



HRP Training Aid: Dimensional Inspection Machines, Instruments, or Systems

Description	ECCN
Dimensional inspection or measuring systems, equipment, position feedback units	2B006
Dimensional inspection machines, instruments or systems, other than those described in 2B006	2B206
Dimensional inspection or measuring systems or equipment not controlled by 2B006 or 2B206	2B996
Coordinate measuring machines (CMMs)	2B006.a, 2B206.a
Linear displacement measuring instruments or systems	2B006.b
Noncontact type measuring systems	2B006.b.1
Linear position feedback units specially designed for machine tools	2B006.b.2
Linear displacement measuring systems containing a laser.....	2B006.b.3, 2B206.c
Angular displacement measuring instruments	2B006.c
Rotary variable differential transformer (RVDT) systems.....	2B006.c
Equipment for measuring surface roughness.....	2B006.d
Rotary contour gauges (RCGs)	2B206.b
Systems for simultaneous linear-angular inspection of hemishells.....	2B206.b
Linear variable differential transformer (LVDT) systems.....	2B206.d
Manual dimensional inspection machines.....	2B996.a

Key Points and ECCN Definitions

Under the US Commerce Control List, Export Control Classification Numbers (ECCNs) 2B006 and 2B206 cover highly specific, high-precision dimensional inspection and measuring systems.

- **Dimensional inspection systems** are used to measure the dimensions of machined parts or components to ensure that they have been produced with the required accuracy.
 - There are two basic types of dimensional inspection systems: Contact (stylus-based) and noncontact (optical, laser-based).

- Such equipment provides quantitative measurements of dimensional and form attributes such as wall thickness, depth, height, length, inner diameter, outer diameter, taper, bore, roundness, angularity, squareness, straightness, flatness, runout, taper, concentricity, and cylindricity.
- The two types of dimensional inspection machines used most in nuclear programs are CMMs and RCGs.
- **CMM:** A device that physically or optically measures physical geometric characteristics of an object. CMMs with extremely high accuracy are controlled.
- **MPE:** Maximum permissible error. The highest amount of deviation or error allowed by specifications or standards for a measuring device.
- **ISO:** International Organization for Standardization. For example, ECCN 2B006 strictly reference testing standards (such as ISO 10360-2) to determine whether a measuring machine exceeds export control thresholds.
- **μm:** Micrometer (micron). A unit of measure ($1 \mu\text{m} = 1 \times 10^{-6} \text{ m}$).
- **L:** Measured length. L is the physical length being measured, in millimeters.

Common Acronyms and Technologies Under ECCNs 2B006 and 2B206

- Computer numerical control (CNC)
- Coordinate measuring machines (CMMs)
- Computed tomography (CT) scanners
- Dimensional gauges
- Form gauges
- Laser scanners and tracker systems
- Laser interferometers
- Linear encoders
- Linear variable differential transformers (LVDTs)
- Metrology equipment
- Optical comparators and vision measuring systems
- Profilometers
- Resolvers
- Rotary contour gauges (RCGs)
- Rotary encoders
- Rotary variable differential transformers (RVDTs)
- Synchros

How to Identify

- Review technical manuals and specifications sheets: Examine original equipment manufacturer (OEM) documentation for the equipment's technical specifications—such as resolution, measurement uncertainty/accuracy, and axes—and compare them against the specific parameter thresholds listed under ECCN 2B006 and ECCN 2B206.
- Contact the manufacturer: Reach out to the vendor or the OEM to ask for the ECCN of the exact model number.

Example: How to Read CMM Specifications

Model		
Measuring Range	X axis	1210mm
	Y axis	1210mm
	Z axis	810mm
Measurement standard		Ultra-high precision
Resolution		0.00001mm
Accuracy (ISO 10360-2)	MPEE	(0.6+1.5L/1000)um
	MPEP	0.6um
	MPETHP	1.8um
Guide Method		Air bearings
Maximum drive speed		200mm/s
Maximum acceleration		1000mm/s ²
Worktable	Material	Cast iron
	Working area	1250*1250mm
	Tapped inserts	M8*1.25mm
Maximum workpiece height		1060mm
Maximum worktable loading		1000kgf
Air pressure, consumption		0.4MPa,120L/min
Mass		10500kg

- Number of axes (3)
- ISO 10360-2 specifies three uncertainties:
 1. Volumetric length measuring uncertainty (**MPEE**)
 2. Volumetric probing uncertainty (**MPEP**)
 3. Volumetric scanning error (**MPETHP**)
- **MPE** is maximum permissible error
- Machine is controlled if it exceeds the specified threshold **anywhere** within its operating range.
- **Controlled: ECCN 2B206**

Dimensional Inspection or Measuring Systems, ECCN 2B006 Equipment, Position Feedback Units

This ECCN controls dimensional inspection or measuring systems, equipment, position feedback units and electronic assemblies, as follows:

- a. Computer-controlled or numerically controlled CMMs, having a 3D length (volumetric) maximum permissible error of length measurement ($E_{0,MPE}$) at any point within the operating range of the machine (i.e., within the length of axes) equal to or less (better) than $(1.7 + L/1,000) \mu\text{m}$ (L is the measured length in mm) according to ISO 10360-2 (2009);

Technical Note: For the purposes of 2B006.a, $E_{0,MPE}$ of the most accurate configuration of the CMM specified by the manufacturer (e.g., best of the following: Probe, stylus length, motion parameters, environment) and with all compensations available shall be compared to the $1.7 + L/1,000 \mu\text{m}$ threshold.

- b. Linear displacement measuring instruments or systems, linear position feedback units, and electronic assemblies, as follows:

Note: Interferometer and optical-encoder measuring systems containing a laser are only specified by 2B006.b.3.

- b.1. Noncontact type measuring systems with a resolution equal to or less (better) than $0.2 \mu\text{m}$ within 0 to 0.2 mm of the measuring range;

Technical Notes: For the purposes of 2B006.b.1

1. Noncontact type measuring systems are designed to measure the distance between the probe and measured object along a single vector, where the probe or measured object is in motion.

2. *Measuring range* means the distance between the minimum and maximum working distance.

- b.2. Linear position feedback units specially designed for machine tools and having an overall accuracy less (better) than $(800 + (600 \times L/1,000)) \text{ nm}$ (L equals effective length in mm);

- b.3. Measuring systems having all of the following:

- b.3.a. Containing a laser;

- b.3.b. A resolution over their full scale of 0.200 nm or less (better); and

- b.3.c. Capable of achieving a measurement uncertainty equal to or less (better) than $(1.6 + L/2,000) \text{ nm}$ (L is the measured length in mm) at any point within a measuring range, when compensated for the refractive index of air and measured over a period of 30 s at a temperature of $20^\circ\text{C} \pm 0.01^\circ\text{C}$;

Technical Note: For the purposes of 2B006.b, resolution is the least increment of a measuring device; on digital instruments, the least significant bit.

b.4. Electronic assemblies specially designed to provide feedback capability in systems controlled by 2B006.b.3;

c. Rotary position feedback units specially designed for machine tools or angular displacement measuring instruments, having an angular position accuracy equal to or less (better) than 0.9 second of arc;

Note: 2B006.c does not control optical instruments, such as autocollimators, using collimated light (e.g., laser light) to detect angular displacement of a mirror.

d. Equipment for measuring surface roughness (including surface defects), by measuring optical scatter with a sensitivity of 0.5 nm or less (better).

Note: 2B006 includes machine tools, other than those specified by 2B001, that can be used as measuring machines, if they meet or exceed the criteria specified for the measuring machine function.

Major Manufacturers (ECCN 2B006)

- **Carl Zeiss Industrial Metrology:** Known for high-end bridge and horizontal arm CMMs as well as multi-sensor, optical, and x-ray CT systems.
- **Hexagon Manufacturing Intelligence:** Market leader that produces the Brown & Sharpe and Leica Geosystems product lines. Hexagon products range from portable measuring arms (Absolute Arm) to stationary ultrahigh-accuracy CMMs.
- **Mitutoyo:** An industry staple for absolute precision. Manufactures an extensive lineup of precision measuring tools, optical vision measuring machines, and high-accuracy 3D CMMs such as the CRYSTA-Apex series.
- **Keyence:** A premier source for rapid, automated image dimension measurement systems. Their instant measurement machines are ideal for high-volume, noncontact quality assurance and pass/fail part checks.
- **Optical Gaging Products (OGP):** A division of Quality Vision International, renowned for high-speed multi-sensor, optical, and laser dimensional measurement systems (e.g., SmartScope).
- **L.S. Starrett Company:** A legacy American manufacturer of precision measuring tools, digital video systems, and optical comparators.
- **Mahr:** Specializes in high-precision surface, form, and length measuring instruments, including the MarForm and MarSurf systems.

Specific Equipment Models

Specific equipment models from major manufacturers typically fall under ECCN 2B006 if they include the following:

- **CMMs and optical scanners:** Ultrahigh-precision, laser-based noncontact measuring systems designed for extreme geometries.
 - Examples: Zeiss high-end systems (e.g., Zeiss PRISMO or XENOS), and Hexagon systems (e.g., Leica Absolute Tracker AT960 or Leitz PMM-C)
- **Contour and surface measuring systems:** Systems measuring the distance between a probe and an object along a single vector while in motion, with resolutions less than 0.2 μm .
 - Examples: Taylor Hobson's Form Talysurf PGI series and Mahr's MarSurf series
- **Linear position feedback units:** Specialized scales and encoders used for high-accuracy machine tools.
 - Examples: Heidenhain's LIP 6000 or LIC 4000 series
- **Laser interferometers:** Measuring systems that use lasers with a full-scale resolution of 0.200 nm or less, capable of achieving extreme measurement uncertainty.
 - Examples: Renishaw's XL-80 laser interferometer system or XM-60 multiaxis calibrator

CMMs

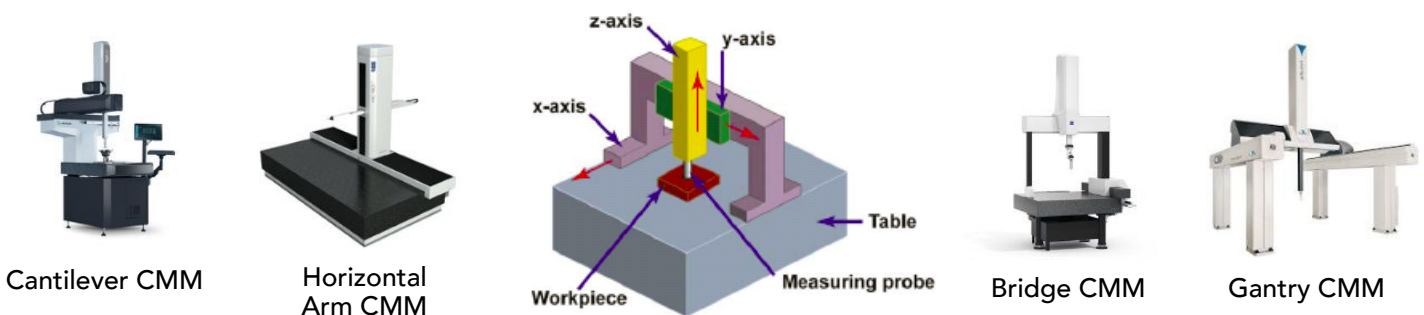
Key Points

- CMMs operate based on two fundamental principles:
 - A mechanical probe that physically contacts the object
 - Noncontact probes, such as lasers or cameras
- High-precision machines often use a granite base or table.



Types of CMMs

- **Bridge type**
 - Most widely used
 - High accuracy and rigidity
 - Probe/arm is suspended vertically from a horizontal beam that is supported by two vertical posts.
- **Cantilever type**
 - Open structure for easy loading
 - Suitable for small to medium parts
 - A vertical arm is supported by a cantilevered support structure.
- **Horizontal arm**
 - Used to inspect large sheet metal panels and automotive bodies
 - The arm that supports the probe is horizontally cantilevered from a movable vertical support.
- **Gantry type**
 - Designed for very large and heavy components
 - Common in aerospace and in heavy industry





Zeiss PRISMO CMM

- Flagship model among Zeiss CMMs
- Available in different sizes
 - Smallest: measuring range of 700 × 900 × 500 mm
 - Largest: measuring range of 1,600 × 4,200 × 1,400 mm
- Accuracy from 0.9 + L/350 µm

Hexagon Leica Absolute Tracker ATS600

- Industry's first direct-scanning laser tracker
- Eliminates the need for a user to physically hold a scanner, probe, or reflector at the measurement point
- Projects a laser directly onto a surface and produces a digital scan from a distance of up to 60 m
- Ideal for inspecting massive surfaces (e.g., aerospace parts, large automotive components)



Leitz PMM-C

- Premium, ultrahigh-accuracy 3D CMM manufactured by Hexagon
- Widely used in industry (e.g., aerospace, automotive, and medical technology) for submicron precision inspections, form testing, and gear measurements
- Features a solid granite base, fixed portal, and cast-iron pedestals to ensure maximum stability, thermal resistance, and rigidity
- Employs 3D probe technology that enables rapid data collection without sacrificing submicron accuracy

Linear Encoders

ECCN 2B006.b

Linear encoders measure the position of linear axes without using intervening mechanical elements. They are essential wherever rigorous position accuracy and high machining speeds are needed.



Sealed linear encoders

- Optimal protection from dust, chips, and splash water
- For use in manually operated and numerically controlled machine tools

Exposed linear encoders

- Zero mechanical contact between the scanning head and the scale or scale tape
- Applications include production and measuring equipment in the semiconductor industry



Heidenhain LIC 4100 absolute linear encoder (exposed)

- High accuracy with high traversing speed
- High immunity to contamination
- Measuring steps down to 1 nm
- **ECCN 2B006.b**

Heidenhain LIP 6001 incremental linear encoder (exposed)

- Designed for measuring precise linear movement in semiconductor manufacturing, metrology equipment, and micromachining
- Very high accuracy and large measuring lengths
- Very small measuring step (<1 nm)
- **ECCN 2B006.b**



Renishaw XL-80 laser interferometer

- Measurement device used to assess and enhance machine performance
- Produces an extremely stable laser beam to detect issues in motion systems before they affect production
- New kits: \$17–\$32k

Applications

- Measuring the performance of machine tools, CMMs, and motion systems

Accuracy/uncertainty

Full-scale resolution of 0.200 nm or less; capable of achieving extreme measurement uncertainty

ECCN 2B006.b



Angular Displacement Measuring Instruments

- Angular displacement is movement of an object around an axis, such as the angular motion of a motor shaft. The output signal from an angular displacement sensor represents the rotation of the measured object.
- Four common types of sensors are used to measure angular displacement (look for references to any of the following on available paperwork):
 - **RVDTs**
 - **Synchros**
 - **Resolvers**
 - **Rotary encoders**
- Appearance:
 - RVDTs, synchros, and resolvers are electromechanical devices that often resemble electric motors.
 - Rotary encoders may be electromechanical, or they may be optical devices.
 - › *Enclosed* rotary encoders also may resemble an electric motor.
 - › However, *modular* rotary encoder designs are composed of a ring structure called a grating disk and rotary displacement sensors, or counters, that attach to the perimeter of the ring.



Rotary variable displacement transformers (RVDTs)



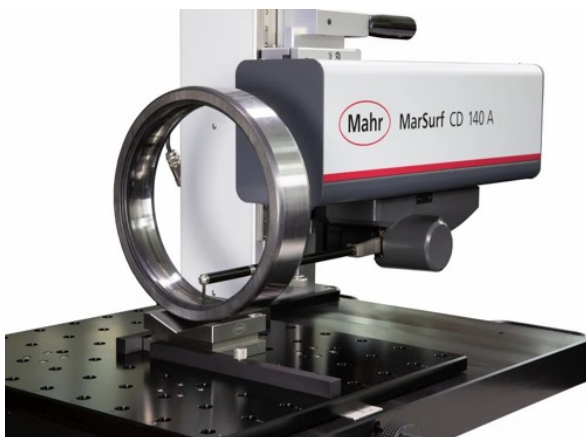
Typical resolvers



Enclosed rotary encoders



Modular rotary encoder with dual counters



Mahr MarSurf CD140 AG11 combined contour and roughness measuring station

Applications

- **Mechanical engineering**
Bearings, threads, threaded rods, ball spindles, shafts, racks
- **Measurements close to production**
Semiautomatic contour measurements
- **Automotive industry**
Steering and brake system, transmission, crankshaft, camshaft, cylinder head
- **Medical technology**
Contours of hip and knee prostheses, contours on medical screws, contours on dental implants

Accuracy/uncertainty

Mahr's LD series delivers contour measuring precision that is typically in the low-micrometer range. For high-resolution measuring systems, the linearity/measuring deviation is usually guaranteed at $\pm 0.75 + L/100 \mu\text{m}$.

ECCN 2B006.d

Dimensional Inspection Machines, Instruments, or Systems Other than Those Controlled Under 2B006

ECCN 2B206

This ECCN controls dimensional inspection machines, instruments, or systems other than those described in 2B006, as follows:

Control notes to ECCN 2B206:

- (1) Machine tools that can be used as measuring machines are controlled by ECCN 2B206 if they meet or exceed the control parameters specified in this entry for the measuring machine function.
- (2) The machines described in ECCN 2B206 are controlled by this entry if they exceed the specified control threshold anywhere in their operating range.

Technical Note to ECCN 2B206: All parameters of measurement values in this entry represent plus/minus (i.e., not total band).

- a. Computer-controlled or numerically controlled CMMs with either of the following characteristics:
 - a.1. Having only two axes with a maximum permissible error of length measurement along any axis (one dimension), identified as any combination of $E_{0x\text{ MPE}}$, $E_{0y\text{ MPE}}$ or $E_{0z\text{ MPE}}$, equal to or less (better) than $(1.25 + L/1,000) \mu\text{m}$ (where L is the measured length in millimeters) at any point within the operating range of the machine (i.e., within the length of the axis), according to ISO 10360-2 (2009); or
 - a.2. Having three or more axes with a 3D (volumetric) maximum permissible error of length measurement, identified as $E_{0,\text{MPE}}$, equal to or less (better) than $(1.7 + L/800) \mu\text{m}$ (where L is the measured length in millimeters) at any point within the operating range of the machine (i.e., within the length of the axis), according to ISO 10360-2 (2009).

Technical Note to 2B206.a.2: The $E_{0,\text{MPE}}$ of the most accurate configuration of the CMM specified according to ISO 10360-2 (2009) by the manufacturer (e.g., best of the following: Probe, stylus length, motion parameters, environment) and with all compensations available shall be compared to the $1.7 + L/800 \mu\text{m}$ threshold.

- b. Systems for simultaneous linear-angular inspection of hemishells, having both the following characteristics:
 - b.1. Measurement uncertainty along any linear axis equal to or less (better) than $3.5 \mu\text{m}$ per 5 mm; and
 - b.2. Angular position deviation equal to or less than 0.02° .

- c. Linear displacement measuring systems having both the following characteristics:
 - c.1. Containing a laser; and
 - c.2. Capable of maintaining, for at least 12 h over a temperature range of ± 1 K around a c.2.a. A resolution over their full scale of $0.1 \mu\text{m}$ or better; and
 - c.2.b. A measurement uncertainty equal to or better (less) than $(0.2 + L/2,000) \mu\text{m}$ (L is the measured length in millimeters).

Control Note to 2B206.c: 2B206.c does not control measuring interferometer systems, without closed or open loop feedback, containing a laser to measure slide movement errors of machine tools, dimensional inspection machines, or similar equipment.

Technical Note to 2B206.c: In 2B206.c, *linear displacement* means the change of distance between the measuring probe and the measured object.

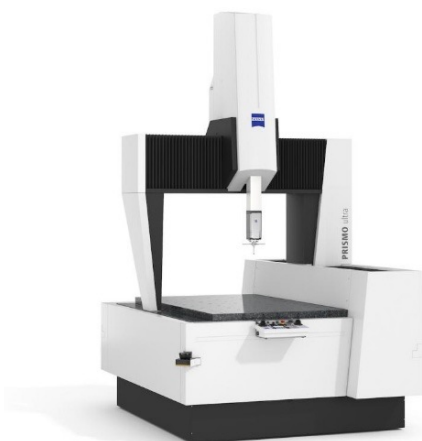
- d. LVDT systems having all of the following:
 - d.1. Having any of the following:
 - d.1.a. Linearity equal to or less (better) than 0.1% measured from 0 to the full operating range, for LVDTs with a full operating range up to and including ± 5 mm; or
 - d.1.b. Linearity equal to or less (better) than 0.1% measured from 0 to 5 mm for LVDTs with a full operating range greater than ± 5 mm; and
 - d.2. Drift equal to or less (better) than 0.1% per day at a standard ambient test room temperature ± 1 K.

Major Manufacturers/Specific Models and Platforms

ECCN 2B206

Several top-tier manufacturers offer specific models capable of meeting or exceeding the rigorous control parameters of ECCN 2B206:

- **Zeiss:**
 - **PRISMO series:** High-accuracy CMMs widely used for precision inspection.
 - **O-INSPECT:** Multisensor optical and contact inspection machines.
 - **CenterMax** (released in 2001; discontinued): High-speed, highly accurate scanning systems suitable for shop floor environments. Production measuring device for temperature-stable measuring (e.g., in measuring rooms).
- **Mitutoyo:**
 - **LEGEX series:** Ultrahigh-precision CNC CMMs known for exceptional measurement uncertainty values.
 - **CRYSTA-Apex S series:** Standard CNC CMMs that offer top-tier scanning capabilities.
- **Hexagon Manufacturing Intelligence:**
 - **Leica Absolute Tracker (AT960/ATS600):** High-end laser trackers that measure large parts with extreme precision.
 - **DEA GLOBAL S series:** Flexible CMMs built for heavy-duty, high-accuracy structural measuring.



Zeiss PRISMO ultra

- Length measurement error: $0.5 + L/500 \mu\text{m}$
- Glass ceramic scale
- Particularly suitable for tasks in which maximum precision is required (e.g., research, development, and quality assurance) and for calibrating gauges or test specimens in reference measuring rooms or measuring laboratories

ECCN 2B206.a



Zeiss O-INSPECT 8/6/3

- Measuring volume: $800 \times 600 \times 300 \text{ mm}^3$
- Length measurement error MPE(E):
 - in 1D: $1.5 \mu\text{m} + L/250 \mu\text{m}$
 - in 2D: $1.8 \mu\text{m} + L/250 \mu\text{m}$
 - in 3D: $2.2 \mu\text{m} + L/250 \mu\text{m}$

Zeiss CenterMax 11/12/7

- Measuring range: $1,100 \times 1,200 \times 700 \text{ mm}$
- Weight: 6000 kg
- Accuracy adjusts dynamically depending on ambient temperature
- Length measurement error MPE(E):
 - $1.2 \mu\text{m} + L/280 \mu\text{m}$ (standard lab conditions)
 - $1.5 \mu\text{m} + L/250 \mu\text{m}$ (modern production floors)
 - $2.2 \mu\text{m} + L/180 \mu\text{m}$ (conventional shop floors)



Mitutoyo LEGEX 500/700/900/1200 series

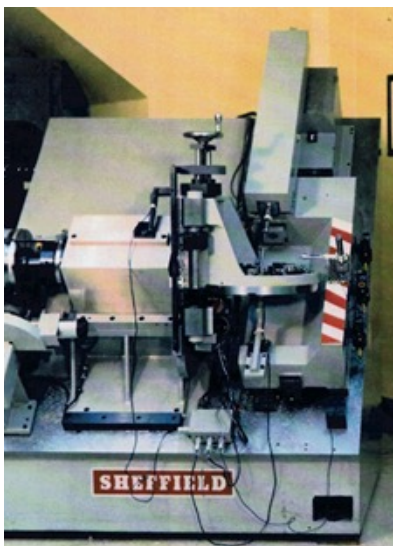
- Ultrahigh-accuracy CNC CMM
- Use of air-damped spring isolators to virtually eliminate factory floor-induced vibrations
- Length measurement error MPE(E): $0.35 + L/1,000 \mu\text{m}$
- **ECCN 2B206.a**

Rotary Contour Gauges (RCGs)

ECCN 2B206.b

Key Points:

- RCGs are ultrahigh-precision dimensional inspection machines for the simultaneous measurement of the internal and external contours of hollow solids of revolution; thus, they are particularly useful for nuclear weapons programs.
- Historically, the US Department of Energy national laboratories relied on specialized RCGs manufactured by Sheffield (note: Sheffield Measurement Company is now part of Hexagon Measurement Intelligence.) Later operations have transitioned toward the use of modern CMM inspection systems.
- Ring Rotacon: An advanced RCG developed in the 1990s that uses hardware from legacy Sheffield gauges.
- Shell Measuring Machine (SMM): A highly customized dimensional inspection machine for measuring hollow solids of revolution developed in the early 2000s via a partnership with Moore Machine Inc. (Bridgeport, Connecticut).
- RCG's look like other CMMs, but they can be recognized by the fact that they have two probes, also known as form gauges or surface profilometers.
- Available paperwork: Look for any references to RCG, Sheffield, Moore Machine, Ring Rotacon, SMM, form gauges, or profilometers.
- To be controlled under ECCN 2B206.b, such systems must have measurement uncertainties along any linear axis equal to or less (better) than $3.5 \mu\text{m}$ per 5 mm and angular position deviation equal to or less than 0.02° .



RCG—Sheffield

- Measures the radial distance to the inner and outer surfaces of the object
- Uses a pair of air-bearing-supported helium–neon laser interferometer probes



SMM—Moore Machine Inc.

- A rotary table mounted to a granite base
- A second rotary table mounted at a slant relative to the first rotary table
- Two opposing probes mounted on rigid arms affixed to the granite base
- Probes are positioned to contact the part on the inner and outer surface

Laser Dimensional Inspection Sensors

ECCN 2B206.c

- Laser sensors determine the position of a target by measuring light reflected from the target surface.
- A laser diode (transmitter) projects a spot of light on the target, and the reflection is focused via an optical lens on a light-sensitive CCD receiver.
- Appearance:
 - Typically hand-sized or larger boxes that include a transmitter lens and a receiver lens on the same side of the sensor
 - Connection ports to connect the sensor to a signal processor and data acquisition system or computer



Laser measurement/displacement sensor

- Acuity Laser, a division of Schmitt Industries Inc.
- Note the size of a typical laser dimensional measurement sensor relative to a human hand
- **ECCN 2B206.c**



Laser displacement sensor

- Panasonic (formerly SUNX) HL-C2 Series
- Designed for high-precision distance or thickness measurements
- 0.04 to 0.01 μm resolution
- **ECCN 2B206.c**

Laser displacement sensor signal processing unit

- Micro-Epsilon CSP2008
- Processes up to two sensor signals simultaneously (note the Sensor 1 and Sensor 2 inputs on the front panel)



Hexagon Leica Absolute Tracker AT960

- Premium, portable 3D laser measurement system
- All-in-one system capable of six degrees of freedom measurements
- Dynamic measurement capability makes this device ideal for tracking moving targets and high-speed robotic automation
- Dimensions: 9.9 × 11.3 × 21.0 in.
- Weight: 30.4 lb
- **ECCN 2B206.c**

Linear Variable Differential Transformer (LVDT)

ECCN 2B206.d

- An LVDT is an electromechanical transducer that can linearly convert the position of an object to which it is mechanically attached into DC voltage. LVDTs can measure movements as small as 0.01 μm (0.4 microinches) up to several millimeters but are also capable of measuring positions up to 200 mm (± 4 in.).
- LVDTs are high-precision, noncontact devices built for extreme environments, nuclear applications, aerospace and defense, robotics automation, medical applications, and more
- They are used because they are accurate, sturdy, reliable, frictionless, and low maintenance.
- They must be laser-equipped and meet the strict parameters specified under ECCN 2B206.

Top US Manufacturers Key Points:

- **Sentech Inc.:** Specializes in custom-tailored LVDT and RVDT solutions for mission-critical aerospace, defense, and heavy industry applications.
- **Stellar Technology:** Designs extremely durable, fully welded stainless steel LVDTs that can operate in high-temperature, high-pressure, and radioactive environments.
- **Alliance Sensors Group:** Manufactures heavy-duty LVDT sensors and associated signal conditioning for power generation and industrial automation.
- **Trans-Tek Inc.:** Produces standard and customized general-purpose DC-DC LVDTs.
- **Columbia Research Laboratories:** Offers high-temperature, high-reliability LVDT transducers for use in aerospace and specialized industries.

Physical Components and Appearance

- **Sensor housing:** A cylindrical, ruggedized stainless steel or aluminum tube (typically 19–25 mm in diameter) enclosing internal coils. It is often hermetically sealed and rated ingress protection (IP)67 for harsh environments.
- **Laser module:** Mounted on or integrated into the end of the cylinder, this module contains a focused semiconductor laser (typically a visible red Class II laser). It emits a highly visible, tiny dot or line onto the target surface.
- **Optical receiver:** Situated adjacent to the laser, the optical receiver consists of a receiving lens and a CMOS/CCD detector.
- **Cabling and connectors:** An M12 connector or heavy-duty shielded cable emerges from the rear of the unit; connects the sensor head to an external signal conditioner or digital display.

LVDT systems



Dimensional Inspection or Measuring Systems or Equipment Not Controlled by 2B006 or 2B206

ECCN 2B996

This ECCN controls dimensional inspection or measuring systems or equipment not controlled by 2B006 or 2B206, as follows:

- a. Manual dimensional inspection machines, having both of the following characteristics:
 - a.1. Two or more axes; and
 - a.2. A measurement uncertainty equal to or less (better) than $(3 + L/300) \mu\text{m}$ in any axes (L is the measured length in millimeters).

ECCN 2B996 generally covers high-precision, manually operated or manually guided inspection systems that do not rely on fully automated computer controls. Fully automated and computer-controlled systems are typically classified under the higher-tier 2B006 or 2B206 ECCNs.

Examples of 2B996 Items

1. Manual CMMs

Standard automated CMMs run on preprogrammed software paths. However, manual CMMs require an operator to physically guide the probe across the part. Examples include the following:

- **Floating-bridge manual CMMs:** Benchtop or floor-standing CMMs that require the operator to move the x-, y-, and z-axes by hand using low-friction bearings to touch features on a manufactured part.
- **Manual shop floor CMMs:** Hardened measuring machines positioned next to machine tools used by operators to check part tolerances manually between machining passes.



Manual shop floor CMM

- Benchtop design makes it easy to put these instruments next to machine tools
- Provide precise dimensional and geometric evaluation of parts immediately after machining



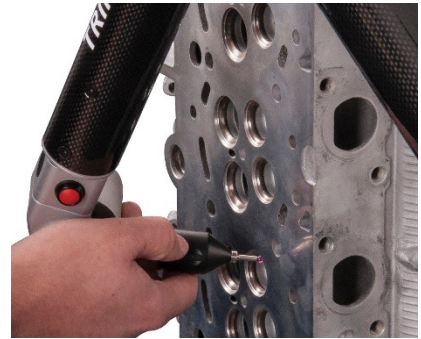
2. Manual articulated metrology arms

- Portable, multi-axis measuring arms (often called CMM arms) use internal optical encoders to track the position of a hard probe or noncontact scanner. They are held and moved entirely by a human operator.
- **High-precision six- or seven-axis inspection arms:** Used in aerospace or automotive manufacturing to inspect internal cavities or large machined parts right on the shop floor.



Fowler Trimos A3 portable measuring arm, 70 in./1,800 mm

- Certified according to the ISO 10360-2 standard
- Arms are configured with six or seven axes



3. Manual profile projectors and optical comparators

These machines project a magnified silhouette of a part onto a screen to measure dimensions against a master template.

- **Multi-axis measuring stages:** Although the light source is electronic, the stage holding the part is moved manually via micrometer heads or handwheels across two axes (x and y) to calculate dimensions, meeting the ECCN 2B996 “two or more axes” criterion.



Nikon V-12B optical profile projector

- Precise measurement of a feature's x-,y-coordinates
- An image of the sample is displayed on a 20 in. screen

4. Nonautomated video measuring systems

Also known as manual vision systems, these units use a high-resolution camera and crosshair software to inspect parts.

- **Hand-operated vision systems:** To use these systems, the operator turns physical knobs or handles to translate the stage in the x- and y-axes and focuses manually in the z-axis; the camera is used purely to capture edge points for the measurement calculation.



Nikon video measuring systems

- Advanced 2D and 3D optical measurements for diverse industrial needs
- High-resolution optics, LED illumination, crosshair software

