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Preparations for Gage Block Comparison Measurements

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PREPARATIONS FOR GAGE BLOCK COMPARISON MEASUREMENTS

by

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Introduction

The methods described here for the cleaning and deburring of gage blocks can be useful to those individuals who have not established formal laboratory procedures for these operations. Many individuals may employ valid methods that vary somewhat from those employed at the National Bureau of Standards.

Many of the gage block comparators that are in use have not been periodically evaluated by the user. It is the intent of this report to set forth guidelines and procedures that may be used conveniently by metrologists to aid in obtaining more meaningful comparisons of gage blocks by the use of probe-type transducers.

I. Gage Block Cleaning and Deburring Procedures

It is essential that gage blocks being calibrated, as well as standards being used, be cleaned and free from burrs and nicks if the calibration is to be valid. Therefore, it is necessary to institute a cleaning and deburring procedure as a part of every calibration.

A. Types of Gage Blocks

For cleaning purposes, gage blocks may be divided into two types.

1. Rectangular

   This is a solid block with a width of 3/8 inch and from 1 1/8 to 1 3/8 inches in length.

2. Square (Hoke)

   This type of block is 0.95 inch in cross section with a 3/8 inch hole drilled and chamfered through the center of the gaging surfaces.

B. Cleaning Procedures

1. It is recommended that a cleaning bath be used consisting of a

solvent such as Varsol,[1] trichlorethylene, Freon or any of the commercial cleaning agents recommended by the various gage block manufacturers. The bottom of the bath should be lined with a mat of neoprene rubber to minimize scratches and burrs to gage block surfaces caused by grit or metal to metal contact.

2. The rectangular gage block should be immersed in the bath and a soft bristle brush be used to remove the layer of protective film from all surfaces. Lint-free towels should be used to dry the block. A second cleaning of the block using either Freon or ethyl alcohol is recommended to remove any remaining residue. Again, wipe with lint-free towels.

3. The exterior surfaces of the square style blocks are cleaned in the same manner as the rectangular blocks. The hole through the center of the block must be thoroughly cleaned and dried to prevent "bleeding out" of an oil film onto the contact surfaces and supporting platen when positioned in the vertical. A .22 caliber gun cleaning rod makes an ideal instrument for cleaning the bore of blocks in the size range of 0.4 through 20 inches. One can take a solvent moistened patch of line-free paper towel and push the material through the hole. This should be repeated until all visible residue is removed.

C. Cleaning Interval

1. After the initial cleaning, it is recommended that gage blocks be cleaned several hours prior to use because a film sometimes forms on the contact surfaces from the surrounding atmosphere. This film affects the smooth insertion of the gage block under the stylus tip when performing mechanical gaging.

   If blocks are to be joined by wringing, recleaning is necessary prior to introducing a "wringing film" to ensure that no foreign substances are on the wringing surfaces that could corrode or mar the contact surfaces when using "wrung" combinations.

D. Storage

Cleaned blocks should be stored in trays covered with lint-free paper or on temperature equalization plates that are clean. A cover of lint-free towels should be used to secure the blocks from airborne pollutants that occur in occupied spaces.

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[1] Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

When blocks are not in daily use, they should be coated with any one of the many gage block preservatives that are recommended by the gage block manufacturers. It is recommended that gage blocks be coated when the relative humidity of the work area exceeds 50%.

Foodstuffs should be banned from all calibration areas, as citric acids and salts will corrode steel gage surfaces. Hands should be washed to reduce corrosion on blocks when gloves or tongs cannot be used conveniently.

E. Deburring of Gage Blocks

Gage blocks can often be restored to serviceable condition after being damaged by using three different optically flat gage block stones - black granite, natural Arkansas, or sintered aluminum oxide.

1. Black Granite Deburring Stone

The black granite deburring stone is used on steel blocks when one wants to push a burr of metal back into the area from which it was gouged. Clean stone and block before and after (per instructions No. 5). Sweep with camel's hair brush; then slide the damaged surface of the block onto the stone, taking precautions that no foreign matter is trapped between the two surfaces, and with firm downward pressure the block is moved over the stone in either a circular or a back and forth motion until the metal is restored to its original placement. Generally, there is a lessening of the drag between the two surfaces as the burr is reduced.

2. Natural Arkansas Deburring Stone

This white fine-grained stone is used on steel blocks to remove burrs and nicks caused by everyday misuse. It is especially effective on damaged edges of gaging faces. If a burr is removed on the contact surface of a block, the gouge in the surface may not be bridged by the measuring probe and erroneous readings will result.

3. Sintered Aluminum Oxide

A block of this material is used to treat either steel or carbide gage blocks. This stone is used in the same manner as the Arkansas stone. It is most effective on the hard materials such as tungsten and chromium carbide.

4. Checking the Stoned Surface

After stoning a block, one can wring the restored surface to a fused silica optical flat. Looking through the backside of the flat, the interface between the block and flat should appear uniformly grey when it reflects white light. Any light areas or color in the interface indicates poor wringing caused by a burr that has not been fully reduced to the normal gage surface.

5. Cleaning Gage Block Stones

The gage block stones should be cleaned with Freon or ethyl alcohol prior to use. Periodically, depending on use, the stone should be cleaned with a stiff natural fiber brush, soap and water to remove embedded pieces of metal and other foreign matter that contaminates the surface with use. It is advisable to allow any moisture that may be absorbed by the stone surface to evaporate before using the stone after cleaning with water.

II. Instrument Preparation

The typical electro-mechanical gage block comparator consists of a rigid frame with a gage block support anvil or platen and one or more linear variable differential transformers (LVDT) commonly known as probe type transducers. The gaging pressure, magnification and linearity of the transducer should be checked and adjusted to make valid comparisons of gage blocks.

A. Fundamental Principle of Operation of a Linear Variable Differential Transformer

The LVDT transducer is a simple voltage transformer whose current output varies as an iron rod is passed between the primary and secondary coils of the transformer. A stylus attached to one end of the iron rod is used to probe the gage block surface and the difference between two nominally equal blocks is measured by the rod with respect to the position of the core when gaging the initial block [1][1]. See Figure 1.

B. Linearity Test

This check should be made initially when the instrument is acquired, when a malfunction is suspected, and when repairs are made on the transducer or accompanying amplifier. There are two different methods that may be employed: (1) the weight method and (2) the gage block method.

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[1]Figures in brackets indicate the literature references at the end of this paper.

1. The weight method

(a) The complete instrument must be placed on a vibration free table in the gaging area. The instrument should be turned on for a minimum of 30 minutes to assure the instrument is at operating temperature.

(b) The platen or anvil used to hold the gage block is removed from the instrument. The stylus tip is removed from the transducer core. A piece of shim stock (0.015 inch thick and about one inch square with a hole the diameter of the threaded part of the stylus tip) is placed on the core and then the stylus tip, acting as a retainer for the shim stock, is replaced. The shim stock is used as a receiving pan for small weights. See Figure 2.

(c) Place enough weight on the pan, usually several ounces, to bring the amplifier meter needle on scale at the left end of the meter. One then commences to load the pan with equal increments of weight, e.g. 50 milligrams, noting the scale reading for each successive weight on the pan. When the needle approaches full deflection (all the way to the right hand side of the meter), one then removes each weight successively, again noting the scale reading and load until all weights are removed. Do this operation several times and average all of the load data separately from the unload data. The difference, if any, between the load and unload will indicate any hysteresis present in the transducer.

(d) The data points are plotted on graph paper using weight versus meter readings. The plotted data points should fall in a straight line if the transducer is linear. Acceptable disparities depend upon users' needs. See Figure 3.

2. The gage block method

(a) The alternate test for linearity, the gage block method, is not as discriminating as the weight method. This test can be performed quickly with two gage blocks differing nominally by 10 microinches.

The smallest block is inserted under the probe and the meter is adjusted to zero by means of the control knob. Reposition the block several times under the stylus and note the average reading.

The longer block is then inserted under the stylus several times and the average reading recorded. One can check each 10 microinch segment of the meter in this fashion.

The difference between these two blocks for each scale segment should be very similar if the transducer is linear.

C. Alignment

Proper alignment of the probes on opposed contacting type transducers is necessary to ensure the best accuracy in the comparison measurement. Misalignment can add errors of several microinches in some cases.

1. One of the two probes on the instrument should have some form of alignment adjustment, usually a 3-point adjustment consisting of 3 set screws. The probe tips must have some sphericity to enable adjustment by this method. The upper probe is lowered to contact the bottom probe with enough contact pressure to move the meter needle to approximately mid-scale.

2. The set screws are then gently turned until the most positive reading on the scale is attained. This reading indicates that the upper and lower styli are properly aligned, that is, touching at their highest points.

D. Adjusting and Calibrating the Scale Magnification

The scale magnification of the gage block comparator should be checked daily until one has a history of the stability of the instrument, then a weekly check may be sufficient.

There are two methods by which the magnification may be checked: (1) a cursory method that employs 2 calibrated gage blocks and (2) a least squares method that uses 4 calibrated gage blocks.

1. The cursory method is a very simple test of the magnification. The smaller of two blocks, with a nominal difference between them approximately equal to the range of the meter scale, is inserted under the probe and a zero setting is obtained by adjusting the control knob on the amplifier. Reseat the gage block under the probe several times to secure a reliable zero reference. Then, one places the longer block under the probe, reseating as before, until repeated readings are obtained.

   The indicated difference should be equal to the calibrated difference between the two blocks. If not, adjust the instrument magnification with the potientiometer screw indicated on the amplifier and repeat the readings as in the preceding paragraph. The allowable error for the full scale reading is ± 1 per cent for the highest order of calibration uncertainty.

2. The least squares method of checking the scale magnification involves checking two intermediate points as well as the full range of the scale. This method gives a measure of the random error in

the observations as well as additional checks on the instrument magnification. The observations are taken in the sequence as outlined in a "4-1" series design [2]. After the observed data has been reduced, the observed difference versus the actual difference is plotted. The resultant plot should be a straight line 45° above the horizontal (X) axis or within ±1 per cent for highest order calibration uncertainty.

This least squares method will indicate the most linear portion of the meter scale thus enabling the observer to use that portion of the scale for his comparison measurements.

E. Transducer Pressure

The pressure exerted by the stylus probe on the surface of the gage block must be greater for the upper probe than the lower probe. This differential pressure keeps the gage block resting on the anvil or platen. A higher pressure on the lower anvil would raise the block off the anvil and make accurate reading impossible. A differential pressure of 1 or 2 ounces is accepted practice.

The stylus pressures must be known when comparing blocks of dissimilar materials and to guard against damaging gage blocks with unnecessarily high probe forces.

Most transducer probes are spring loaded and by turning a threaded cup, rod or knurled adjustment wheel can be regulated to the desired pressure within the manufacturer's design limitations. A dynamometer is used to check for the correct adjustment. This force measurement should be correct to ± 1/4 ounce. The pressure check should be done at the magnification that you are using. Many manufacturers of comparators suggest using this test on low magnification which may be entirely satisfactory except for those users that are striving for the ultimate accuracy in comparison measurements.

The pressures should be checked weekly, making a record of such readings, until one has confidence in the stability of the pressures, and then a bimonthly check may be appropriate.

III. Conclusions

The linear variable differential transformer provides one of the most convient and precise means for obtaining high accuracy comparative measurements.

The observer must be aware of such refinements as comparator warm-up, deburring of the instrument anvil, cleanliness of instrument probes and block storage areas, and the use of heat sinks as well as the above guidelines before making the first comparison measurement.

The author has noted from his conversations with many metrologists that not enough time has been spent in instrument preparation before making, hopefully, meaningful comparison measurements.

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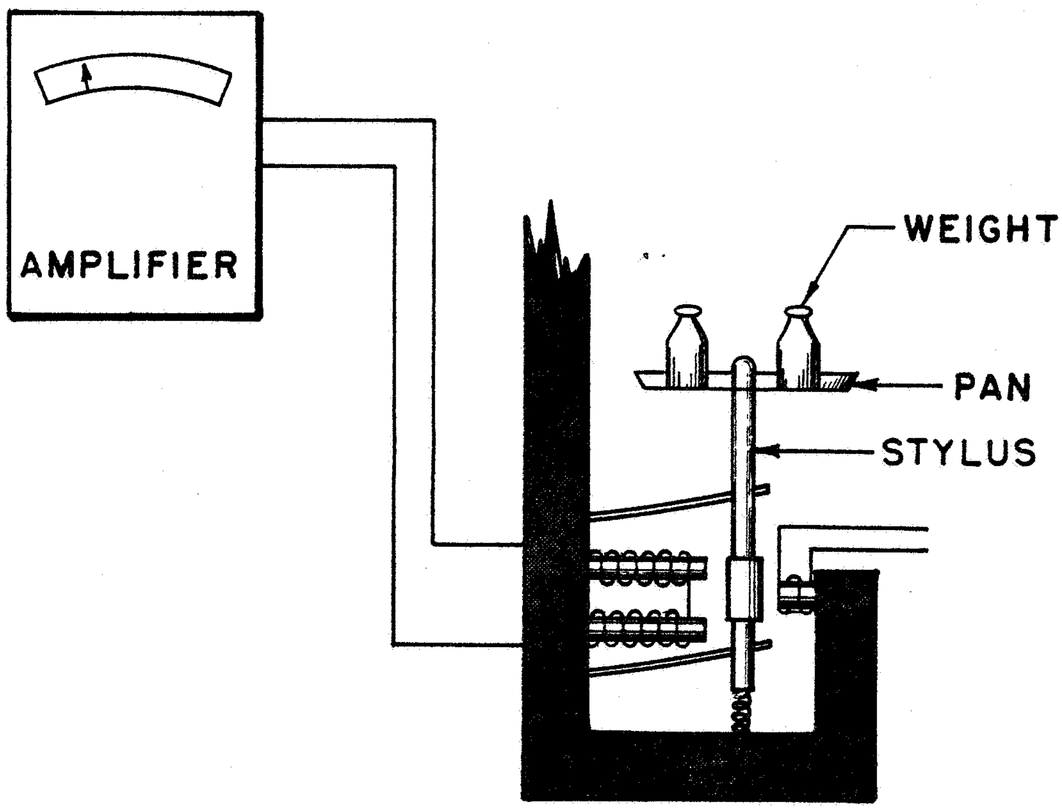
References

[1] Meyerson, M. R., Young, T. R., and Ney, W. R., Gage Blocks of Superior Stability: Initial Developments in Materials and Measurement, J. Res. Nat. Bur. Stand. (U.S.), 64C (Eng. and Instr.), No. 3, (1960).

[2] Pontius, P. E., The Measurement Assurance Program - A case study in length measurements, NBS Monograph (to be published in 1974).



SET-UP FOR LINEARITY CHECK

FIGURE 2.

AMPLIFIER SCALE READINGS AS A FUNCTION OF STYLUS PRESSURE

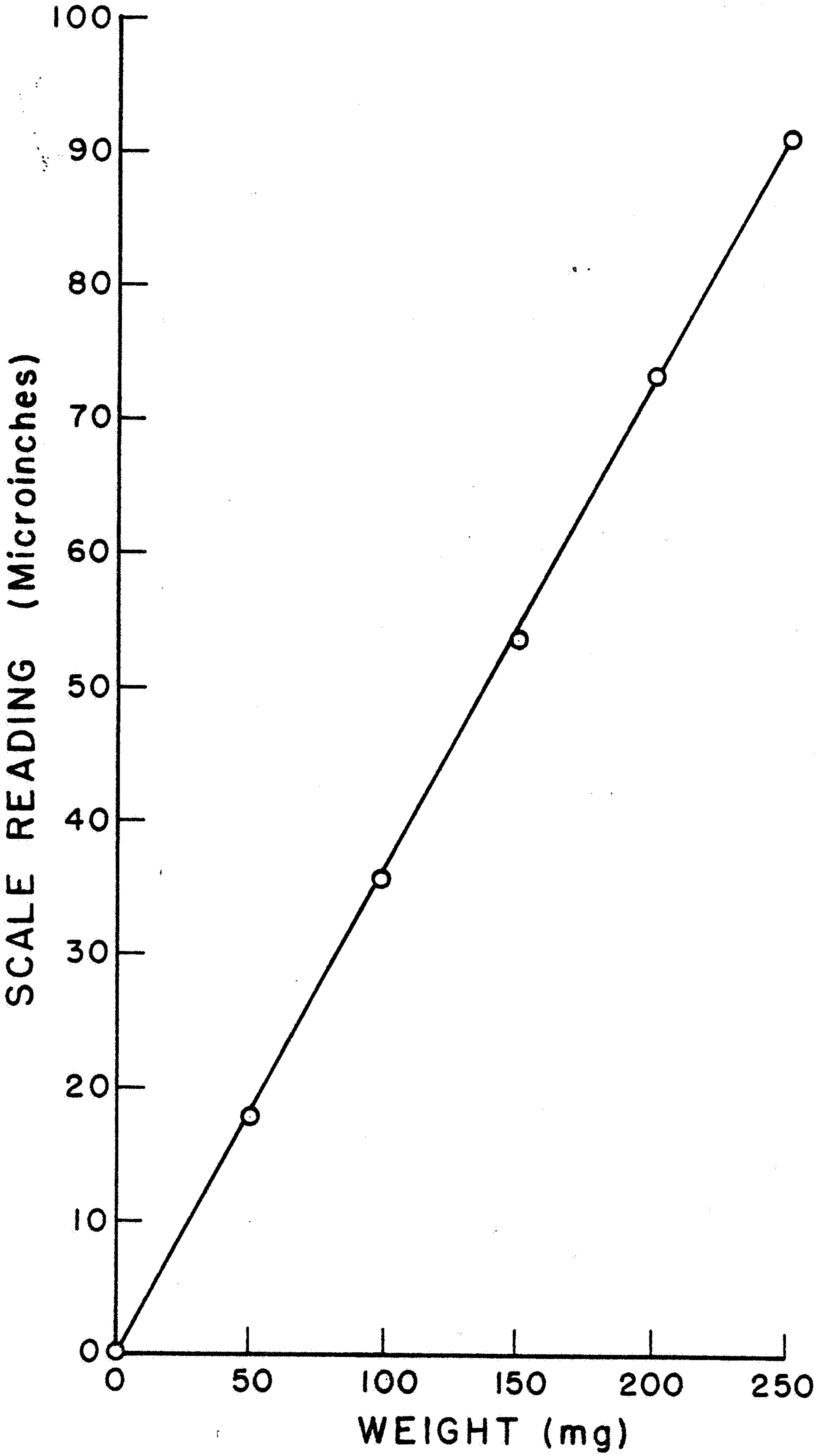


FIGURE 3