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CMMs

Understanding Performance Standards

Understanding CMM Performance Standards

1.0 When determining how good a coordinate measuring machine is, manufacturers rely on performance standards. These standards are useful in comparing the performance of different brands of machines, to determine, in a general way, how well the machine will measure parts, and to check that the machine is working properly.

2.0 There are different standards of measurement or calibration, however, and this often causes confusion among not only customers, but CMM manufacturers themselves. In this Tech Brief, we'll discuss how these standards differ.

3.0 Today, there are three primary standards used to verify the accuracy of measuring machine performance: ASME B89.4.1, VDI/VDE 2617, and ISO 10360. Standards organizations throughout the world agree that all three do an equally good job of measuring the overall performance of a machine. They differ principally in approach.

4.0 The chief differences are in the number of tests used to evaluate the performance of CMMs, and the way in which the performance specifications are written. The B89 standard uses five tests to evaluate length measuring performance. VDI/VDE 2617 uses three tests and ISO 10360 uses two tests, one being for the probe. B89 specifications use a single number to represent a performance range. For example, Brown & Sharpe's GAGE 2000 Measurement Station has a B89 volumetric performance specification of 0.010 mm/325 mm, the number after the slash being the length of the ball bar that was measured. This means that the range of measured lengths with the ball bar in many positions is no greater than 10 micrometers. VDI/VDE and ISO specifications represent length measuring performance as a formula.

5.0 GAGE 2000 volumetric performance is stated in the VDI/VDE format as U3 = 4 + 5L/1000. This means that over the same measured 325 mm length, there could be an error no larger than + or - 6 (actually 5.625) micrometers.

6.0 VDI/VDE and ISO Performance Testing
The VDI/VDE and ISO standards use measurements made on a calibrated step gage, or an equivalent set of gage blocks (Figure 1). In the VDI/VDE standard, the gage is measured in three types of positions: axial (U1), planar (U2), and volumetric (U3). Differences between the measured lengths and the calibrated lengths of the gage are compared in the formula U= a + b X L/1000 for the VDI/VDE specification.

7.0 The "a" term is a value representing the error made when measuring something of zero length. The "b" and "L" terms divided by 1000 represent the increase in error based on the length being measured. The formula represents a line that for zero measured length is the "a" value, 4 micrometers, for example, and goes up by a slope defined by the "b" term. The "b" term is the number of micrometers that the error increases for every 1000 millimeters of "L" length. So, the formula U3 = 4 + 5L/1000 for volumetric accuracy means that the error for zero measured length is 4 micrometers, and for every additional meter of length measured it gets 5 micrometers larger. U3 = 4 + 5L is the way the specification is commonly referred to.

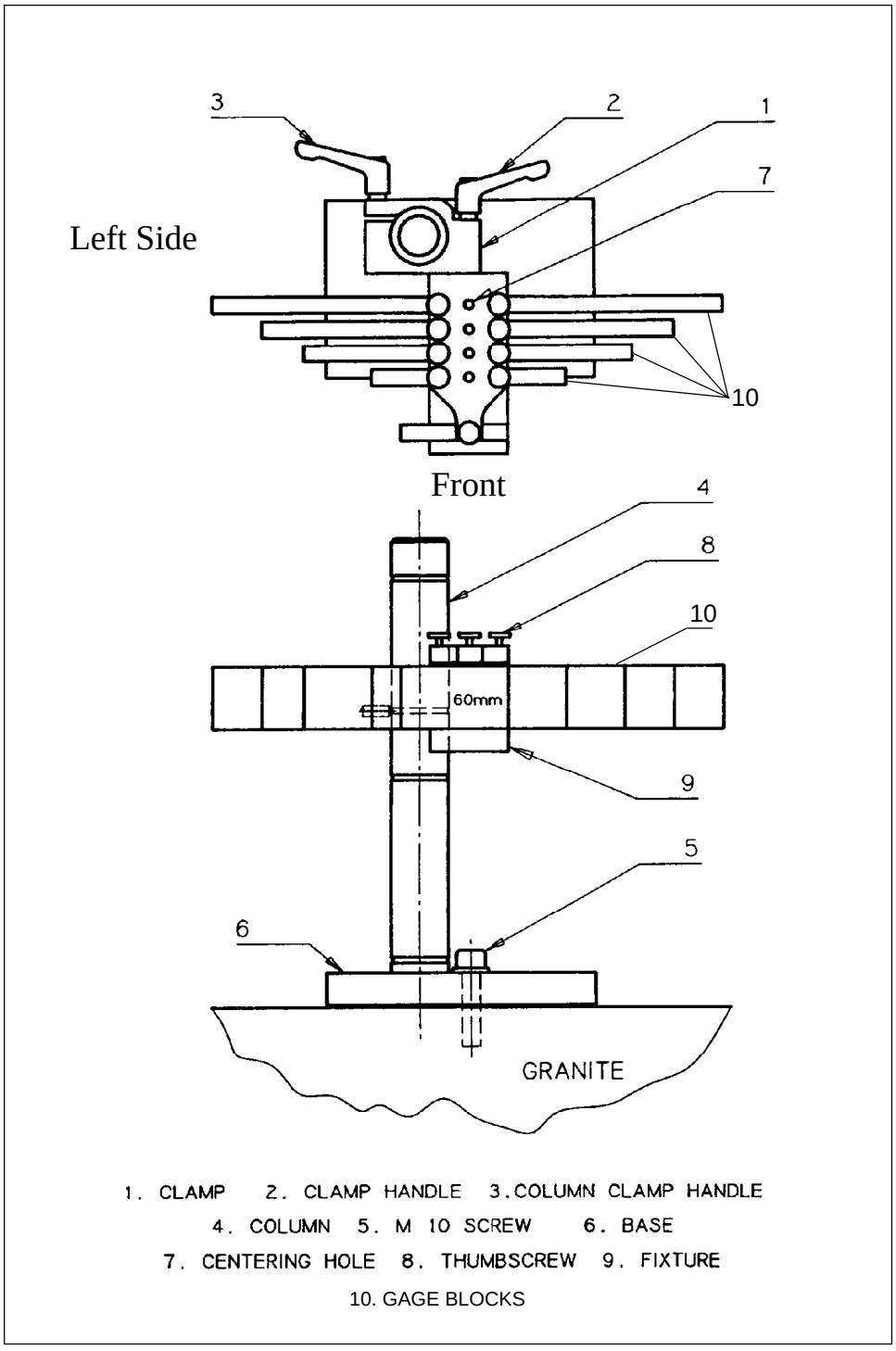

Figure 1 Gageblock Fixture

8.0 The measurement approach is the same for the ISO standard, but the formula is changed to E = a + L/k where "k" is the "b" value for the VDI/VDE formula divided into 1000. There are no individual axial and planar specifications; they are included in the volumetric "E" specification.

9.0 B89 Performance Testing

The basic test of CMM performance under the B89 standard includes five measurements:

9.1 Multiple measurements of the position of a fixed ball. The range (largest minus smallest) is the repeatability of the machine.

9.2 Measurements with a step gage or laser in each axial direction. This is the linear accuracy of the machine.

9.3 Measurements of a ball bar at multiple positions and orientations in the machine's working volume. This is the volumetric performance of the machine (Figures 2 and 3).

9.4 Measurement of the ball bar in four diagonal positions in vertical planes. In each position, the ball bar is measured with two right angle probe offsets and the difference of measured lengths is determined. The differences are compared with an offset probe performance specification. The test is sensitive to Z axis probe offset errors. This is important when using the probe at right angles to the Z axis, such as with indexing probes.

9.5 Measurement of length of a short gage block in four orientations. The measurement is compared with a bi-directional accuracy measuring capability specification. This test is sensitive to probe qualification errors.

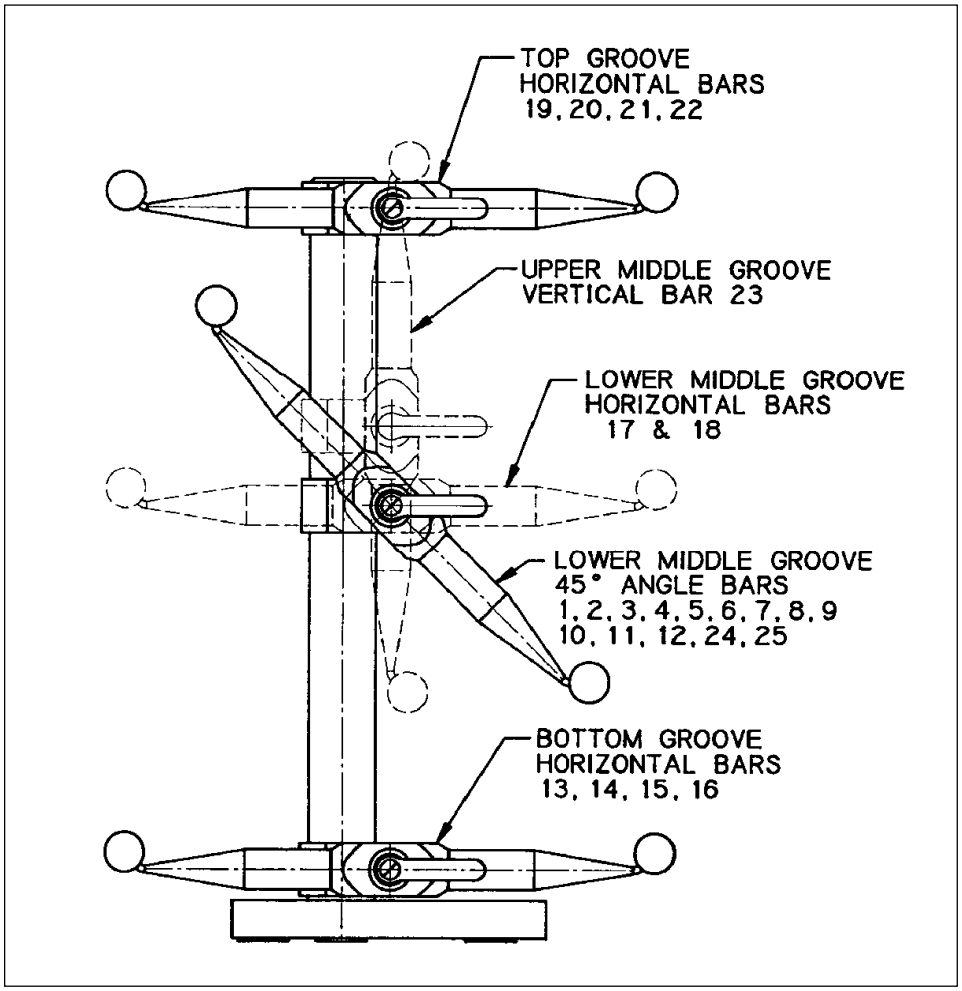

Figure 2
Positioning the Ballbar on the Ballbar Stand

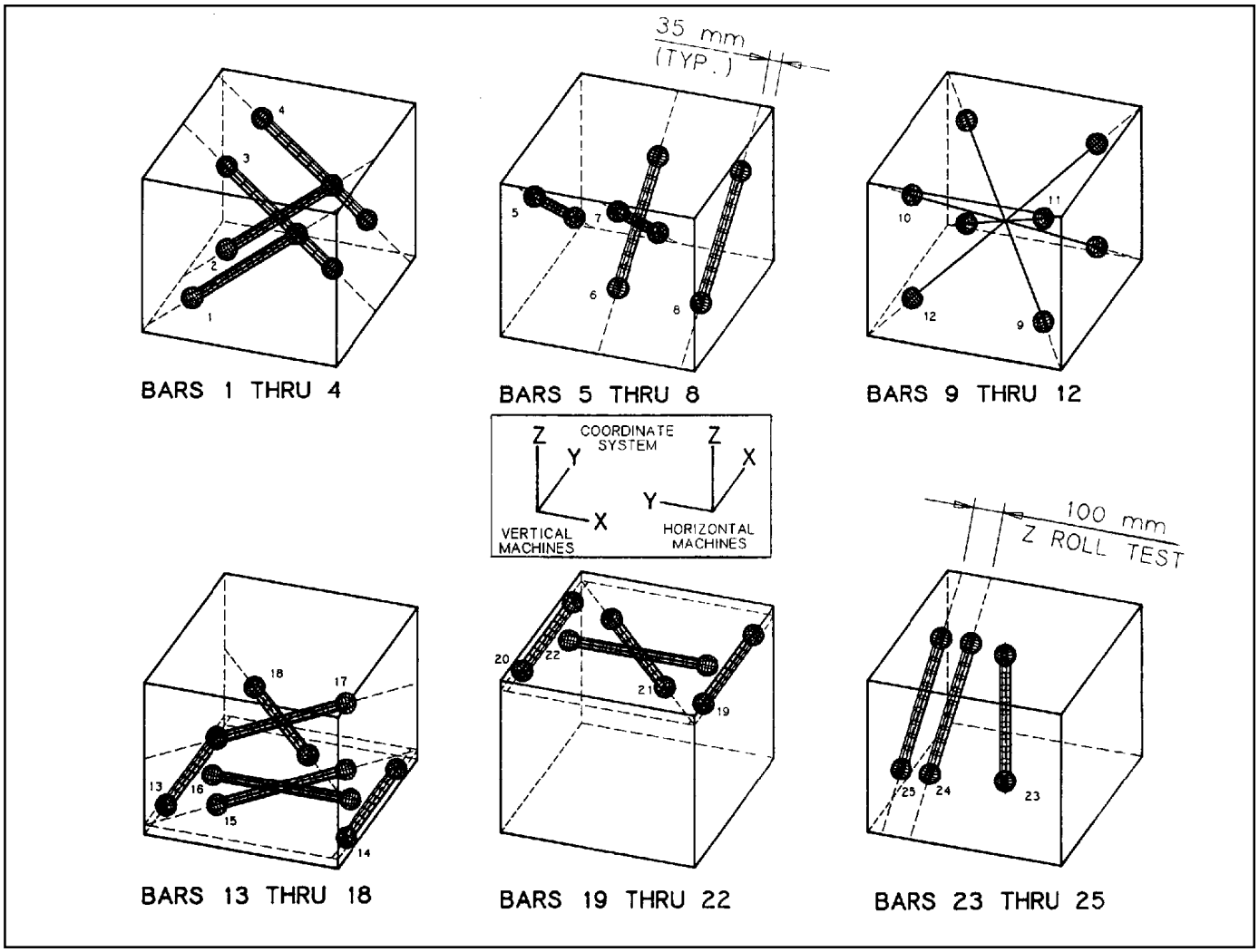

Figure 3 Ballbar Positions in the Measuring Volume

10.0 Standard-Specific Tests

There are some other differences as well. For example, the VDI/VDE standard specifies a method for very long measurement distances, called the block method, and for the use of other gage types such as ball plates and ring gages for probe testing. Both VDI/VDE and B89 provide specific tests for machines equipped with rotary tables. The B89 standard also provides specific tests for multiple probe tips, plus laser diagonal measurements for large machines, duplex performance for dual-arm horizontal machines, and performance with heavy workpieces.

11.0 The ISO standards working group now has many of these extensions in the committee draft or balloting stage. The US B89 committee is cooperating closely with the ISO group to insure that future national and international standards are consistent.

12.0 Test Environment

ISO standards generally require that the operating environment for acceptance tests, especially temperature, be within limits specified by the machine manufacturer. VDI/VDE standards have a similar requirement. The B89 standard allows acceptance testing in any environment. If the environment is not within the limits specified by the machine supplier, other tests are performed to determine the effects of the environment on machine performance. The results of these tests are used to modify machine performance specifications.

13.0 Other Standards

There are other standards in addition to these three. The most frequently referred to are the CMM Manufacturers' Association standard, CMMA; the Japanese standard, JIS B7440; and the British standard, BS 6808. These standards are generally limited in application, except in the countries of origin.

14.0 The Accuracy Issue

The most important subject now in both US and ISO standards committees is that while these performance tests provide an overall characterization of machine quality, they don't give the user enough information about how accurately the machine can measure a feature such as the diameter of a bore in an engine block. Right now, technical standards committees around the world are working to determine how to characterize what is called "task specific measurement uncertainty" as a way of describing how accurately the machine can perform a real measurement task, including the machine performance.

	B89.4.1	**VDI/VDE 2617**	**ISO 10360**
No. of Tests	5 (¶4,9)	3 (¶4,6)	2 (¶4)
Specification	Single Number (¶4)	Formula (¶5,6,7)	Formula (¶8)
Test Environment	Non-specific (¶12)	Manufacturer Specific (¶12)	Manufacturer Specific (¶12)
Standard-Specific Tests	Tests for Multiple probe tips. Laser diagonal measurements. Duplex performance. Heavy workpiece performance. Rotary Tables.(¶10)	Block Method. Ball Plates Ring Gages. Rotary Tables. (¶10)	Numerous extensions in committee draft form being balloted upon. (¶11)

Figure 4 Simple Comparison of B89, VDI/VDE and ISO Performance Standards

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