ arc)	Displacement from Base Plane (0.00001 in.)
				South Perimeter Line East to West				
4	—	—	—	— 36	—36		32	6
8	164	0	0	— 18	—18		50	10
12	150	—14	— 14	0	—14		54	11
16	156	— 8	— 22	+ 19	— 3		65	13
20	155	— 9	— 31	+ 37	+ 6		74	15
24	151	—13	— 44	+ 55	+11		79	16
28	153	—11	— 55	+ 73	+18		86	17
32	151	—13	— 68	+ 92	+24		92	18
36	146	—18	— 86	+110	+24		92	18
40	140	—24	—110	+128	+18		86	17
44	135	—29	—139	+147	+ 8		76	15
48	135	—29	—168	+165	— 3		65	13
52	133	—31	—199	+183	—16		52	11
56	133	—31	—230	+201	—29		39	8
60	134	—30	—260	+220	—40		28	6
64	140	—24	—284	+238	—46		22	4
68	139	—25	—309	+256	—53		15	3
				West Perimeter Line North to South				
4	—	—	—	—36	—36		32	6
8	60	0	0	—30	—30		38	4
12	46	—14	—14	—24	—38		30	6
16	45	—15	—29	—17	—46		22	4
20	47	—13	—42	—11	—53		15	3
24	50	—10	—52	— 5	—57		11	2
28	45	—15	—67	+ 1	—66		2	0
32	59	— 1	—68	+ 7	—61		7	1
36	60	0	—68	+14	—54		14	3
40	60	0	—68	+20	—48		20	4
44	49	—11	—79	+26	—53		15	3
				Center Line East to West				
4	—	—	—	—65	—65	—58	10	2
8	117	0	0	—59	—59	—52	16	3
12	124	+ 7	+ 7	—53	—46	—39	29	6
16	121	+ 4	+11	—47	—36	—29	39	8
20	125	+ 8	+19	—42	—23	—16	52	10
24	120	+ 3	+22	—36	—14	— 7	61	12
28	115	— 2	+20	—31	—11	— 4	64	13
32	115	— 2	+18	—26	— 8	— 1	67	13
36	113	— 4	+14	—21	— 7	0	68	14
40	113	— 4	+10	—15	— 5	+ 2	70	14
44	103	—14	— 4	—10	—14	— 7	61	12
48	108	— 9	—13	— 4	—17	—10	58	12
52	103	—14	—27	+ 1	—26	—19	49	10
56	100	—17	—44	+ 7	—37	—30	38	8
60	107	—10	—54	+12	—42	—35	33	7
64	104	—13	—67	+18	—49	—42	26	5
68	104	—13	—80	+23	—57	—50	18	3
				Center Line North to South				
4	—	—	—	+11	+11		79	16
8	66	0	0	+10	+10		78	16
12	64	—2	— 2	+ 9	+ 7		75	15
16	63	—3	— 5	+ 8	+ 3		71	14
20	65	—1	— 6	+ 7	+ 1		69	14
24	66	0	— 6	+ 6	0		68	14
28	69	+3	— 3	+ 5	+ 2		70	14
32	75	+9	+ 6	+ 4	+10		78	16
36	74	+8	+14	+ 3	+17		85	17
40	71	+5	+19	+ 2	+21		89	18
44	70	+4	+23	+ 1	+24		92	18

*All values except Columns 1 & 8 are in tenths of a second of arc.

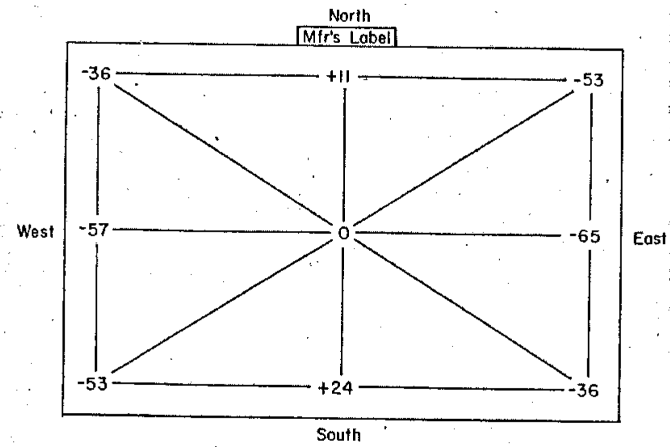


Fig. 5. Data reduction work sketch for determining correction factors and displacements from datum plane.

Column 6 in the work sheets as shown. This chart is important as without it there is danger of confusing the figures.

3. Enter the value for the NE end of the NE-SW diagonal in Columns 5 and 6 opposite the first station. Enter the value of the NW end of the NW-SE diagonal opposite the last station in Column 6 only.
4. Next, find the correction factor. Subtract the value opposite the last station in Column 4 from the value opposite the same station in Column 6 [—36 —(—199) = 163]. Enter this value opposite the last station in Column 5. Subtract this value from that opposite the first station in Column 5 (—53 —163 = —216) and divide the result by the total number of stations on the line minus one (—216/16 = —13.5). The result is the correction factor.
5. Beginning at the last station in Column 5, add the correction factor cumulatively up the column at each station. (Since the correction factor in the example is —13.5 to avoid decimals —13 and —14 are used alternately.)
6. To find the angular displacement from the datum plane, algebraically add the values opposite each station in Columns 4 and 5 and enter the results in Column 6.

Complete the conversion for each of the perimeter lines to this point and enter the values at the midpoints in *Fig.* 5. Now proceed with the center lines.

CONVERSION FOR EAST TO WEST CENTER LINE:

1. Carry the conversion through Column 4. The procedure for the center lines is exactly the same as for the diagonal and perimeter lines to this point.
2. From *Fig.* 5, enter the value for the midpoint of the east perimeter line opposite the first station in Columns 5 and 6. Enter the value for the midpoint of the west perimeter line opposite the last station in Column 6 only.
3. Subtract the value opposite the last station in Column 4 from the value opposite the same station in Column 6 and enter this value at the last station in Column 5.
4. Subtract the last value in Column 5 from the first and divide the result by the total number of stations on the line minus one. The result is the correction factor.
5. Beginning at the last station in Column 5, add the correction factor up the Column in an arithmetic progression to find the cumulative correction factor for each station.
6. At each station, algebraically add the values in Columns 4 and 5 and enter the result in Column 6. This is the angular displacement from the datum plane.
7. Change the sign of the value opposite the midstation in Column 6 and add it to the value opposite each station in Column 6. Enter the sums in Column 6a.

A word of explanation is necessary at this point. The center line check is the criterion of accuracy for the entire operation. The value at the point at which the center lines and diagonals intersect is physically zero. If everything were done perfectly, the value opposite the center station would be zero. But this is not possible because each slight error in reading the instrument is reflected at the midstation of the center lines. If the magnitude of this error is under 0.0001, the calibration may be regarded as satisfactory; if not, the job must be done over.

Column 6a, which appears only in the work sheets for the center lines, is used to move the error away from the center, which is known to be zero, out to the perimeter.

Final Steps in Conversion: The work sheets for the eight lines are now completed through Column 6, including Column 6a for the center lines. The procedure for Columns 7 and 8 is identical for all work sheets and must be done together.

1. Seach through Column 6 for all work sheets, Column 6a of the center lines, for the lowest value in all of the 8 columns. Add this value to the value opposite each station in Column 6 (6a for the center lines) and enter the sums in Column 7. This

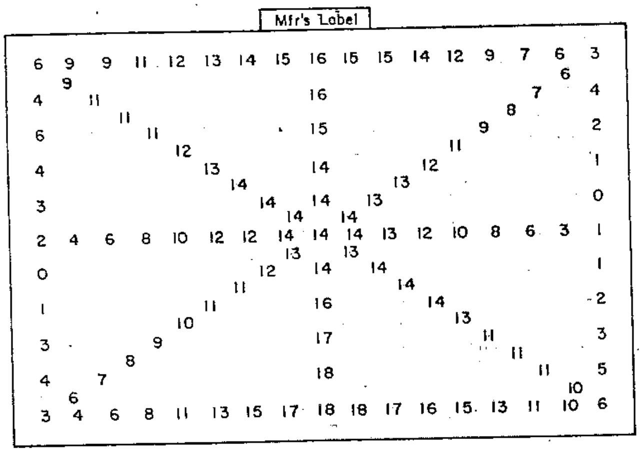


Fig. 6. Linear deviations from base plane indicated along the eight principal lines of a 48 x 72-inch granite surface plate. Figures represent height from base plane in 0.00001 inch units. All points lie between two parallel planes 0.00018 inch apart.

figure is the displacement from the true base plane. This is defined as that plane containing the point of lowest reading and parallel to the datum plane.

2. Next, convert the values in Column 7 to linear values in 0.00001 inch. To do this, multiply the product of the sine of 1 second (0.000005) times the distance between the center lines of the mirror mounts (4 inches in the example) (0.000005 × 4 = 0.00002) by the values in Column 7 at each station. Since the values in Column 7 are in tenths of a second of arc, it is necessary to divide the product at each station by 10 to get the decimal point in the right place. Round out the answer to the nearest hundred-thousandth of an inch, drop out the decimal point, and enter the value in Column 8.

Conclusion: The data from Column 8, when reported on the form shown in *Fig.* 6, allows the user to see at a glance the features of the surface plate he is using. It shows not only the extremes of variation, but also the best areas on the plate.

Acknowledgments: The author wishes to acknowledge the technical assistance given to this work by J. M. Bunch, physical standards division, Sandia Corp. and A. R. Darling, formerly of Sandia Corp. Appreciation is also expressed for the editorial efforts of W. F. Carstens, reports and editorial division, Sandia Corp.

Cold Rolling 'Builds In' Longer Life in Backup

By cold rolling fillets between the neck and roll body of backup rolls, tensile strength at the point of most common failure was increased automatically and life of the rolls was substantially lengthened. The technique was devised at the Roll Div. of Blaw-Knox Co. where, as a result of fatigue, a hairline crack in the fillet at or near the surface has consistently shortened roll life. Because of the geometric proportions of the rolls, there is greater stress concentration at the fillet accounting for the need for special working at that point. Fatigue limits, which are approximately one-half of tensile strength, increased proportionately with the utilization of cold rolling.

The cold rolling tool used in the technique developed at Blaw-Knox consists of a wheel, positioning apparatus and a gage to provide a constant register of the amount of pressure applied to the metal being rolled.

Uncertainty Budgets for Electrical Parameters

by Dr. Klaus Jaeger

Introduction:

R205 – Specific Requirements: Calibration Laboratory Accreditation Program states that for each measurement parameter and associated range(s), the laboratory shall provide with the application an uncertainty budget showing how the claimed Calibration and Measurement Capability (CMC) was derived. The assumptions made for the determination of the uncertainty budgets, if any, must be specified and documented. A2LA accredited and enrolled calibration laboratories shall calculate measurement uncertainties using the method detailed in the ISO "Guide to the Expression of Uncertainty in Measurement" (GUM)1.

Purpose:

The purpose of this document is to provide guidance for determining the proper contributors of electrical parameters that should be taken into consideration when developing uncertainty calculations that support the Calibration and Measurement Capability (CMC) claim made on a scope of accreditation. This guidance also serves as a means for Conformance Assessment Bodies (CABs) to be in compliance with *P110 – Policy on Measurement Uncertainty in Calibration*. Finally this guidance serves to clarify how an approach that includes the simple use of the specification of the standard along with the resolution of the standard and "best" unit under test is not sufficient for meeting the GUM.

Background:

Historically an acceptable approach for generating electrical uncertainty budgets has excluded the determination of any "Type A" data and included only three "Type B" considerations: specification of the standard used, resolution of the standard and resolution of the (best) unit under test.

This approach does not appear to meet the GUM[1], M3003[2] or RP-12[3] for the following reasons:

It does not provide any evidence for:

a) Traceability
b) Type A contributors such as:

- Short term stability
- Repeatability error

c) Type B contributors such as:

- Operator error
- System Performance including cable behavior and/or faults
- Environmental effects

a. Traceability

P102 – A2LA Policy on Measurement Traceability requires that uncertainty budgets be compliant with Traceability:

(T4) Where measurement uncertainty analysis is applicable[1]*, A2LA requires laboratories to calculate measurement uncertainty in accordance with the ISO "Guide to the Expression of Uncertainty in Measurement." These uncertainties, when reported, shall be reported as the expanded uncertainty with a defined coverage factor, k (typically k = 2) and the confidence interval (typically to approximate the 95% confidence level).*

ISO/IEC 17025:2005 states: *When estimating the uncertainty of measurement, all uncertainty components which are of importance in the given situation shall be taken into account using appropriate methods of analysis.*

b. Type A Uncertainty Contributors

- The GUM states that all statistical data is treated as Type A contributors with normal distributions. Typical examples in these areas are:

  1) Repeatability
  2) Reproducibility
  3) Stability / Drift
  4) others

  Repeatability is required by the GUM and M3003, and is recommended by NCSLI RP-12 and G103 – A2LA Guide for Estimation of Uncertainty of Dimensional Calibration and Testing Results.

- **In the GUM, Section 8.2 and 8.3 states:**

  8.2 Determine x_i, the estimated value of the input quantity X_i, either on the basis of statistical analysis of series on observations ***or by other means.***

  8.3 Evaluate the standard uncertainty $u(x_i)$ of each input estimate xi. For an input estimate obtained from the statistical analysis of series of observations, the standard uncertainty is evaluated as described in 4.2 (Type A evaluation of standard uncertainty). For an input estimate obtained by other means, the standard uncertainty $u(x_i)$ is evaluated as described in 4.3 (Type B evaluation of standard uncertainty).

  Comment: In electrical calibrations one determines x_i, the estimated value of the input quantity X_i by measurement; hence the need for repeatability.

- **In M3003, it is strongly recommended to include random effects**. A Type A evaluation will normally be used to obtain a value for the repeatability or randomness of a measurement process.

[1] Measurement uncertainty analysis is required for all calibrations and dimensional inspections. For applicability of testing, please see the *P103 - Policy on Estimating Measurement Uncertainty for Testing Laboratories* and the relevant Annexes *P103a-P103d*.

For some measurements, the random component of uncertainty may not be significant in relation to other contributions to uncertainty. **It is nevertheless desirable for any measurement process that the relative importance of random effects be established**. When there is a significant spread in a sample of measurement results, the arithmetic mean or average of the results should be calculated.

In all the examples listed in M3003, repeatability is included.

- **In NCSLI RP-12, section 2.2 states:**

2.3. Identify Measurement Errors and Distributions Measurement process errors are the basic elements of uncertainty analysis. Once these fundamental error sources have been identified; we can begin to develop uncertainty estimates. The errors most often encountered in making measurements include, but are not limited to the following:

- *Measurement Bias*
- ***Random or Repeatability Error***
- *Resolution Error*
- *Digital Sampling Error*

Example1: 100 kΩ Range

	U		DIST	DIV	STD U	Squared	% of Total
Type A							
Repeatability	0.002335	kΩ	N	1	0.0023	5.45E-06	53.2
Type B							
Specifications of 5520A	0.0028	kΩ	Norm	2.58	0.0011	1.18E-06	11.5
UUT Resolution, Std.	0.000005	kΩ	Rec	1.732	0.0000029	8.33E-12	0.00008
Uncertainty of 5520A	0.0038	kΩ	Norm	2.0	0.0019	3.61E-06	35.2
Resolution of 5520A	0.00005	kΩ	Rec	1.732	0.000029	8.33E-10	0.008
					Sum	1.02E-05	100.0
					U	0.00320	
					U(k=2)	0.00640	kΩ

- *Computation Error*
- *Operator Bias*
- *Environmental Factors Error*
- *Stress Response Errors*

Clearly, repeatability is required.

Example 1 shows an uncertainty budget that clearly indicates the need for repeatability.

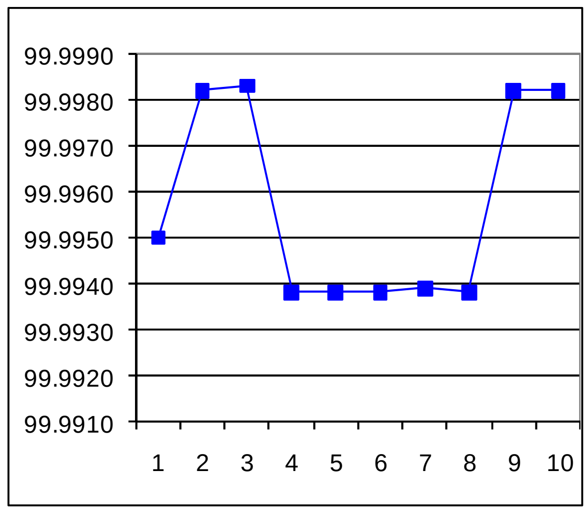
Table 1

In this example there are two concerns with the approach taken:

1. The repeatability is too high.
2. The actual uncertainty (from the calibration certificate) is greater than those noted on the specifications.

Data in support of Example 1:

Repeatability		
1	99.9950	
2	99.9982	
3	99.9983	
4	99.9938	
5	99.9938	
6	99.9938	
7	99.9939	
8	99.9938	
9	99.9982	
10	99.9982	
STDEV	0.002203	
DOF=9	1.06	0.002335



Since the repeatability value dominates the overall uncertainty budget, this clearly indicates a problem with the system and further studies are needed. Without such statistics one would not have known of any problems with the measuring system.

c. Type B uncertainty contributors

- **In the GUM section 4.3 states:**

4.3 Type B evaluation of standard uncertainty
4.3.1 For an estimate x_i of an input quantity X_i that has ***not been obtained from repeated observations****, the associated estimated variance $u^2(x_i)$ or the standard uncertainty $u(x_i)$ is evaluated by scientific judgment based on all of the available information on the possible variability of X_i. The pool of information may include:*

- *previous measurement data;*
- *experience with or general knowledge of the behavior and properties of relevant materials and instruments;*
- *manufacturer's specifications;*
- *data provided in calibration and other certificate;*

- *uncertainties assigned to reference data taken from handbooks.*

- **In M3003, it is strongly recommended to include the following contributors:**

  5.3 In evaluating the components of uncertainty it is necessary to consider and include ***at least the following possible sources****:*

  (a) The reported calibration uncertainty assigned to reference standards and any drift or instability in their values or readings.
  (b) The calibration of measuring equipment, including ancillaries such as connecting leads etc., and any drift or instability in their values or readings.
  (c) The equipment or item being measured, for example its resolution and any instability during the measurement. It should be noted that the anticipated long-term performance of the item being calibrated is not normally included in the uncertainty evaluation for that calibration.
  (d) The operational procedure.
  (e) Variability between different staff carrying out the same type of measurement.
  (f) The effects of environmental conditions on any or all of the above.

- ***In NCSLI RP-12, section 2.2 states:***

  2.3 Identify Measurement Errors and Distributions Measurement process errors are the basic elements of uncertainty analysis. Once these fundamental error sources have been identified, we can begin to develop uncertainty estimates. The errors most often encountered in making measurements include, but are not limited to the following:

  - *Measurement Bias*
  - *Random or Repeatability Error*
  - *Resolution Error*
  - *Digital Sampling Error*
  - *Computation Error*
  - *Operator Bias*
  - *Environmental Factors Error*
  - *Stress Response Errors*

  Most of these can be covered by statistics, specifications, traceable values, etc.

  Example 2: AC Current

  Accredited A2LA certificate issued includes the following information:

AC Current	Frequency	Range	Value		Uncertainty
	1 kHz	100 µA	99.9926*	µA	0.0200 µA
	1 kHz	1 mA	1.000029*	mA	0.000110 mA
	1 kHz	10 mA	10.00023	mA	0.001000 mA
	1 kHz	100 mA	100.0057	mA	0.01000 mA
	1 kHz	1A	1.000018	A	0.000100 A
* Ranges are not accredited					

Table 2

While there is nothing wrong with this report format, the **CAB** used all the data to claim traceability and uncertainties on the scope for all ranges.

Example 3: 1 mA Range (*Measure)*

	U		DIST	DIV	STD U	Squared	% of Total
Type A							
Repeatability	6.28E-07	mA	N	1	6.28E-07	3.95E-13	0.012
Type B							
Specification of 3458A	2.50E-05	mA	Rec	1.732	1.44E-05	2.08E-10	6.4
Resolution of HP 3458A	5.00E-08	mA	Rec	1.732	2.89E-08	8.33E-16	0.000026
5520A Resolution	5.00E-06	mA	Rec	1.732	2.89E-06	8.33E-12	0.26
Cert value	1.10E-04	mA	N	2	5.50E-05	3.03E-09	93.3
					Sum	3.24E-09	100.0
					U	0.00006	
					U(k=2)	0.00011	mA

Table 3

In this example the uncertainty from the calibration certificate is too high. The traceable uncertainty should never be larger than the specification. See also example 1.

Example 4: 300 mV Range

	U		DIST	DIV	STD U	Squared	% of Total
Type A							
Repeatability	**5.43E-05**	**mV**	**Norm**	1	**0.000054**	**2.95E-09**	**0.29**
Type B							
Specifications	**0.0020**	**mV**	**Norm**	**2.0**	**0.0010**	**1.00E-06**	**99.6**
UUT Resolution	**0.00005**	**mV**	**Rec**	**1.732**	**0.0000289**	**8.33E-10**	**0.08**
Standard Resolution	**0.000005**	**mV**	**Norm**	**2**	**0.0000**	**6.25E-12**	**0.00062**
Uncertainty of 5520A	**0**	**mV**	**Rec**	**1.732**	**0.000000**	**0.00E+00**	**0.000**
					Sum	**1.00E-06**	**100.0**
					U	**0.0010**	
					U(k=2)	**0.0020**	**mV**

Table 4

In this example, the uncertainty from the calibration certificate is higher than the specification and was ignored in favor of the specification. In this case the laboratory did have a traceable certificate with a value stated. However since the value stated was higher than the specification, it was ignored.

If it had been included, the budget would have been:

	U		DIST	DIV	STD U	Squared	% of Total
Type A							
Repeatability	5.43E-05	mV	Norm	1	0.000054	2.95E-09	0.03
Type B							
Specifications	0.0020	mV	Norm	2.0	0.0010	1.00E-06	10.7
UUT Resolution	0.00005	mV	Rec	1.732	0.0000289	8.33E-10	0.01
Standard Resolution	0.000005	mV	Norm	2	0.0000	6.25E-12	0.00007
Uncertainty from Certificate	0.005	mV	Rec	1.732	0.002887	8.33E-06	89.250
					Sum	9.34E-06	100.0
					U	0.00306	
					U(k=2)	0.00611	mV

Table 5

There is a large difference between this overall uncertainty and the one without the certificate value included. In this case the CAB chose to use the budget without the certificate value. This means that there is no claimed traceability.

The CAB should have complied with ISO/IEC 17025, section 4.6.3 and reviewed the traceable certificate. This discrepancy should have been discussed with the facility that provided the "traceable" certificate and corrective actions should have been taken. The CAB could also have chosen to accept the value as reported and used it in the uncertainty budget. In that case it would have been com pliant with traceability requirements.

Recommendations

A. Based on all the above mentioned requirements and recommendations, we are recommending that at least the following contributors are identified in all electrical uncertainty budgets:

Item 1: Repeatability
Per M3003 this is highly recommended and listed in all their examples. Therefore the CAB shall always include.

Item 2: Reproducibility
This is required or strongly recommended by the GUM, M3003, and RP-12. If available, the CAB shall include.

Item 3: Stability
This is extremely useful if a CAB requires tighter uncertainties. If this is not available, a CAB shall include Item 6, specifications in order to cover the instrument specifications between calibrations. An exception would be if the customer only requires the uncertainty at the date of calibration. In that case, it is the customer’s responsibility to add long term behavior.

Item 4: Others
In many cases, statistical data is available for items usually listed under Type B. In that case include them under Type A and treat the distributions as normal.

Item 5: Traceable Certificate Value
This is required by the GUM, M3003 and RP-12.

- By listing the value, it is demonstrated that the traceability is current and that the certificate from an NMI or ISO accredited calibration source was reviewed and approved (see ISO/IEC 17025, 5.4.7 Control of data; 5.5.9 Equipment; 4.6.3 Purchasing services and supplies).

- In addition, a CAB can compare with Item 1 and see if the repeatability makes sense; i.e., calibration system is operating correctly. (As long as Item 1 is << Item 5.)

- Furthermore a CAB can check if this value is < Item 6. Sometimes the traceable calibration value as received is larger than the specifications. Should this **occur, a** CAB would need to investigate in order to find a reason for this discrepancy. Usually it is a typographical error that increases your overall uncertainty significantly or the accredited facility / NMI could not perform the traceability to the required specification.

Item 6: Absolute Specifications
This is required or strongly recommended by the GUM, M3003 and RP-12.

- By listing the specifications, the CAB indicates that they are using (or not) the latest manuals. In comparing with Item 5, these values should always be larger. If not, a CAB should investigate and find out why.

- Also, Item 1, repeatability should never be larger than Item 6 and in fact they should be much smaller. If not, there are problems with the system, operator, incorrect cables, etc.

- Also, as mentioned before, if tighter uncertainties are really required, set the divisor/multiplier in the spreadsheet to 0, but ensure that Item 3, stability data, is available.

Item 7: Resolution of UUT
This is required or strongly recommended by the GUM, M3003 and RP-12. This is really a sanity check to ensure that all the listed contributors make sense. For instance, it does not make sense to list a contributor to four decimal places when the resolution has only two. It is also useful to compare with the resolution of the (best) unit under test (UUT), Item 8. If the latter is worse than the reference, the CAB is limited by the UUT.

Item 8: Resolution of standards used
This is required or strongly recommended by the GUM, M3003, and RP-12. This is essentially the same arguments as for Item 7. It serves as a sanity check.

Item 9: Environmental Effects
This is required or strongly recommended by: GUM, M3003, and RP-12. There could be multiple entries for this. Sometimes additional specifications for temperature and relative humidity at certain specific ranges require additional entries in addition to Item 6. (Keep in mind also that if Stability is used in Item 3 and Specifications are calculated as 0 value contributors, then these need to be considered.) It is even possible that pressure coefficients and vibrational effects need to be considered.

Item 10: Others
Required or strongly recommended by the GUM and M3003. It is recommended to list here any other possible uncertainty contributors. It really helps to have as much as possible listed to indicate that you have reviewed these possibilities.

Table 6: Summary of Recommendations:

Type A			
Item #	Name		Comment
1	Repeatability	Must have	Try getting at least 10 measurements so you have at least 9 DoF.
2	Reproducibility	If possible	
3	Stability	If available	See item 6 below.
4	Others	If identified	
Type B			
5	Reference value from Traceable Certificate	Must have	Without this value you have no proof of traceability.

Type B (cont)			
6	Absolute Specification for calibration interval	Must have to check if item 5 is less than item 6	Also, if you have long term stability for this parameter for this range, you can set the multiplier/divisor to 0.
7	Resolution of standards used	Must have	This is usually small with respect to the rest, but there are exceptions.
8	Resolution of UUT	Must have	This is usually small with respect to to the rest, but there are exceptions.
9	Environmental effects	There can be multiple lines for it.	This is usually small with respect to to the rest, but there are exceptions.
10	Any other entries that might be helpful		

Having these basic frameworks for uncertainties, both the assessors and CABs can be reasonably assured of consistency from assessment to assessment. It avoids the confusion of the A2LA customers and covers not only uncertainty requirements but also document control as well as incoming inspections, etc.

References

1 Guide to the Expression of Uncertainty in Measurement (GUM), ISBN 92-67-10188-9, 1993

2 The Expression of Uncertainty and Confidence in Measurement UKAS - M3003, January 2007

3 NCSLI—RP12, Determining and Reporting Measurement Uncertainties. 2009 edition scheduled for release in 2009.

4 International vocabulary of metrology – Basic and general concepts and associated terms (VIM), GCGM 2090-2008, 2.21
See Appendix 1

5. International vocabulary of metrology – Basic and general concepts and associated terms (VIM), GCGM 2090-2008, 2.25
See Appendix 1

Appendix 1

2.21 measurement repeatability
repeatability **measurement precision** under a set of **repeatability conditions** of measurement

2.20 repeatability condition of measurement
repeatability condition -- condition of measurement, out of a set of conditions that includes the same **measurement procedure, same operators**, **same measuring system**, **same operating conditions** and **same location**, and **replicate measurements** on the **same or similar objects** over a short period of time NOTE 1 A condition of measurement is a repeatability condition only with respect to a specified set of repeatability conditions. NOTE 2 In chemistry, the term "intra-serial precision condition of measurement" is sometimes used to designate this concept.

2.25 measurement reproducibility
reproducibility **measurement precision** under **reproducibility conditions of measurement**

NOTE Relevant statistical terms are given in ISO5725-1:1994 and ISO 5725-2:1994.

2.24 reproducibility condition of measurement
reproducibility condition -- condition of **measurement,** out of a set of conditions that **includes different locations**, **operators**, **measuring systems,** and **replicate measurements** on the same or similar objects NOTE 1 The different measuring systems may use different measurement procedures. NOTE 2 A specification should give the conditions changed and unchanged, to the extent practical.

TAB 5

Proposal: Consensus on Calibration of an Environmental Chamber
Pam Wright
11/15/2010

Background:

A deficiency was written for a Conformance Assessment Body (CAB) because a testing laboratory did not have their thermocouple calibrated within their environmental chamber. The laboratory just had the controller calibrated by electrical simulation as part of their (T9) internal calibration. The assessor and the lab disagreed on the issue and the issue eventually went to the Measurement Advisory Committee (MAC) for voting. The MAC voted that it was not acceptable to calibrate the controller only and that the thermocouple needed to be calibrated or the chamber needed to be mapped. The decision of the MAC was presented to the Materials Testing Advisory Committee (MTAC) and they agreed by a majority with the decision made by the MAC. Staff brought up a concern that this decision by the MAC and MTAC would put an undue burden on our CABs as one had expressed during their initial assessment that if they were required to calibrate the thermocouples in all their environmental chambers, they would stop the assessment and elect not be accredited by A2LA. Several others CABs expressed concern over the burden this would cause when even the Original Equipment Manufacturer (OEM) did not calibrate the thermocouple upon the completion of the manufacturing process. Management agreed that we did not want to put an undue burden on our CABs beyond that of other equivalent Accrediting Bodies (ABs) and tasked the Calibration Accreditation Manager (AM) with investigating this matter further. It should be noted that the Calibration AM contacted several international peers regarding this matter and received little to no response.

The Calibration Senior Accreditation Officer (SrAcO) was tasked with contacting several OEMs, both accredited and non-accredited to determine whether or not they actually calibrate the thermocouples as part of the calibration provided with the chamber. The SrAcO discussed the calibration process with both accredited and non-accredited OEMs and upon discussion with the manufacturers it was discovered that none of them calibrate the thermocouple after manufacturing a new chamber, rather, they only calibrate the controller. Almost all the OEMs noted that upon special request they will calibrate the thermocouple and map (multipoint calibration of the entire chamber) the chamber. One OEM did state that they actually do not like to map the chamber as they would be mapping an empty chamber and once the user puts a load into the chamber that the mapping of that empty chamber is invalid as the characteristics and behaviors of the chamber is changed when putting a load in. From these discussions it appears that the consensus of the MAC/MTAC to calibrate the thermocouple would be going above and beyond what the manufacturers are doing when they calibrate their new chambers.

In conducting a review of guidance documents available on this matter a Euramet document *Calibration of Climatic Chambers Requirements for the Accreditation of Calibration Laboratories* was consulted which describes the guidance laid out by the EU for their Accreditation Bodies for the accredited calibration of climatic chambers. In this document it was acknowledged that calibration of a climatic chamber is not the best method for documenting the environmental condition during operation, rather, the use of at least one sensor for temperature and/or humidity in close proximity with the load will provide much more reliable data. It was also recommended that calibration providers inform their customer of this fact. Furthermore, it was acknowledged that customers in many cases “want a calibration certificate as cheap as possible” and they ask for a “one-point-calibration” typically in the center of an empty climatic chamber. The document goes on to explain while this approach does not make much sense and that it is not a “calibration” it acknowledges that it is difficult to refuse an accreditation for such a service.

This entire issue was then discussed at the management level in order to develop a policy that allows for the integrity of the test to be preserved while also ensuring that A2LA does not place an undue burden on our CABs beyond that of other ABs.

Conclusion:

It was determined that a calibration performed in accordance with the manufacturer instructions/recommendations of an environmental chamber, whether an accredited external or (T9) internal calibration, is deemed an acceptable calibration as long as the CAB, when using the environmental chamber, includes an accredited sensor with the load to measure the environment during the test.