**Measurement and Gaging**

**Training Objective**

After watching this video and reviewing the printed material, the student/trainee will learn the basics of measurement and the use of measuring and gaging tools.

- The concepts of measurements are explained.
- Both nongraduated and graduated tools are detailed.
- Direct-reading devices are shown.
- Optical, vision, and coordinate methods are discussed.

All manufacturing is built around the measurement of both in-process work and in the final inspection of the finished part. Some typical measurable values include:

- time
- weight
- temperature
- pressure
- hardness
- part dimensions

Part dimensions refer to the physical aspects of the item in respect to size and shape and to the size, orientation, form, and location of part details such as holes, slots, projections, etc. Two systems for linear measurement are used today in industry, the familiar English system based on the yard and the Metric system based on the meter.

Measurement systems are calibrated to primary standards that are actual physical objects that provide a common dimensional reference. “Gage Blocks” are extremely accurate and stable alloy steel units which either, singly or in groups, are used to calibrate and check the accuracy of various measurement tools. Additionally, flat, hard surface plates provide reference points from which other dimensions can be obtained.

The use of the various measurement tools is dependent upon the understanding of the following core concepts:

- **Precision** - the quality of being clearly defined or how close the indicated value is to the true value
- **Resolution** - referring to the fineness of the tool’s graduations. A rule graduated in 1/2 mm is more precise than one graduated in whole millimeters
- **Accuracy** - the degree to which an indicated value conforms to an established standard
- **Repeatability** - the degree of consistency achieved with a measuring tool, with a single reader measuring the same dimension several times
- **Reproducibility** - the degree of consistency achieved when a measuring device is used by different readers to inspect the same part or part dimension

Nongraduated measuring tools and gages are used to transfer existing or preset dimensions to or from a graduated tool. In other instances they act as pass/fail comparisons such as the go-no go gage. The common non-graduated tools and gages include:
Measurement and Gaging

- dividers
- calipers (plus the hermaphrodite caliper)
- telescope gages
- small hole gages
- squares
- straight edges
- adjustable parallels
- go/no-go gages

Each has its own application during an inspection sequence. A typical example is in the divider being set to a radius dimension on a graduated scale then used to scribe a circle of a given diameter.

Graduated measuring tools and gages have either linear or angular graduations and may be in English or metric units. Some of the more common tools include:

- rules
- combination squares
- calipers
- micrometers
- height gages

These tools have either specific or universal use in a variety of inspection sequences. For example, calipers may be used for reading both “inside” and “outside” diameter. The use of the combination square can be expanded to the measurement of angles with a “protractor” head, and to the locating of the centers of round objects with a “centering” head.

Vernier calipers are calipers that have an additional scale, called a “vernier scale,” for greater resolution and precision. This additional scale will divide each millimeter into 50 units representing two one hundredths (.02) of a millimeter. Height gages and depth gages have also been refined by the addition of vernier scales.

Micrometers use a stationary anvil and moveable spindle mounted on a “C” type frame. By rotation of a thimble the spindle moves towards the anvil. Measurement is obtained by the graduated thimble revolving around the graduated portion of the spindle shaft. Similar to the vernier caliper, the micrometer’s shaft is graduated in millimeters and the thimble in one hundredths of a millimeter (.01).

Dial read-outs and electronic digital displays have improved the precision of measurement readings. Vernier calipers have dials with a pointer that rotates as the moveable jaw slides along the frame of the caliper. Also available are electronic digital readout. A dial indicator uses a contact point attached to a spindle and rack arrangement. The movement of the contact is transmitted to the face of the dial that is appropriately graduated. Both dials and digital read-outs have been incorporated in most standard measuring tools and instruments. They have the important advantage of providing direct readings and eliminating the chance of errors associated with the interpretation of sliding vernier scales. Additionally, the electronic digital read-out devices are useful in collecting data for statistical process control (SPC) functions.
Other measuring devices work by comparing the part dimensions and characteristics with an image or model of the specified part’s characteristics or dimensions. The three most common devices are:

- optical measuring projectors
- vision systems
- coordinated measuring machines or CMMs

The optical projection method is a non-contact device that displays the feature in question on a display screen. Measurements are checked by cross hairs etched directly on the screen or with overlay charts. Usually the part profile is depicted, but some systems enable surface viewing as well. Other systems have edge detection capabilities that use beams of light to trigger a coordinate reading when light or dark edges are crossed.

Vision systems use visual sensors to read part characteristics and make intelligent decisions as to acceptance or rejection. The main applications of visual systems are gaging and flaw detection, symbol and object recognition, and machine tracking and object location.

Coordinate measuring machines (CMM) are extremely accurate devices ranging from small tabletop units to very large CMMs capable of inspecting whole aircraft components. They use a probing system to collect raw data and feed it into a computer to be processed and analyzed. In operation the probe or probes are brought into contact with the part either manually or by machine controls. Geometric and dimensional data is then transmitted to the system’s computer. Probes will operate in the X, Y, and vertical Z axes.
Review Questions

1. An example of a primary calibration standard is a:
   a. tolerance
   b. digital readout
   c. gage block
   d. dial indicator

2. “Resolution” refers to:
   a. vision
   b. tool graduations
   c. consistency
   d. repeatability

3. An example of “comparison” tool is the:
   a. caliper
   b. height gage
   c. adjustable parallels
   d. go/no-go gage

4. A centering head is used to:
   a. calculate the center of a tolerance
   b. find the center of round objects
   c. bisect known angles
   d. find right angles

5. The vernier scale divides the principle scale into:
   a. 10 units
   b. 50 units
   c. 100 units
   d. 1000 units

6. The stationary part of the micrometer is the:
   a. thimble
   b. spindle
   c. anvil
   d. shaft

7. A major advantage of an electronic digital readout system is:
   a. direct reading of dimensions
   b. automatic data collection
   c. errorless interpretation of readings
   d. all of the above

8. Optical projection:
   a. is a laser device
   b. depends upon probes
   c. is a noncontact method
   d. finds X and Y coordinates

9. Optical projection most often depicts the part’s:
   a. profile
   b. Z axis
   c. interior details
   d. perspective view
10. Coordinate measuring machines collect and record:
   a. X, Y, and Z coordinate locations
   b. hole locations
   c. raw data
   d. direct measurements
**Answer Key**

1. c
2. b
3. d
4. b
5. b
6. c
7. d
8. c
9. a
10. c