CATEGORY 2 – MATERIALS PROCESSING

2A Systems, Equipment and Components

N.B.: For quiet running bearings, see ML9.g.

2A001 Anti-friction bearings and bearing systems, as follows, and components therefor:

Note: 2A001 does not control balls with tolerances specified by the manufacturer in accordance with ISO 3290 as grade 5 or worse.

a. Ball bearings and solid roller bearings having all tolerances specified by the manufacturer in accordance with ISO 492 Tolerance Class 4 (or ANSI/ABMA Std 20 Tolerance Class ABEC-7 or RBEC-7, or other national equivalents), or better, and having both rings and rolling elements (ISO 5593) made from monel or beryllium;
Note: 2A001.a. does not control tapered roller bearings.

b. Other ball bearings and solid roller bearings having all tolerances specified by the manufacturer in accordance with ISO 492 Tolerance Class 2 (or ANSI/ABMA Std 20 Tolerance Class ABEC-9 or RBEC-9, or other national equivalents), or better;
Note: 2A001.b. does not control tapered roller bearings.

c. Active magnetic bearing systems using any of the following:
   1. Materials with flux densities of 2.0 T or greater and yield strengths greater than 414 MPa;
   2. All-electromagnetic 3D homopolar bias designs for actuators; or
   3. High temperature (450 K (177°C) and above) position sensors.

2A225 Crucibles made of materials resistant to liquid actinide metals, as follows:

a. Crucibles having both of the following characteristics:
   1. A volume of between 150 cm^3 and 8,000 cm^3; and
   2. Made of or coated with any of the following materials, having a purity of 98% or greater by weight:
      a. Calcium fluoride (CaF_2);
      b. Calcium zirconate (metazirconate) ($CaZrO_3$);
      c. Cerium sulphide (Ce_2S_3);
      d. Erbium oxide (erbia) (Er_2O_3);
      e. Hafnium oxide (hafnia) (HfO_2);
      f. Magnesium oxide (MgO);
      g. Nitrided niobium-titanium-tungsten alloy (approximately 50% Nb, 30% Ti, 20% W);
      h. Yttrium oxide (yttria) (Y_2O_3); or
      i. Zirconium oxide (zirconia) (ZrO_2);

b. Crucibles having both of the following characteristics:
   1. A volume of between 50 cm^3 and 2,000 cm^3; and
   2. Made of or lined with tantalum, having a purity of 99.9% or greater by weight;

c. Crucibles having all of the following characteristics:
   1. A volume of between 50 cm^3 and 2,000 cm^3;
   2. Made of or lined with tantalum, having a purity of 98% or greater by weight; and
   3. Coated with tantalum carbide, nitride, boride, or any combination thereof.

2A226 Valves having all of the following characteristics:

a. A 'nominal size' of 5 mm or greater;
b. Having a bellows seal; and
c. Wholly made of or lined with aluminium, aluminium alloy, nickel, or nickel alloy containing more than 60% nickel by weight.

Technical Note:
For valves with different inlet and outlet diameters, the 'nominal size' in 2A226 refers to the smallest diameter.

2B Test, Inspection and Production Equipment

Technical Notes:
1. *Secondary parallel contouring axes, (e.g., the w-axis on horizontal boring mills or a secondary rotary axis the centre line of which is parallel to the primary rotary axis) are not counted in the total number of contouring axes. Rotary axes need not rotate over 360°. A rotary axis can be driven by a linear device (e.g. a screw or a rack-and-pinion).*
2. *For the purposes of 2B, the number of axes which can be co-ordinated simultaneously for "contouring control" is the number of axes along or around which, during processing of the workpiece, simultaneous and interrelated motions are performed between the workpiece and a tool. This does not include any additional axes along or around which other relative movements within the machine are performed such as:*
   a. *Wheel-dressing systems in grinding machines;*
   b. *Parallel rotary axes designed for mounting of separate workpieces;*
   c. *Co-linear rotary axes designed for manipulating the same workpiece by holding it in a chuck from different ends.*
3. *Axis nomenclature shall be in accordance with International Standard ISO 841, 'Numerical Control Machines - Axis and Motion Nomenclature'.*
4. *For the purposes of 2B001 to 2B009 a "tilting spindle" is counted as a rotary axis.*

5. Stated positioning accuracy levels derived from measurements made according to ISO 230/2 (1988)[1] or national equivalents may be used for each machine tool model instead of individual machine tests. Stated positioning accuracy means the accuracy value provided to the competent authorities of the Member State in which the exporter is established as representative of the accuracy of a machine model.
Determination of Stated Values

a. Select five machines of a model to be evaluated;
b. Measure the linear axis accuracies according to ISO 230/2 (1988)[2];
c. Determine the A-values for each axis of each machine. The method of calculating the A-value is described in the ISO standard;
d. Determine the mean value of the A-value of each axis. This mean value Â becomes the stated value of each axis for the model (Âx Ây...);
e. Since the Category 2 list refers to each linear axis there will be as many stated values as there are linear axes;
f. If any axis of a machine model not controlled by 2B001.a. to 2B001.c. or 2B201 has a stated accuracy Â of 6 microns for grinding machines and 8 microns for milling and turning machines or better, the manufacturer should be required to reaffirm the accuracy level once every eighteen months.

2B001 Machine tools and any combination thereof, for removing (or cutting) metals, ceramics or "composites", which, according to the manufacturer's technical specification, can be equipped with electronic devices for "numerical control", and specially designed components as follows:

N.B.: SEE ALSO 2B201.

Note 1: 2B001 does not control special purpose machine tools limited to the manufacture of gears. For such machines see 2B003.

Note 2: 2B001 does not control special purpose machine tools limited to the manufacture of any of the following parts:
a. Crankshafts or cam shafts;
b. Tools or cutters;
c. Extruder worms;
d. Engraved or facetted jewellery parts.

Note 3: A machine tool having at least two of the three turning, milling or grinding capabilities (e.g. a turning machine with milling capability), must be evaluated against each applicable entry 2B001.a., b. or c.

a. Machine tools for turning, having all of the following characteristics:
1. Positioning accuracy with "all compensations available" equal to or less (better) than 6 µm according to ISO 230/2 (1988)[3] or national equivalents along any linear axis; and

[1] Manufacturers calculating positioning accuracy in accordance with ISO 230/2 (1997) should consult the competent authorities of the Member State in which they are established.

[2] Manufacturers calculating positioning accuracy in accordance with ISO 230/2 (1997) should consult the competent authorities of the Member State in which they are established

2. Two or more axes which can be coordinated simultaneously for "contouring control";

Note: *2B001.a. does not control turning machines specially designed for the production of contact lenses, having all of the following characteristics:*

1. Machine controller limited to using ophthalmic based software for part programming data input; and

2. No vacuum chucking.

b. Machine tools for milling, having any of the following characteristics:

1. Having all of the following:
   a. Positioning accuracy with "all compensations available" equal to or less (better) than 6 µm according to ISO 230/2 (1988)[4] or national equivalents along any linear axis; and
   b. Three linear axes plus one rotary axis which can be coordinated simultaneously for "contouring control";
2. Five or more axes which can be coordinated simultaneously for "contouring control";
3. A positioning accuracy for jig boring machines, with "all compensations available", equal to or less (better) than 4 µm according to ISO 230/2 (1988)[5] or national equivalents along any linear axis; or
4. Fly cutting machines, having all of the following characteristics:
   a. Spindle "run-out" and "camming" less (better) than 0.0004 mm TIR; and
   b. Angular deviation of slide movement (yaw, pitch and roll) less (better) than 2 seconds of arc, TIR over 300 mm of travel.

c. Machine tools for grinding, having any of the following characteristics:

1. Having all of the following:
   a. Positioning accuracy with "all compensations available" equal to or less (better) than 4 µm according to ISO 230/2 (1988)[6] or national equivalents along any linear axis; and
   b. Three or more axes which can be coordinated simultaneously for "contouring control"; or
2. Five or more axes which can be coordinated simultaneously for "contouring control";

Note: *2B001.c. does not control grinding machines, as follows:*

1. Cylindrical external, internal, and external-internal grinding machines having all the following characteristics:

a. Limited to cylindrical grinding; and

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3 Manufacturers calculating positioning accuracy in accordance with ISO 230/2 (1997) should consult the competent authorities of the Member State in which they are established

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b. Limited to a maximum workpiece capacity of 150 mm outside diameter or length.

2. Machines designed specifically as jig grinders that do not have a z-axis or a w-axis, with a positioning accuracy with "all compensations available" less (better) than 4 µm according to ISO 230/2 (1988)[7] or national equivalents.

3. Surface grinders.

d. Electrical discharge machines (EDM) of the non-wire type which have two or more rotary axes which can be coordinated simultaneously for "contouring control";

e. Machine tools for removing metals, ceramics or "composites" having all of the following characteristics:
   1. Removing material by means of any of the following:
      a. Water or other liquid jets, including those employing abrasive additives;
      b. Electron beam; or
      c. "Laser" beam; and
   2. Having two or more rotary axes which:
      a. Can be coordinated simultaneously for "contouring control"; and
      b. Have a positioning accuracy of less (better) than 0.003°;

f. Deep-hole-drilling machines and turning machines modified for deep-hole-drilling, having a maximum depth-of-bore capability exceeding 5,000 mm and specially designed components therefor.

2B002 Numerically controlled optical finishing machine tools equipped to produce non-spherical optical surfaces, having all of the following characteristics:
a. Finishing the form to less (better) than 1.0 µm;
b. Finishing to a roughness less (better) than 100 nm rms.
c. Three or more axes which can be coordinated simultaneously for "contouring control"; and
d. Using any of the following processes:
   1. Magnetorheological finishing ('MRF');
   2. Electrorheological finishing ('ERF'); or
   3. Energetic particle beam finishing.

Technical Note:
For the purposes of 2B002, 'MRF' is a material removal process using an abrasive magnetic fluid whose viscosity is controlled by a magnetic field. 'ERF' is a removal process using an abrasive fluid whose viscosity is controlled by an electric field. 'Energetic particle beam finishing' uses Reactive Atom Plasmas (RAP) or ion-beams to selectively remove material.

[7] Manufacturers calculating positioning accuracy in accordance with ISO 230/2 (1997) should consult the competent authorities of the Member State in which they are established

2B003 "Numerically controlled" or manual machine tools, and specially designed components, controls and accessories therefor, specially designed for the shaving, finishing, grinding or honing of hardened (R_C = 40 or more) spur, helical and double-helical gears with a pitch diameter exceeding 1,250 mm and a face width of 15% of pitch diameter or larger finished to a quality of AGMA 14 or better (equivalent to ISO 1328 class 3).

2B004 Hot "isostatic presses", having all of the following, and specially designed components and accessories therefor:

N.B.: SEE ALSO 2B104 AND 2B204.

a. A controlled thermal environment within the closed cavity and a chamber cavity with an inside diameter of 406 mm or more; and
b. Any of the following:
   1. A maximum working pressure exceeding 207 MPa;
   2. A controlled thermal environment exceeding 1,773 K (1,500°C); or
   3. A facility for hydrocarbon impregnation and removal of resultant gaseous degradation products.

Technical Note:
The inside chamber dimension is that of the chamber in which both the working temperature and the working pressure are achieved and does not include fixtures. That dimension will be the smaller of either the inside diameter of the pressure chamber or the inside diameter of the insulated furnace chamber, depending on which of the two chambers is located inside the other.
N.B.: For specially designed dies, moulds and tooling see 1b003, 9b009 and ML18.

2B005 Equipment specially designed for the deposition, processing and in-process control of inorganic overlays, coatings and surface modifications, as follows, for non-electronic substrates, by processes shown in the Table and associated Notes following 2E003.f., and specially designed automated handling, positioning, manipulation and control components therefor:

a. Chemical vapour deposition (CVD) production equipment having all of the following:
   N.B.: SEE ALSO 2B105.
   1. Process modified for one of the following:
      a. Pulsating CVD;
      b. Controlled nucleation thermal deposition (CNTD); or
      c. Plasma enhanced or plasma assisted CVD; and
   2. Any of the following:
      a. Incorporating high vacuum (equal to or less than 0.01 Pa) rotating seals; or
      b. Incorporating *in situ* coating thickness control;

b. Ion implantation production equipment having beam currents of 5 mA or more;

c. Electron beam physical vapour deposition (EB-PVD) production equipment incorporating power systems rated for over 80 kW, having any of the following:
   1. A liquid pool level "laser" control system which regulates precisely the ingots feed rate; or
   2. A computer controlled rate monitor operating on the principle of photo-luminescence of the ionised atoms in the evaporant stream to control the deposition rate of a coating containing two or more elements;

d. Plasma spraying production equipment having any of the following characteristics:
   1. Operating at reduced pressure controlled atmosphere (equal to or less than 10 kPa measured above and within 300 mm of the gun nozzle exit) in a vacuum chamber capable of evacuation down to 0.01 Pa prior to the spraying process; or
   2. Incorporating *in situ* coating thickness control;

e. Sputter deposition production equipment capable of current densities of 0.1 mA/mm^2 or higher at a deposition rate of 15 µm/h or more;

f. Cathodic arc deposition production equipment incorporating a grid of electromagnets for steering control of the arc spot on the cathode;

g. Ion plating production equipment allowing for the *in situ* measurement of any of the following:
   1. Coating thickness on the substrate and rate control; or
   2. Optical characteristics.

Note: *2B005 does not control chemical vapour deposition, cathodic arc, sputter deposition, ion plating or ion implantation equipment specially designed for cutting or machining tools.*

2B006 Dimensional inspection or measuring systems, equipment and "electronic assemblies", as follows:

a. Computer controlled or "numerically controlled" co-ordinate measuring machines (CMM), having a three dimensional (volumetric) maximum permissible error of indication (MPE_E) 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) µm (L is the measured length in mm) tested according to ISO 10360-2 (2001);

N.B.: SEE ALSO 2B206.

b. Linear and angular displacement measuring instruments, as follows:

   1. Linear displacement measuring instruments having any of the following:

Technical Note:
For the purpose of 2B006.b.1. 'linear displacement' means the change of distance between the measuring probe and the measured object.

a. Non-contact type measuring systems with a "resolution" equal to or less (better) than 0.2 µm within a measuring range up to 0.2 mm;

b. Linear voltage differential transformer systems having all of the following characteristics:
   1. "Linearity" equal to or less (better) than 0.1% within a measuring range up to 5 mm; and
   2. Drift equal to or less (better) than 0.1% per day at a standard ambient test room temperature ±1 K;

c. Measuring systems having all of the following:
   1. Containing a "laser"; and
   2. Maintaining, for at least 12 hours, over a temperature range of ±1 K around a standard temperature and at a standard pressure, all of the following:
      a. A "resolution" over their full scale of 0.1 µm or less (better); and
      b. A "measurement uncertainty" equal to or less (better) than (0.2 + L/2,000) µm (L is the measured length in mm); or

d. "Electronic assemblies" specially designed to provide feedback capability in systems specified in 2B006.b.1.c.;

Note: *2B006.b.1. does not control measuring interferometer systems, with an automatic control system that is designed to use no feedback techniques, containing a "laser" to measure slide movement errors of machine-tools, dimensional inspection machines or similar equipment.*

2. Angular displacement measuring instruments having an "angular position deviation" equal to or less (better) than 0.00025°;
   Note: *2B006.b.2. does not control optical instruments, such as autocollimators, using collimated light (e.g. laser light) to detect angular displacement of a mirror.*

c. Equipment for measuring surface irregularities, by measuring optical scatter as a function of angle, with a sensitivity of 0.5 nm or less (better).

Note: *Machine tools which can be used as measuring machines are controlled if they meet or exceed the criteria specified for the machine tool function or the measuring machine function.*

2B007 "Robots" having any of the following characteristics and specially designed controllers and "end-effectors" therefor:
N.B.: SEE ALSO 2B207.

a. Capable in real time of full three-dimensional image processing or full three-dimensional 'scene analysis' to generate or modify "programs" or to generate or modify numerical program data;
Technical Note:
The 'scene analysis' limitation does not include approximation of the third dimension by viewing at a given angle, or limited grey scale interpretation for the perception of depth or texture for the approved tasks (2 1/2 D).

b. Specially designed to comply with national safety standards applicable to explosive munitions environments;

c. Specially designed or rated as radiation-hardened to withstand a total radiation dose greater than 5×10^3 Gy (silicon) without operational degradation; or
Technical Note:
The term Gy (silicon) refers to the energy in Joules per kilogram absorbed by an unshielded silicon sample when exposed to ionising radiation.

d. Specially designed to operate at altitudes exceeding 30,000 m.

2B008 Assemblies or units, specially designed for machine tools, or dimensional inspection or measuring systems and equipment, as follows:

a. Linear position feedback units (e.g., inductive type devices, graduated scales, infrared systems or "laser" systems) having an overall "accuracy" less (better) than $(800 + (600 \times L \times 10^{-3}))$ nm (L equals the effective length in mm);
N.B.: For "laser" systems see also Note to 2B006.b.1.

b. Rotary position feedback units (e.g., inductive type devices, graduated scales, infrared systems or "laser" systems) having an "accuracy" less (better) than 0.00025°;
N.B.: For "laser" systems see also Note to 2B006.b.1.

c. "Compound rotary tables" and "tilting spindles", capable of upgrading, according to the manufacturer's specifications, machine tools to or above the levels specified in 2B.

2B009 Spin-forming machines and flow-forming machines, which, according to the manufacturer's technical specification, can be equipped with "numerical control" units or a computer control and having all of the following:
N.B.: SEE ALSO 2B109 AND 2B209.

a. Two or more controlled axes of which at least two can be coordinated simultaneously for "contouring control"; and

b. A roller force more than 60 kN.

Technical Note:
Machines combining the function of spin-forming and flow-forming are for the purpose of 2B009 regarded as flow-forming machines.

2B104 "Isostatic presses", not controlled in 2B004, having all of the following:
N.B.: SEE ALSO 2B204.

a. Maximum working pressure of 69 MPa or greater;
b. Designed to achieve and maintain a controlled thermal environment of 873 K (600°C) or greater; and
c. Possessing a chamber cavity with an inside diameter of 254 mm or greater.

2B105 Chemical vapour deposition (CVD) furnaces, not controlled in 2B005.a., designed or modified for the densification of carbon-carbon composites.

2B109 Flow-forming machines, not controlled in 2B009, and specially designed components as follows:
N.B.: SEE ALSO 2B209.

a. Flow-forming machines having all of the following:
   1. According to the manufacturer's technical specification, can be equipped with "numerical control" units or a computer control, even when not equipped with such units; and
   2. With more than two axes which can be coordinated simultaneously for "contouring control".
b. Specially designed components for flow-forming machines specified in 2B009 or 2B109.a.

Note: *2B109 does not control machines that are not usable in the production of propulsion components and equipment (e.g. motor cases) for systems specified in 9A005, 9A007.a. or 9A105.a.*

Technical Note:
Machines combining the function of spin-forming and flow-forming are for the purpose of 2B109 regarded as flow-forming machines.

2B116 Vibration test systems, equipment and components therefor, as follows:

a. Vibration test systems employing feedback or closed loop techniques and incorporating a digital controller, capable of vibrating a system at an acceleration equal to or greater than 10 g rms between 20 Hz and 2 kHz and imparting forces equal to or greater than 50 kN, measured 'bare table';

2B116 continued

b. Digital controllers, combined with specially designed vibration test software, with a "real-time bandwidth" greater than 5 kHz designed for use with vibration test systems specified in 2B116.a.;

c. Vibration thrusters (shaker units), with or without associated amplifiers, capable of imparting a force equal to or greater than 50 kN, measured 'bare table', and usable in vibration test systems specified in 2B116.a.;

d. Test piece support structures and electronic units designed to combine multiple shaker units in a system capable of providing an effective combined force of 50 kN, measured 'bare table', or greater, and usable in vibration systems specified in 2B116.a.

Technical Note:
In 2B116, 'bare table' means a flat table, or surface, with no fixture or fittings.

2B117 Equipment and process controls, not controlled in 2B004, 2B005.a., 2B104 or 2B105, designed or modified for densification and pyrolysis of structural composite rocket nozzles and reentry vehicle nose tips.

2B119 Balancing machines and related equipment, as follows:
N.B.: SEE ALSO 2B219.

a. Balancing machines having all the following characteristics:
   1. Not capable of balancing rotors/assemblies having a mass greater than 3 kg;
   2. Capable of balancing rotors/assemblies at speeds greater than 12,500 rpm;
   3. Capable of correcting unbalance in two planes or more; and
   4. Capable of balancing to a residual specific unbalance of 0.2 g mm per kg of rotor mass;

   Note: *2B119.a. does not control balancing machines designed or modified for dental or other medical equipment.*

b. Indicator heads designed or modified for use with machines specified in 2B119.a.
   Technical Note:
   Indicator heads are sometimes known as balancing instrumentation.

2B120 Motion simulators or rate tables having all of the following characteristics:

a. Two axes or more;

b. Slip rings capable of transmitting electrical power and/or signal information; and

c. Having any of the following characteristics:
   1. For any single axis having all of the following:
      a. Capable of rates of 400 degrees/s or more, or 30 degrees/s or less; and
      b. A rate resolution equal to or less than 6 degrees/s and an accuracy equal to or less than 0.6 degrees/s;
   2. Having a worst-case rate stability equal to or better (less) than plus or minus 0.05 % averaged over 10 degrees or more; or
   3. A positioning accuracy equal to or better than 5 arc second.

Note: *2B120 does not control rotary tables designed or modified for machine tools or for medical equipment. For controls on machine tool rotary tables see 2B008.*

2B121 Positioning tables (equipment capable of precise rotary positioning in any axes), not controlled in 2B120, having all the following characteristics:

a. Two axes or more; and
b. A positioning accuracy equal to or better than 5 arc second.

Note: *2B121 does not control rotary tables designed or modified for machine tools or for medical equipment. For controls on machine tool rotary tables see 2B008.*

2B122 Centrifuges capable of imparting accelerations above 100 g and having slip rings capable of transmitting electrical power and signal information.

2B201 Machine tools and any combination thereof, not controlled in 2B001, as follows, for removing or cutting metals, ceramics or "composites", which, according to the manufacturer's technical specification, can be equipped with electronic devices for simultaneous "contouring control" in two or more axes:

a. Machine tools for milling, having any of the following characteristics:
   1. Positioning accuracies with "all compensations available" equal to or less (better) than 6 µm according to ISO 230/2 (1988)[8] or national equivalents along any linear axis; or
   2. Two or more contouring rotary axes;

   Note: *2B201.a. does not control milling machines having the following characteristics:*
      a. X-axis travel greater than 2 m; and
      b. Overall positioning accuracy on the x-axis more (worse) than 30 µm.

[8] Manufacturers calculating positioning accuracy in accordance with ISO 230/2 (1997) should consult the competent authorities of the Member State in which they are established

b. Machine tools for grinding, having any of the following characteristics:
   1. Positioning accuracies with "all compensations available" equal to or less (better) than 4 µm according to ISO 230/2 (1988)[9] or national equivalents along any linear axis; or
   2. Two or more contouring rotary axes.

   Note: 2B201.b. does not control the following grinding machines:
   - *a. Cylindrical external, internal, and external-internal grinding machines having all of the following characteristics:*
     - *1. Limited to a maximum workpiece capacity of 150 mm or length; and*
     - *2. Axes limited to x, z and c;*
   - *b. Jig grinders that do not have a z-axis or a w-axis with an overall positioning accuracy less (better) than 4 µm according to ISO 230/2 (1988)[10] or national equivalents.*

Note 1: 2B201 does not control special purpose machine tools limited to the manufacture of any of the following parts:
- *a. Gears;*
- *b. Crankshafts or camshafts;*
- *c. Tools or cutters;*
- *d. Extruder worms.*

Note 2: A machine tool having at least two of the three turning, milling or grinding capabilities (e.g., a turning machine with milling capability), must be evaluated against each applicable entry 2B001.a. or 2B201.a. or b.

2B204 "Isostatic presses", not controlled in 2B004 or 2B104, and related equipment, as follows:

a. "Isostatic presses" having both of the following characteristics:
   1. Capable of achieving a maximum working pressure of 69 MPa or greater; and
   2. A chamber cavity with an inside diameter in excess of 152 mm;

b. Dies, moulds and controls, specially designed for "isostatic presses" specified in 2B204.a.

[9] Manufacturers calculating positioning accuracy in accordance with ISO 230/2 (1997) should consult the competent authorities of the Member State in which they are established

[10] Manufacturers calculating positioning accuracy in accordance with ISO 230/2 (1997) should consult the competent authorities of the Member State in which they are established

Technical Note:
In 2B204 the inside chamber dimension is that of the chamber in which both the working temperature and the working pressure are achieved and does not include fixtures. That dimension will be the smaller of either the inside diameter of the pressure chamber or the inside diameter of the insulated furnace chamber, depending on which of the two chambers is located inside the other.

2B206 Dimensional inspection machines, instruments or systems, not controlled in 2B006, as follows:

a. Computer controlled or numerically controlled dimensional inspection machines having both of the following characteristics:
   1. Two or more axes; and
   2. A one-dimensional length "measurement uncertainty" equal to or less (better) than (1.25 + L/1000) µm tested with a probe of an "accuracy" of less (better) than 0.2 µm (L is the measured length in millimetres) (Ref.: VDI/VDE 2617 Parts 1 and 2);

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

Note 1: *Machine tools that can be used as measuring machines are controlled if they meet or exceed the criteria specified for the machine tool function or the measuring machine function.*

Note 2: *A machine specified in 2B206 is controlled if it exceeds the control threshold anywhere within its operating range.*

Technical Notes:

1. The probe used in determining the measurement uncertainty of a dimensional inspection system shall be described in VDI/VDE 2617 parts 2, 3 and 4.

2. All parameters of measurement values in 2B206 represent plus/minus i.e., not total band.

2B207 "Robots", "end-effectors" and control units, not controlled in 2B007, as follows:

a. "Robots" or "end-effectors" specially designed to comply with national safety standards applicable to handling high explosives (for example, meeting electrical code ratings for high explosives);

b. Control units specially designed for any of the "robots" or "end-effectors" specified in 2B207.a.

2B209 Flow forming machines, spin forming machines capable of flow forming functions, not controlled in 2B009 or 2B109, and mandrels, as follows:

a. Machines having both of the following characteristics:
   1. Three or more rollers (active or guiding); and
   2. Which, according to the manufacturer's technical specification, can be equipped with "numerical control" units or a computer control;

b. Rotor-forming mandrels designed to form cylindrical rotors of inside diameter between 75 mm and 400 mm.

Note: *2B209.a. includes machines which have only a single roller designed to deform metal plus two auxiliary rollers which support the mandrel, but do not participate directly in the deformation process.*

2B219 Centrifugal multiplane balancing machines, fixed or portable, horizontal or vertical, as follows:

a. Centrifugal balancing machines designed for balancing flexible rotors having a length of 600 mm or more and having all of the following characteristics:
   1. Swing or journal diameter greater than 75 mm;
   2. Mass capability of from 0.9 to 23 kg ; and
   3. Capable of balancing speed of revolution greater than 5,000 r.p.m.;

b. Centrifugal balancing machines designed for balancing hollow cylindrical rotor components and having all of the following characteristics:
   1. Journal diameter greater than 75 mm;
   2. Mass capability of from 0.9 to 23 kg;
   3. Capable of balancing to a residual imbalance equal to or less than 0.01 kg x mm/kg per plane; and
   4. Belt drive type.

2B225 Remote manipulators that can be used to provide remote actions in radiochemical separation operations or hot cells, having either of the following characteristics:

a. A capability of penetrating 0.6 m or more of hot cell wall (through-the-wall operation); or

b. A capability of bridging over the top of a hot cell wall with a thickness of 0.6 m or more (over-the-wall operation).

Technical Note:
Remote manipulators provide translation of human operator actions to a remote operating arm and terminal fixture. They may be of 'master/slave' type or operated by joystick or keypad.

2B226 Controlled atmosphere (vacuum or inert gas) induction furnaces, and power supplies therefor, as follows:
N.B: SEE ALSO 3B.

a. Furnaces having all of the following characteristics:
   1. Capable of operation above 1,123 K (850°C);
   2. Induction coils 600 mm or less in diameter; and
   3. Designed for power inputs of 5 kW or more;

b. Power supplies, with a specified power output of 5 kW or more, specially designed for furnaces specified in 2B226.a.

Note: *2B226.a. does not control furnaces designed for the processing of semiconductor wafers.*

2B227 Vacuum or other controlled atmosphere metallurgical melting and casting furnaces and related equipment as follows:

a. Arc remelt and casting furnaces having both of the following characteristics:
   1. Consumable electrode capacities between 1,000 cm^3 and 20,000 cm^3, and
   2. Capable of operating with melting temperatures above 1,973 K (1,700°C);

b. Electron beam melting furnaces and plasma atomization and melting furnaces, having both of the following characteristics:
   1. A power of 50 kW or greater; and
   2. Capable of operating with melting temperatures above 1,473 K (1,200°C).

c. Computer control and monitoring systems specially configured for any of the furnaces specified in 2B227.a. or b.

2B228 Rotor fabrication or assembly equipment, rotor straightening equipment, bellows-forming mandrels and dies, as follows:

a. Rotor assembly equipment for assembly of gas centrifuge rotor tube sections, baffles, and end caps;
Note: 2B228.a. includes precision mandrels, clamps, and shrink fit machines.

b. Rotor straightening equipment for alignment of gas centrifuge rotor tube sections to a common axis;
Technical Note:
In 2B228.b. such equipment normally consists of precision measuring probes linked to a computer that subsequently controls the action of, for example, pneumatic rams used for aligning the rotor tube sections.

c. Bellows-forming mandrels and dies for producing single-convolution bellows.
Technical Note:
In 2B228.c. the bellows have all of the following characteristics:
1. Inside diameter between 75 mm and 400 mm;
2. Length equal to or greater than 12.7 mm;
3. Single convolution depth greater than 2 mm; and
4. Made of high-strength aluminium alloys, maraging steel or high strength "fibrous or filamentary materials".

2B230 "Pressure transducers" capable of measuring absolute pressures at any point in the range 0 to 13 kPa and having both of the following characteristics:

a. Pressure sensing elements made of or protected by aluminium, aluminium alloy, nickel or nickel alloy with more than 60% nickel by weight; and

b. Having either of the following characteristics:
1. A full scale of less than 13 kPa and an 'accuracy' of better than ± 1% of full-scale; or
2. A full scale of 13 kPa or greater and an 'accuracy' of better than ± 130 Pa.

Technical Note:
For the purposes of 2B230, 'accuracy' includes non-linearity, hysteresis and repeatability at ambient temperature.

2B231 Vacuum pumps having all of the following characteristics:

a. Input throat size equal to or greater than 380 mm;
b. Pumping speed equal to or greater than 15 m^3/s; and
c. Capable of producing an ultimate vacuum better than 13 mPa.

Technical Notes:

1. *The pumping speed is determined at the measurement point with nitrogen gas or air.*
2. *The ultimate vacuum is determined at the input of the pump with the input of the pump blocked off.*

2B232 Multistage light gas guns or other high-velocity gun systems (coil, electromagnetic, and electrothermal types, and other advanced systems) capable of accelerating projectiles to 2 km/s or greater.

2B350 Chemical manufacturing facilities, equipment and components, as follows:

a. Reaction vessels or reactors, with or without agitators, with total internal (geometric) volume greater than 0.1 m^3 (100 litres) and less than 20 m^3 (20,000 litres), where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:
   1. Alloys with more than 25% nickel and 20% chromium by weight;
   2. Fluoropolymers;
   3. Glass (including vitrified or enamelled coating or glass lining);
   4. Nickel or alloys with more than 40% nickel by weight;
   5. Tantalum or tantalum alloys;
   5. Titanium or titanium alloys;
   6. Zirconium or zirconium alloys; or
   7. Niobium (columbium) or niobium alloys;

b. Agitators for use in reaction vessels or reactors specified in 2B350.a.; and impellers, blades or shafts designed for such agitators, where all surfaces of the agitator that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:
   1. Alloys with more than 25% nickel and 20% chromium by weight;
   2. Fluoropolymers;
   3. Glass (including vitrified or enamelled coatings or glass lining);
   4. Nickel or alloys with more than 40% nickel by weight;
   5. Tantalum or tantalum alloys;
   6. Titanium or titanium alloys;
   7. Zirconium or zirconium alloys; or
   8. Niobium (columbium) or niobium alloys;

c. Storage tanks, containers or receivers with a total internal (geometric) volume greater than 0.1 m^3 (100 litres) where all surfaces that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:
   1. Alloys with more than 25% nickel and 20% chromium by weight;
   2. Fluoropolymers;
   3. Glass (including vitrified or enamelled coatings or glass lining);
   4. Nickel or alloys with more than 40% nickel by weight;
   5. Tantalum or tantalum alloys;

6. Titanium or titanium alloys;
7. Zirconium or zirconium alloys; or
8. Niobium (columbium) or niobium alloys;

d. Heat exchangers or condensers with a heat transfer surface area greater than 0.15 m^2, and less than 20 m^2; and tubes, plates, coils or blocks (cores) designed for such heat exchangers or condensers, where all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
   1. Alloys with more than 25% nickel and 20% chromium by weight;
   2. Fluoropolymers;
   3. Glass (including vitrified or enamelled coatings or glass lining);
   4. Graphite or 'carbon graphite';
   5. Nickel or alloys with more than 40% nickel by weight;
   6. Tantalum or tantalum alloys;
   7. Titanium or titanium alloys;
   8. Zirconium or zirconium alloys;
   9. Silicon carbide;
   10. Titanium carbide; or
   11. Niobium (columbium) or niobium alloys;

e. Distillation or absorption columns of internal diameter greater than 0.1 m; and liquid distributors, vapour distributors or liquid collectors designed for such distillation or absorption columns, where all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
   1. Alloys with more than 25% nickel and 20% chromium by weight;
   2. Fluoropolymers;
   3. Glass (including vitrified or enamelled coatings or glass lining);
   4. Graphite or 'carbon graphite';
   5. Nickel or alloys with more than 40% nickel by weight;
   6. Tantalum or tantalum alloys;
   7. Titanium or titanium alloys;
   8. Zirconium or zirconium alloys; or
   9. Niobium (columbium) or niobium alloys;

f. Remotely operated filling equipment in which all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
   1. Alloys with more than 25% nickel and 20% chromium by weight; or
   2. Nickel or alloys with more than 40% nickel by weight;

g. Valves with nominal sizes greater than 10 mm and casings (valve bodies) or preformed casing liners designed for such valves, in which all surfaces that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:
   1. Alloys with more than 25% nickel and 20% chromium by weight;
   2. Fluoropolymers;
   3. Glass (including vitrified or enamelled coatings or glass lining);

4. Nickel or alloys with more than 40% nickel by weight;
5. Tantalum or tantalum alloys;
6. Titanium or titanium alloys;
7. Zirconium or zirconium alloys; or
8. Niobium (columbium) or niobium alloys;

h. Multi-walled piping incorporating a leak detection port, in which all surfaces that come in direct contact with the chemical(s) being processed or contained are made from any of the following materials:
1. Alloys with more than 25% nickel and 20% chromium by weight;
2. Fluoropolymers;
3. Glass (including vitrified or enamelled coatings or glass lining);
4. Graphite or 'carbon graphite';
5. Nickel or alloys with more than 40% nickel by weight;
6. Tantalum or tantalum alloys;
7. Titanium or titanium alloys;
8. Zirconium or zirconium alloys; or
9. Niobium (columbium) or niobium alloys;

i. Multiple-seal and seal-less pumps, with manufacturer's specified maximum flow-rate greater than 0.6 m^3/hour, or vacuum pumps with manufacturer's specified maximum flow-rate greater than 5 m^3/hour (under standard temperature (273 K (0^oC)) and pressure (101.3 kPa) conditions); and casings (pump bodies), preformed casing liners, impellers, rotors or jet pump nozzles designed for such pumps, in which all surfaces that come in direct contact with the chemical(s) being processed are made from any of the following materials:
1. Alloys with more than 25% nickel and 20% chromium by weight;
2. Ceramics;
3. Ferrosilicon;
4. Fluoropolymers;
5. Glass (including vitrified or enamelled coatings or glass lining);
6. Graphite or 'carbon graphite';
7. Nickel or alloys with more than 40% nickel by weight;
8. Tantalum or tantalum alloys;
9. Titanium or titanium alloys;
10. Zirconium or zirconium alloys; or
11. Niobium (columbium) or niobium alloys;

j. Incinerators designed to destroy chemicals specified in entry 1C350, having specially designed waste supply systems, special handling facilities and an average combustion chamber temperature greater than 1,273 K (1,000^oC), in which all surfaces in the waste supply system that come into direct contact with the waste products are made from or lined with any of the following materials:
1. Alloys with more than 25% nickel and 20% chromium by weight;
2. Ceramics; or
3. Nickel or alloys with more than 40% nickel by weight.

Technical Note:
'Carbon graphite' is a composition consisting of amorphous carbon and graphite, in which the graphite content is eight percent or more by weight.

2B351 Toxic gas monitoring systems, as follows; and dedicated detectors therefor:

a. Designed for continuous operation and usable for the detection of chemical warfare agents or chemicals specified in 1C350, at concentrations of less than 0.3 mg/m^3; or

b. Designed for the detection of cholinesterase-inhibiting activity.

2B352 Equipment capable of use in handling biological materials, as follows:

a. Complete biological containment facilities at P3 or P4 containment level;
Technical Note:
Complete containment facilities that meet the criteria for P3 or P4 (BL3, BL4, L3, L4) containment as specified in the WHO Laboratory Biosafety manual (2nd edition, Geneva 1993).

b. Fermenters capable of cultivation of pathogenic "microorganisms", viruses or capable of toxin production, without the propagation of aerosols, and having a total capacity of 20 litres or more;
Technical Note:
Fermenters include bioreactors, chemostats and continuous-flow systems.

c. Centrifugal separators, capable of continuous separation without the propagation of aerosols, having all the following characteristics:
1. Flow rate exceeding 100 litres per hour;
2. Components of polished stainless steel or titanium;
3. One or more sealing joints within the steam containment area; and
4. Capable of in-situ steam sterilisation in a closed state;
Technical Note:
Centrifugal separators include decanters.

d. Cross (tangential) flow filtration equipment and components as follows:
1. Cross (tangential) flow filtration equipment capable of separation of pathogenic micro-organisms, viruses, toxins or cell cultures, without the propagation of aerosols, having both of the following characteristics:
a. A total filtration area equal to or greater than1 m^2; and
b. Capable of being sterilised or disinfected in-situ;
Technical Note:
In 2B352.d.1.b. sterilised denotes the elimination of all viable microbes from the equipment through the use of either physical (e.g. steam) or chemical agents. Disinfected denotes the destruction of potential microbial infectivity in the equipment through the use of chemical agents with a germicidal effect. Disinfection and sterilisation are distinct from sanitisation, the

latter referring to cleaning procedures designed to lower the microbial content of equipment without necessarily achieving elimination of all microbial infectivity or viability.

2. Cross (tangential) flow filtration components (e.g. modules, elements, cassettes, cartridges, units or plates) with filtration area equal to or greater than 0.2 m^2 for each component and designed for use in cross (tangential) flow filtration equipment specified in 2B352.d.;

Note: *2B352.d. does not control reverse osmosis equipment, as specified by the manufacturer.*

e. Steam sterilisable freeze drying equipment with a condenser capacity exceeding 10 kg of ice in 24 hours and less than 1,000 kg of ice in 24 hours;

f. Protective and containment equipment, as follows:
   1. Protective full or half suits, or hoods dependent upon a tethered external air supply and operating under positive pressure;
      Note: *2B352.f.1. does not control suits designed to be worn with self-contained breathing apparatus.*
   2. Class III biological safety cabinets or isolators with similar performance standards;
      Note: *In 2B352.f.2., isolators include flexible isolators, dry boxes, anaerobic chambers, glove boxes and laminar flow hoods (closed with vertical flow).*

g. Chambers designed for aerosol challenge testing with "microorganisms", viruses or "toxins" and having a capacity of 1 m^3 or greater.

2C Materials

None.

2D Software

2D001 "Software", other than that specified in 2D002, specially designed or modified for the "development", "production" or "use" of equipment specified in 2A001 or 2B001 to 2B009.

2D002 "Software" for electronic devices, even when residing in an electronic device or system**,** enabling such devices or systems to function as a "numerical control" unit, capable of co-ordinating simultaneously more than four axes for "contouring control".

Note 1: *2D002 does not control "software" specially designed or modified for the operation of machine tools not controlled by Category 2.*

Note 2: *2D002 does not control "software" for items controlled by 2B002. See 2D001 for control of "software" for items controlled by 2B002.*

2D101 "Software" specially designed or modified for the "use" of equipment specified in 2B104, 2B105, 2B109, 2B116, 2B117 or 2B119 to 2B122.
N.B.: SEE ALSO 9D004.

2D201 "Software" specially designed for the "use" of equipment specified in 2B204, 2B206, 2B207, 2B209, 2B219 or 2B227.

2D202 "Software" specially designed or modified for the "development", "production" or "use" of equipment specified in 2B201.

2E Technology

2E001 "Technology" according to the General Technology Note for the "development" of equipment or "software" specified in 2A, 2B or 2D.

2E002 "Technology" according to the General Technology Note for the "production" of equipment specified in 2A or 2B.

2E003 Other "technology", as follows:

a. "Technology" for the "development" of interactive graphics as an integrated part in "numerical control" units for preparation or modification of part programs;

b. "Technology" for metal-working manufacturing processes, as follows:

1. "Technology" for the design of tools, dies or fixtures specially designed for any of the following processes:
   a. "Superplastic forming";
   b. "Diffusion bonding"; or
   c. "Direct-acting hydraulic pressing";

2. Technical data consisting of process methods or parameters as listed below used to control:

   a. "Superplastic forming" of aluminium alloys, titanium alloys or "superalloys":
      1. Surface preparation;
      2. Strain rate;
      3. Temperature;
      4. Pressure;

2E003 b. continued

b. "Diffusion bonding" of "superalloys" or titanium alloys:
   1. Surface preparation;
   2. Temperature;
   3. Pressure;

c. "Direct-acting hydraulic pressing" of aluminium alloys or titanium alloys:
   1. Pressure;
   2. Cycle time;

d. "Hot isostatic densification" of titanium alloys, aluminium alloys or "superalloys":
   1. Temperature;
   2. Pressure;
   3. Cycle time;

c. "Technology" for the "development" or "production" of hydraulic stretch-forming machines and dies therefor, for the manufacture of airframe structures;

d. "Technology" for the "development" of generators of machine tool instructions (e.g., part programs) from design data residing inside "numerical control" units;

e. "Technology" for the "development" of integration "software" for incorporation of expert systems for advanced decision support of shop floor operations into "numerical control" units;

f. "Technology" for the application of inorganic overlay coatings or inorganic surface modification coatings (specified in column 3 of the following table) to non-electronic substrates (specified in column 2 of the following table), by processes specified in column 1 of the following table and defined in the Technical Note.
   Note: *The table and Technical Note appear after entry 2E301.*

2E101 "Technology" according to the General Technology Note for the "use" of equipment or "software" specified in 2B004, 2B009, 2B104, 2B109, 2B116, 2B119 to 2B122 or 2D101.

2E201 "Technology" according to the General Technology Note for the "use" of equipment or "software" specified in 2A225, 2A226, 2B001, 2B006, 2B007.b., 2B007.c., 2B008, 2B009, 2B201, 2B204, 2B206, 2B207, 2B209, 2B225 to 2B232, 2D201 or 2D202.

2E301 "Technology" according to the General Technology Note for the "use" of goods specified in 2B350 to 2B352.

TABLE - DEPOSITION TECHNIQUES

1. Coating Process (1)*	2. Substrate	3. Resultant Coating
A. Chemical Vapour Deposition (CVD)	"Superalloys"	Aluminides for internal passages
	Ceramics (19) and Low-expansion glasses (14)	Silicides Carbides Dielectric layers (15) Diamond Diamond-like carbon (17)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Refractory metals Mixtures thereof (4) Dielectric layers (15) Aluminides Alloyed aluminides (2) Boron nitride
	Cemented tungsten carbide (16), Silicon carbide (18)	Carbides Tungsten Mixtures thereof (4) Dielectric layers (15)
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15) Diamond Diamond-like carbon (17)
	Sensor window materials (9)	Dielectric layers (15) Diamond Diamond-like carbon (17)

* The numbers in parenthesis refer to the Notes following this Table.

TABLE - DEPOSITION TECHNIQUES

1. Coating Process (1)	2. Substrate	3. Resultant Coating
B. Thermal-Evaporation Physical Vapour Deposition (TE-PVD)		
B.1. Physical Vapour Deposition (PVD): Electron-Beam (EB-PVD)	"Superalloys"	Alloyed silicides Alloyed aluminides (2) MCrAlX (5) Modified zirconia (12) Silicides Aluminides Mixtures thereof (4)
	Ceramics (19) and Low-expansion glasses (14)	Dielectric layers (15)
	Corrosion resistant steel (7)	MCrAlX (5) Modified zirconia (12) Mixtures thereof (4)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Refractory metals Mixtures thereof (4) Dielectric layers (15) Boron nitride
	Cemented tungsten carbide (16), Silicon carbide (18)	Carbides Tungsten Mixtures thereof (4) Dielectric layers (15)
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15) Borides Beryllium
	Sensor window materials (9)	Dielectric layers (15)
	Titanium alloys (13)	Borides Nitrides

TABLE - DEPOSITION TECHNIQUES

1. Coating Process (1)	2. Substrate	3. Resultant Coating
B.2. Ion assisted resistive heating Physical Vapour Deposition (PVD) (Ion Plating)	Ceramics (19) and Low-expansion glasses (14)	Dielectric layers (15) Diamond-like carbon (17)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Dielectric layers (15)
	Cemented tungsten carbide (16), Silicon carbide	Dielectric layers (15)
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15)
	Sensor window materials (9)	Dielectric layers (15) Diamond-like carbon (17)
B.3. Physical Vapour Deposition (PVD): "Laser" Vaporization	Ceramics (19) and Low-expansion glasses (14)	Silicides Dielectric layers (15) Diamond-like carbon (17)
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Dielectric layers (15)
	Cemented tungsten carbide (16), Silicon carbide	Dielectric layers (15)
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Dielectric layers (15)
	Sensor window materials (9)	Dielectric layers (15) Diamond-like carbon

TABLE - DEPOSITION TECHNIQUES

1. Coating Process (1)	2. Substrate	3. Resultant Coating
B.4. Physical Vapour Deposition (PVD): Cathodic Arc Discharge	"Superalloys"	Alloyed silicides Alloyed aluminides (2) MCrAlX (5)
	Polymers (11) and Organic "matrix" "composites"	Borides Carbides Nitrides Diamond-like carbon (17)
C. Pack cementation (see A above for out-of-pack cementation) (10)	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Mixtures thereof (4)
	Titanium alloys (13)	Silicides Aluminides Alloyed aluminides (2)
	Refractory metals and alloys (8)	Silicides Oxides
D. Plasma spraying	"Superalloys"	MCrAlX (5) Modified zirconia (12) Mixtures thereof (4) Abradable Nickel-Graphite Abradable materials containing Ni-Cr-Al Abradable Al-Si-Polyester Alloyed aluminides (2)
	Aluminium alloys (6)	MCrAlX (5) Modified zirconia (12) Silicides Mixtures thereof (4)
	Refractory metals and alloys (8)	Aluminides Silicides Carbides

TABLE - DEPOSITION TECHNIQUES

1.	Coating Process (1)	2. Substrate	3. Resultant Coating
D.	(continued)	Corrosion resistant steel (7)	MCrAlX (5) Modified zirconia (12) Mixtures thereof (4)
		Titanium alloys (13)	Carbides Aluminides Silicides Alloyed aluminides (2) Abradable Nickel-Graphite Abradable materials containing Ni-Cr-Al Abradable Al-Si-Polyester
E.	Slurry Deposition	Refractory metals and alloys (8)	Fused silicides Fused aluminides except for resistance heating elements
		Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Mixtures thereof (4)
F.	Sputter Deposition	"Superalloys"	Alloyed silicides Alloyed aluminides (2) Noble metal modified aluminides (3) MCrAlX (5) Modified zirconia (12) Platinum Mixtures thereof (4)
		Ceramics and Low-expansion glasses (14)	Silicides Platinum Mixtures thereof (4) Dielectic layers (15) Diamond-like carbon (17)

TABLE - DEPOSITION TECHNIQUES

1. Coating Process (1)	2. Substrate	3. Resultant Coating
F. (continued)	Titanium alloys (13)	Borides Nitrides Oxides Silicides Aluminides Alloyed aluminides (2) Carbides
	Carbon-carbon, Ceramic and Metal "matrix" "composites"	Silicides Carbides Refractory metals Mixtures thereof (4) Dielectric layers (15) Boron nitride
	Cemented tungsten carbide (16), Silicon carbide (18)	Carbides Tungsten Mixtures thereof (4) Dielectric layers (15) Boron nitride
	Molybdenum and Molybdenum alloys	Dielectric layers (15)
	Beryllium and Beryllium alloys	Borides Dielectric layers (15) Beryllium
	Sensor window materials (9)	Dielectric layers (15) Diamond-like carbon (17)
	Refractory metals and alloys (8)	Aluminides Silicides Oxides Carbides

TABLE - DEPOSITION TECHNIQUES

1.	Coating Process (1)	2.	Substrate	3.	Resultant Coating
G.	Ion Implantation		High temperature bearing steels		Additions of Chromium Tantalum or Niobium (Columbium)
			Titanium alloys (13)		Borides Nitrides
			Beryllium and Beryllium alloys		Borides
			Cemented tungsten carbide (16)		Carbides Nitrides

TABLE - DEPOSITION TECHNIQUES – NOTES

1. The term 'coating process' includes coating repair and refurbishing as well as original coating.

2. The term 'alloyed aluminide coating' includes single or multiple-step coatings in which an element or elements are deposited prior to or during application of the aluminide coating, even if these elements are deposited by another coating process. It does not, however, include the multiple use of single-step pack cementation processes to achieve alloyed aluminides.

3. The term 'noble metal modified aluminide' coating includes multiple-step coatings in which the noble metal or noble metals are laid down by some other coating process prior to application of the aluminide coating.

4. The term 'mixtures thereof' includes infiltrated material, graded compositions, co-deposits and multilayer deposits and are obtained by one or more of the coating processes specified in the Table.

5. 'MCrAlX' refers to a coating alloy where M equals cobalt, iron, nickel or combinations thereof and X equals hafnium, yttrium, silicon, tantalum in any amount or other intentional additions over 0.01 weight percent in various proportions and combinations, except:
   a. CoCrAlY coatings which contain less than 22 weight percent of chromium, less than 7 weight percent of aluminium and less than 2 weight percent of yttrium;
   b. CoCrAlY coatings which contain 22 to 24 weight percent of chromium, 10 to 12 weight percent of aluminium and 0.5 to 0.7 weight percent of yttrium; or
   c. NiCrAlY coatings which contain 21 to 23 weight percent of chromium, 10 to 12 weight percent of aluminium and 0.9 to1.1 weight percent of yttrium.

6. The term 'aluminium alloys' refers to alloys having an ultimate tensile strength of 190 MPa or more measured at 293 K (20°C).

7. The term 'corrosion resistant steel' refers to AISI (American Iron and Steel Institute) 300 series or equivalent national standard steels.

8. 'Refractory metals and alloys' include the following metals and their alloys: niobium (columbium), molybdenum, tungsten and tantalum.

9. 'Sensor window materials', as follows: alumina, silicon, germanium, zinc sulphide, zinc selenide, gallium arsenide, diamond, gallium phosphide, sapphire and the following metal halides: sensor window materials of more than 40 mm diameter for zirconium fluoride and hafnium fluoride.

10. "Technology" for single-step pack cementation of solid airfoils is not controlled by Category 2.

11. 'Polymers', as follows: polyimide, polyester, polysulphide, polycarbonates and polyurethanes.

12. 'Modified zirconia' refers to additions of other metal oxides (e.g., calcia, magnesia, yttria, hafnia, rare earth oxides) to zirconia in order to stabilise certain crystallographic phases and phase compositions. Thermal barrier coatings made of zirconia, modified with calcia or magnesia by mixing or fusion, are not controlled.

13. 'Titanium alloys' refers only to aerospace alloys having an ultimate tensile strength of 900 MPa or more measured at 293 K (20°C).

14. 'Low-expansion glasses' refers to glasses which have a coefficient of thermal expansion of $1 \times 10^{-7}\ K^{-1}$ or less measured at 293 K (20°C).

15. 'Dielectric layers' are coatings constructed of multi-layers of insulator materials in which the interference properties of a design composed of materials of various refractive indices are used to reflect, transmit or absorb various wavelength bands. Dielectric layers refers to more than four dielectric layers or dielectric/metal "composite" layers.

16. 'Cemented tungsten carbide' does not include cutting and forming tool materials consisting of tungsten carbide/(cobalt, nickel), titanium carbide/(cobalt, nickel), chromium carbide/nickel-chromium and chromium carbide/nickel.

17. "Technology" specially designed to deposit diamond-like carbon on any of the following is not controlled:
magnetic disk drives and heads, equipment for the manufacture of disposables, valves for faucets, acoustic diaphragms for speakers, engine parts for automobiles, cutting tools, punching-pressing dies, office automation equipment, microphones or medical devices or moulds, for casting or moulding of plastics, manufactured from alloys containing less than 5% beryllium.

18. 'Silicon carbide' does not include cutting and forming tool materials.

19. Ceramic substrates, as used in this entry, does not include ceramic materials containing 5% by weight, or greater, clay or cement content, either as separate constituents or in combination.

TABLE - DEPOSITION TECHNIQUES - TECHNICAL NOTE

Processes specified in Column 1 of the Table are defined as follows:

a. Chemical Vapour Deposition (CVD) is an overlay coating or surface modification coating process wherein a metal, alloy, "composite", dielectric or ceramic is deposited upon a heated substrate. Gaseous reactants are decomposed or combined in the vicinity of a substrate resulting in the deposition of the desired elemental, alloy or compound material on the substrate. Energy for this decomposition or chemical reaction process may be provided by the heat of the substrate, a glow discharge plasma, or "laser" irradiation.

   N.B.1 CVD includes the following processes: directed gas flow out-of-pack deposition, pulsating CVD, controlled nucleation thermal deposition (CNTD), plasma enhanced or plasma assisted CVD processes.
   N.B.2 Pack denotes a substrate immersed in a powder mixture.
   N.B.3 The gaseous reactants used in the out-of-pack process are produced using the same basic reactions and parameters as the pack cementation process, except that the substrate to be coated is not in contact with the powder mixture.

b. Thermal Evaporation-Physical Vapour Deposition (TE-PVD) is an overlay coating process conducted in a vacuum with a pressure less than 0.1 Pa wherein a source of thermal energy is used to vaporize the coating material. This process results in the condensation, or deposition, of the evaporated species onto appropriately positioned substrates.

   The addition of gases to the vacuum chamber during the coating process to synthesize compound coatings is an ordinary modification of the process.

   The use of ion or electron beams, or plasma, to activate or assist the coating's deposition is also a common modification in this technique. The use of monitors to provide in-process measurement of optical characteristics and thickness of coatings can be a feature of these processes.

   Specific TE-PVD processes are as follows:

   1. Electron Beam PVD uses an electron beam to heat and evaporate the material which forms the coating;
   2. Ion Assisted Resistive Heating PVD employs electrically resistive heating sources in combination with impinging ion beam(s) to produce a controlled and uniform flux of evaporated coating species;
   3. "Laser" Vaporization uses either pulsed or continuous wave "laser" beams to vaporize the material which forms the coating;
   4. Cathodic Arc Deposition employs a consumable cathode of the material which forms the coating and has an arc discharge established on the surface by a momentary contact of a ground trigger. Controlled motion of arcing erodes the cathode surface creating a highly ionized plasma. The anode can be either a cone attached to the periphery of the cathode, through an insulator, or the chamber. Substrate biasing is used for non line-of-sight deposition.

N.B. This definition does not include random cathodic arc deposition with non-biased substrates.

5. Ion Plating is a special modification of a general TE-PVD process in which a plasma or an ion source is used to ionize the species to be deposited, and a negative bias is applied to the substrate in order to facilitate the extraction of the species from the plasma. The introduction of reactive species, evaporation of solids within the process chamber, and the use of monitors to provide in-process measurement of optical characteristics and thicknesses of coatings are ordinary modifications of the process.

c. Pack Cementation is a surface modification coating or overlay coating process wherein a substrate is immersed in a powder mixture (a pack), that consists of:
   1. The metallic powders that are to be deposited (usually aluminium, chromium, silicon or combinations thereof);
   2. An activator (normally a halide salt); and
   3. An inert powder, most frequently alumina.

   The substrate and powder mixture is contained within a retort which is heated to between 1,030 K (757°C) and 1,375 K (1,102°C) for sufficient time to deposit the coating.

d. Plasma Spraying is an overlay coating process wherein a gun (spray torch) which produces and controls a plasma accepts powder or wire coating materials, melts them and propels them towards a substrate, whereon an integrally bonded coating is formed. Plasma spraying constitutes either low pressure plasma spraying or high velocity plasma spraying.

   N.B.1 Low pressure means less than ambient atmospheric pressure.
   N.B.2 High velocity refers to nozzle-exit gas velocity exceeding 750 m/s calculated at 293 K (20°C) at 0.1 MPa.

e. Slurry Deposition is a surface modification coating or overlay coating process wherein a metallic or ceramic powder with an organic binder is suspended in a liquid and is applied to a substrate by either spraying, dipping or painting, subsequent air or oven drying, and heat treatment to obtain the desired coating.

f. Sputter Deposition is an overlay coating process based on a momentum transfer phenomenon, wherein positive ions are accelerated by an electric field towards the surface of a target (coating material). The kinetic energy of the impacting ions is sufficient to cause target surface atoms to be released and deposited on an appropriately positioned substrate.

   N.B.1 The Table refers only to triode, magnetron or reactive sputter deposition which is used to increase adhesion of the coating and rate of deposition and to radio frequency (RF) augmented sputter deposition used to permit vaporisation of non-metallic coating materials.
   N.B.2 Low-energy ion beams (less than 5 keV) can be used to activate the deposition.

g. Ion Implantation is a surface modification coating process in which the element to be alloyed is ionized, accelerated through a potential gradient and implanted into the surface region of the substrate. This includes processes in which ion implantation is performed simultaneously with electron beam physical vapour deposition or sputter deposition.