Procedure Title: Calibration of Long Gage Blocks by Mechanical Comparison
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Purpose: This procedure establishes the requirements for the calibration by mechanical comparison of standard size metric and English long steel gage blocks.

NOTE! This procedure assumes the operator is familiar with all functions of the NIST GAGE Software. For guidance using the software refer to reference [2]. Additionally, this procedure does not explain the statistical process control theory and calculations performed, for detailed information on this issue refer to reference [1]

References:

[1] NIST Monograph 180, *The Gage Block Handbook*, T. Doiron & J. Beers, June 1995

[2] NISTIR 6387, *The NIST Gage Block Calibration Software System User's Manual*, J. Zimmerman, January 2000

[3] NIST Technical Note 1297, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, B. Taylor & C. Kuyatt, 1994

[4] ANSI/ASME B89.1.9M, *Precision Gage Blocks for Length Measurement (Through 20 in. and 500 mm)*, ANSI/ASME, Current Publication

[5] Journal of Research of the National Institute of Standards and Technology, Volume 102, Number 6, *Uncertainty and Dimensional Calibrations*, T. Doiron & J. Stoup, Nov-Dec 1997

Definitions: Refer to reference [4] for appropriate terms and gage point illustrations.

Equipment Required:

- Federal Model 130B-16 Gage Block Comparator
- Master Gage Blocks, values determined by interferometry

Additional Equipment/Items Needed:

- Mylar gage block wrapping sheets
- Square gage block tongs

- Rectangular gage block tongs
- Black granite gage block stone (Arkansas Stone)
- Dust puffer
- Lint free cleaning towels
- Lint free paper towels
- preservative pan and brush (preservative used is Starrett M-1)

General: The mechanical calibration of standard size long English and metric gage blocks are performed using a two point contact mechanical comparator and two steel master gage blocks of the same nominal size as the test block being measured. The masters are both steel because all standard size long gage blocks sold currently are made of steel. Comparison of like materials eliminates the need to make corrections for differences in deformation and differences in the coefficients of thermal expansion of the gage blocks being compared. The primary uncertainty components of this calibration include: uncertainty in the thermal expansion coefficient of steel, temperature gradients between the blocks being compared, and process reproducibility. Standard size long gage blocks include the following sizes: 5, 6, 7, 8, 10, 12, 16, 20 inch blocks and 125, 150, 175, 200, 250, 300, 400, 500 millimeter blocks.

Environmental Considerations:

1.0 Order Setup:

1.1_ Following unpacking and logging in customer long gage block orders the blocks must be allowed to stabilize in the laboratory environment for a minimum of 48 hours. This is typically not a problem because all dimension items are unpacked and stored in holding drawers in the laboratory environment until the calibration is performed, which is normally several weeks.

1.2_ During cleaning and wrapping, all blocks are to be handle using rubber gloves to protect the blocks from corrosion caused by contact with bare skin. To set up a set of long gage blocks for calibration the set must first be cleaned using Varsol (a type of mineral spirits) to remove any rust inhibiting substance, such as grease, that the blocks are coated with to prevent rusting during transportation. Because different weights of grease or oil are used to cover the blocks and these coatings are sometimes very thin and transparent, all gage blocks must be cleaned in this manner before measurements are initiated.

NOTE! Cleaning towels used for cleaning with Varsol must be kept separate

from towels used to perform the final cleaning of the gaging surfaces with 200 proof ethyl alcohol.

1.3 Rectangular and square style gage blocks often have holes which must be cleaned thoroughly to remove all grease/oil and residual Varsol, otherwise these substances may leach onto the comparator anvil. For holes in rectangular blocks, this can simply be done with a dry portion of the Varsol cleaning towel. However, for long square gage blocks it is recommended that the 22-caliber gun cleaning rod and needle eye attachment are used to clean the hole that traverses the gage block from one end to the other. This can be done by cutting a small piece of lint free paper towel, rolling this piece into a small roll, flattening the roll, then feeding it through needle eye attachment. The rod with the piece of paper towel can then be pushed and pulled thru the gage block to remove any wet substance. The piece of paper towel must be replaced frequently, typically when it becomes coated, saturated, or very dirty.

1.4 Using the customer summary sheet complete all the customer, set, and calibration information. For the set serial number, list the manufacturer's serial number and/or the customer's property number, if available. All nominal sizes and block identification numbers must be completed on the summary sheet before proceeding. If no block identification number exists, record none. Choose a file name for the calibration file and record this on the sheet. The file name cannot exceed the eight characters and typical is chosen to be part or all of the set serial number or internal control number for the order with a two-digit year added to the end of the control number.

1.5 Inspect all test block gaging surfaces for visual burs or nicks. If a gaging surface is suspect, use a black granite gage block stone to stone the suspect surface. It may be necessary to stone a test block after the measurement process has begun if the block does not appear to move smoothly or if it squeals when moved. If either situation is encountered stop the measurement process immediately and either continue to the measurement of the next block or stone the test block and set it up for measurement at a later time.

NOTE! If a block has just been stoned do not set it up for measurement that same day, because the block needs more time than usual to thermally stabilized due to the frictional heat and body heat absorbed by the block during the stoning process.

1.6 Using the GAGE software, create a setup file for the calibration and save it with the name assigned in the previous step. When setting up the file, choose the 3-4-

measurement algorithm for calibration of long square test blocks and the 3-2 measurement algorithm for calibration of long rectangular test blocks. Refer to the table below with the order of each algorithm.

Additional Information: The 3 in the design nomenclature stands for the number of different blocks in the algorithm and the second number stands for the number of measurements to be made on each block. The design for rectangular long blocks is shorter due to the different block geometries, difficult movement of rectangular long blocks, and associated nonlinear drift as a result of these differences. Measurement uncertainties are automatically generated by the NIST software and are higher for long rectangular calibration results.

3-4 Design			3-2 Design	
S	C		S	C
1	S		1	C
C	1		S	1
C	S			
1	C			
S	1			

1.7 As a reminder, the gage blocks should only be handled using rubber gloves. Continue by marking each gage block on the non-gaging surface near the top to indicate which end is the top and on square gage blocks, on the side corresponding to the gage point. This can be done with removable marker or tape.

1.8 Wrap each gage block with the precut and specially sized Mylar sheets. The sheets can be held to the block using rubber bands or masking tape. Square blocks must be wrapped so that at least one inch of the length of the block is exposed at the bottom. This is done so that the Mylar wrapping does not interfere with the placement aid on the comparator anvil.

1.9 After all blocks are wrapped they can be arranged on the soaking plate until they are ready to be measured.

2.0 Measurement Setup

2.1 For measurement of long gage blocks, the ceiling lights must remain off during soaking times and measurement times to reduce gradients. The only light that remains on is the small indirect fluorescent light against the wall between the comparators. Once the comparator and room stabilizes both comparators must be between 19.90 and 20.10 EC. If this condition does not exist, the room must be adjusted to achieve this condition. If this condition cannot be satisfied for both comparators, at the same time, by adjusting room temperature controls contact the lab manager. The requirement is based on the allowance in the uncertainty budget for the uncertainty in the coefficient of thermal expansion for 52100 steel.

2.2 Remove the plexiglass shield from both comparators. Clean both anvils and the measuring contacts with a lint free cleaning towel and 200 proof ethyl alcohol. After cleaning the anvil and contacts with the alcohol wetted portion of the towel, wipe down each with a dry portion of the towel to remove any residue left by the alcohol. Next use the puffer to remove any dust particles remaining on the surfaces. This cleaning sequence also applies when cleaning the gaging surfaces of the master and test blocks.

2.3 As a general rule, long blocks should not be setup to measure the same day as the blocks were cleaned with Varsol and wrapped. Otherwise, follow the schedule below as the recommend setup sequence and soak times.

Block Size (inches)	Block Size (millimeters)	Setup Time
20	500	Evening (for next morning)
16	400	Evening (for next morning)
12	300	Evening (for next morning)
10	250	Evening (for next morning)
8	200	Morning (for late afternoon)
7	175	Morning (for late afternoon)
6	150	Morning (for late afternoon)
5	125	Morning (for late afternoon)

Typically, not considering any remeasures, the operator would clean and prepare an eight piece set then setup up sizes in the following sequence, assuming an eight hour work day:

Day 1 Clean and prepare set, setup 20 and 16 inch blocks for next morning.
Day 2 Measure 20 and 16 inch blocks when operator arrives at work, setup 5 and 6-inch blocks, measure 5 and 6 inch blocks at the end of the work day, then setup the 10 and 12 inch blocks for the next day.
Day 3 Measure 10 and 12 inch blocks when operator arrives at work, setup 7 and 8 inch blocks, measure 7 and 8 inch near the end of the work day, setup any failures or remeasures for next morning. If there are more than two blocks to setup for the next morning consider the previous table for setup guidance.

2.4 Clean the gaging surfaces of the two test blocks and their associated masters with 200 proof ethyl alcohol. Extra care should be taken when cleaning the gaging surfaces of the masters if they are coated with preservative. Cleaning the surfaces several times with alcohol and a different portion of the lint free towel should be sufficient, rather than using Varsol. After cleaning the gaging surfaces with the wetted portion of the towel and recleaning with a dry portion of the towel the puffer should be used to remove any dust particles.

NOTE! Typically, it is recommend practice to coat just the gaging surfaces of the masters with M-1 preservative if they are not going to be used again within a few days.

2.5 Setup for the measurement of two test long blocks, one on each comparator's anvil with its associated masters. The masters are stored in a cabinet in the measurement area, already wrapped. Each master is labeled by size and which master they are, S or C. The first master, second master, and customer are referred to as S, C, and 1 respectively in the NIST GAGE program. When the master is setup on the anvil for measurement this identification should be facing the operator. This puts the gaging point of the square master towards the rear of the comparator and closest to the contacts. Test square gage blocks should be setup on the anvil with the gage point marking facing the contacts, away from the operator. For rectangular test gage blocks this issue is not a concern, only that the block is oriented in the top up position.

2.6 If the test blocks are square then the gage point centering aid should be mounted on the anvil of each comparator. This can be done by attaching the centering aid loosely on the gage block anvil, placing any square gage block on the anvil aligned so that the contacts are touching the block at the gage point, then moving

the centering aid until it is in contact with both sides of the block, and finally removing the block and tightening the centering aid. When measuring rectangular test blocks the centering aid cannot be used and the blocks must be positioned visually each time during the measurement process.

2.7 All three gage blocks should be oriented on the comparator anvil in such a way that the S master is directly in front of the contacts. The other master and test block should be setup as close to the S master and each other but with enough room that the S master can be measured and then slid aside without moving the other blocks to accommodate the removal of the S master. Refer to attached pictures of the rectangular and square test block setups.

Additional Information: These setup requirements have been established to minimize the amount of same number of times. This reduces scratching of the surfaces in contact and reduces the nonlinear drift between blocks caused by uneven frictional heating.

28 Replace plexiglass shields and turn off ceiling lights.

3.0 Measurement

3.1 Once the blocks have thermally stabilized the operator should complete the measurement process in a timely but safe manner.

3.2 Execute the NIST GAGE program, select the appropriate setup file, and select the appropriate workstation you wish to begin measuring on. This is done so that the computer knows which workstation data will be coming from.

3.3 Select the size that you are planning to measure and input the temperature from the temperature indicator for that workstation. This temperature should be the display reading plus or minus any calibration correction for that indicator or indicator/channel.

NOTE! During the measurement process, thick cotton gloves must be worn when manipulating the gage blocks with the tongs. Gloves are worn to reduce heating of the gage blocks.

3.4 Using the tongs to move the appropriate block into measurement position and the foot switch to enter each measurement reading, proceed with the measurements following the block sequence as prompted by the program. All measurements should be made in a timely manner, without interruption. For square test blocks, the program will beep and automatically restart the measurement sequence

prompting for a temperature input if the time between measurement inputs exceeds 30 seconds. For rectangular test blocks this time requirement is nonexistent, however the operator must attempt to make the measurements in a consistent, timely manner.

NOTE! When measuring the rectangular test blocks it will be necessary to use both types of tongs during the measurement process. Square blocks are moved using the square block tongs, holding the block about an inch from the bottom for maximum stability. Rectangular blocks are moved using two rectangular block tongs, taking one in each hand. One tong should be used to move the block by holding it near the base and the other tong should straddle the upper part of the block with out touching it and should follow the movement of the block. This is done to prevent the block from falling if it becomes unstable in its vertical orientation while moving it in or out of position. This second tong may need to be used in the assistance of moving the block or steadying the block but should not be in contact with the block when seating the block for measurement. Refer to the attached picture showing tong orientation and the movement process for long rectangular gage blocks.

3.5 Repeat the described measurement process and calibration setup process until all measurements are completed. If the program statistics fail: clean the blocks, clean the anvil, and setup the blocks to measure the again. Remeasurement of a failed block can be done up to two times, but the blocks should be cleaned and reset up for measurement at another time. Remeasures should not be performed immediately after the failed measurement. The measurement result from a failed test is not recorded in the test set data file.

NOTE! If after the second remeasure the statistics still fail contact the lab manager for assistance with determining the cause of the failure and correcting it.

3.6 After the data file is populated with successful test results and the program indicates that the calibration is complete you can now proceed with the history evaluation section of this procedure.

4.0 History Analysis:

4.1 Using the NIST GAGE Software and the HISTORY Program analyze the new test results against the history for the set, if applicable. Otherwise, archive you data to a floppy disk, label it, file it, then go to Section 5.0, Report Generation.

4.2 If there is history, use the tools provided in the HISTORY Program to analyze the new data. The difference between the new data and the last data point should not be greater than the most current uncertainty, if there is no statistically significant linear trend to the data. This can be determined by using the plot function of the HISTORY Program. If a significant trend exists, either the block is growing or shrinking, then the difference between the new data point and the trend line should not be greater than the uncertainty. A significant trend can be identified using the plot function then the difference between the most recent result and the trend line can be determined using the PLOT LATEST OFFSET TO Function in the HISTORY Program.

Any blocks that do not meet this criterion should be set up for a remeasure. If the result of the releaser does not meet the criteria, then contact the lab manager to determine the reason for this condition.

4.3 When this process is completed, remeasures are resolved, and the data file populated with the correct data use the HISTORY Program to archive the new data with the old and file the history disk.

5.0 Report Generation:

5.1 Using the EDIT Program of the NIST GAGE Software copy the setup file with the data to be reported to a transfer disk.

5.2 This disk should taken to an Internet accessible workstation to be uploaded for report generation.

6.0 Packing Order:

6.1 During the packing process the blocks should be handled with rubber gloves. Remove the Mylar sheets from the test blocks. Using a lint free towel and alcohol remove any tape residue or non-permanent pen markings from the blocks.

NOTE! Use a Varsol cleaning towel or other dirty towel to remove tape residue and pen markings. Do not use the alcohol-cleaning towel that is used to clean the anvil and gaging surfaces when setting up blocks for measurement. The tape residue on the towel can get on the anvil and gaging surfaces and interfere with the measurement process.

6.2 Using the preservative brush and pan coat all surfaces of the blocks and carefully

place all the blocks back into the set.

6.3 When closed the set container should securely keep the blocks from moving, if not, add appropriate packing materials to secure the blocks.

6.4 Tape the case around the short dimension in two equally spaced locations and once around the long dimension of the case with masking tape. Tape the case over top of the masking tape with filament tape in one continuous piece at each location. The masking tape prevents damage to the case when the filament tape is removed and the filament tape prevents the case from opening if the latch(s) fail.

7.0 Probe Calibration:

7.1 After a predetermined time interval or number of measurements the computer will alert the operator to perform a probe calibration. If the operator is in the process of calibrating a test set this task should not be performed until the set is completed. If the operator has not begun the calibration of a set or has just completed the calibration of a set, then the probe calibration should be set up and performed on each long gage block workstation.

Additional Information: The probe calibration for the purposes of long block calibration is only used to determine the scale magnification.

7.2 This is an appropriate time to clean and stone the anvil of each instrument as a normal maintenance procedure to remove burs and nicks that result from normal use. Then anvil should be stoned with a black granite gage block stone, normally a small stone works best. Although this maintenance process is recommended prior to a probe calibration the operator should watch for burrs and nicks that interfere with the measurement process at any time and stone the anvil as needed to correct the condition. Anvil burrs and nicks are typically discovered when the F-test fails continuously or when moving each block the movement feels rough at a particular location on the anvil. If the F-test fails continuously this could suggest that a burr or nick is interfering with the block near the bottom comparator probe.

7.3 Setup the chrome carbide and steel probe calibration blocks. After adequate thermal stabilization time, typically four hours perform the calibration using the PROBE Program of the NIST GAGE Software. Select the workstation for which you want to perform the probe calibration and the two set method. Input the measurement temperature and perform the measurement sequence as prompted by the program.

7.4 The following criteria must be met for a successful probe calibration

(1) Scale magnification within 4 nanometers of previous calibration
(2) Repeat block standard deviation should be # 5 nanometers
(3) Scale magnification standard deviation within 3 nanometers of previous value.
(4) Normalized residual for steel within 2 nanometers of previous value.

NOTE! The normalized residual for steel represents the deformation difference between steel and chrome carbide. This result is not critical because no deformation corrections are being made in long block calibrations because both masters and the test block are steel. This figure is only monitored to verify that the instrument forces have not changed dramatically and that a probe tip has not been damaged.

(5) All results should be consistent with all previous historical figures, unless advised otherwise by lab management.

If all criteria, 1 thru 5, are not satisfied; note failed criteria figures, do not store results, clean the probe blocks, clean anvil, and setup for another probe calibration. If after second attempt criteria is not satisfied, contact lab management to determine assist in determining cause of problem. If only criteria number 4 is not satisfied, it may be necessary to check and possibly adjust instrument force following the direction of the manufacturer's instrument manual.

7.5 After obtaining satisfactory probe calibration results, store the results and select the most recent probe calibration for that workstation. Repeat the probe calibration process for the other workstation.