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COMMUNICATIONS RECEIVED FROM CERTAIN MEMBER STATES REGARDING GUIDELINES FOR THE EXPORT OF NUCLEAR MATERIAL, EQUIPMENT AND TECHNOLOGY

Nuclear-related Dual-use Transfers

1. The Director General has received notes verbales dated 15 May 1992 from the Resident Representatives to the Agency of Australia, Austria, Belgium, Bulgaria, Canada, Czech and Slovak Federal Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Spain, Sweden, Switzerland, the United Kingdom of Great Britain and Northern Ireland, and the United States of America relating to the export of nuclear material, equipment and technology.

2. The purpose of the notes verbales is to provide information on those Governments' Guidelines for Transfers of Nuclear-related Dual-use Equipment, Material and related Technology

3. In the light of the wish expressed at the end of each note verbale, the text of the notes verbales is annexed hereto.

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NOTE VERBALE

The Permanent Mission of [Member State] presents its compliments to the Director General of the International Atomic Energy Agency and has the honour to provide information on its Government's nuclear export policies and practices.

The Government of [Member State] has decided that, when considering the transfer of nuclear-related dual-use equipment, material and related technology, it will act in accordance with the provisions of the attached documents.

In reaching this decision, the Government of [Member State] is fully aware of the need to contribute to economic development while avoiding contributing in any way to the dangers of a proliferation of nuclear weapons or other nuclear explosive devices, and of the need to remove non-proliferation assurances from the field of commercial competition.

The Government of [Member State], so far as trade within the European Community is concerned, will implement these documents in the light of its commitments as a Member State of that Community.*/

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*/ Paragraph in the notes verbales from the members of the European Community.

The Government of [Member State] hopes that other governments may also decide to base their own export policies regarding nuclear-related dual-use equipment, material and related technology upon these documents.

The Government of [Member State) requests that the Director General of the International Atomic Energy Agency should circulate the texts of this letter and the documents concerned to all Member Governments for their information and as a demonstration of support by the Government of [Member State] for the Agency's non-proliferation objectives and safeguards activities.

The Permanent Mission of [Member State] avails itself of this opportunity to renew to the Director General of the International Atomic Energy Agency the assurances of its highest consideration.

GUIDELINES FOR TRANSFERS OF NUCLEAR-RELATED DUAL-USE EQUIPMENT, MATERIAL AND RELATED TECHNOLOGY

OBJECTIVE

1. With the objective of averting the proliferation of nuclear weapons, suppliers have had under consideration procedures in relation to the transfer of certain equipment, material, and related technology that could make a major contribution to a "nuclear explosive activity" or an "unsafeguarded nuclear fuel-cycle activity." In this connection, suppliers have agreed on the following principles, common definitions, and an export control list of equipment, material, and related technology. The Guidelines are not designed to impede international cooperation as long as such cooperation will not contribute to a nuclear explosive activity or an unsafeguarded nuclear fuel-cycle activity. Suppliers intend to implement the Guidelines in accordance with national legislation and relevant international commitments.

BASIC PRINCIPLE

2. Suppliers should not authorize transfers of equipment, material, or related technology identified in the Annex:

   -- for use in a non-nuclear-weapon state in a nuclear explosive activity or an unsafeguarded nuclear fuel cycle activity, or

   -- in general, when there is an unacceptable risk of diversion to such an activity, or when the transfers are contrary to the objective of averting the proliferation of nuclear weapons.

EXPLANATION OF TERMS

3. (a) "Nuclear explosive activity" includes research on or development, design, manufacture, construction, testing or maintenance of any nuclear explosive device or components or subsystems of such a device.

   (b) "Unsafeguarded nuclear fuel-cycle activity" includes research on or development, design, manufacture, construction, operation or maintenance of any reactor, critical facility, conversion plant, fabrication plant, reprocessing plant, plant for the separation of isotopes of source or special fissionable material, or separate storage installation, where there is no obligation to accept International Atomic Energy Agency (IAEA) safeguards at the relevant facility or installation, existing or future, when it contains any source or special fissionable material; or of any heavy water production plant where there is no obligation to accept IAEA safeguards on any nuclear material produced by or used in connection with any heavy water produced therefrom; or where any such obligation is not met.

ESTABLISHMENT OF EXPORT LICENSING PROCEDURES

4. Suppliers should establish export licensing procedures for the transfer of equipment, material, and related technology identified in the Annex. These procedures should include enforcement measures for violations. In considering whether to authorize such transfers, suppliers should exercise prudence in order to carry out the Basic Principle and should take relevant factors into account, including:

(a) Whether the recipient state is a party to the Nuclear Non-Proliferation Treaty (NPT) or to the Treaty for the Prohibition of Nuclear Weapons in Latin America (Treaty of Tlatelolco), or to a similar international legally-binding nuclear non-proliferation agreement, and has an IAEA safeguards agreement in force applicable to all its peaceful nuclear activities;

(b) Whether any recipient state that is not party to the NPT, Treaty of Tlatelolco, or a similar international legally-binding nuclear non-proliferation agreement has any facilities or installations listed in paragraph 3(b) above that are operational or being designed or constructed that are not, or will not be, subject to IAEA safeguards;

(c) Whether the equipment, material, or related technology to be transferred is appropriate for the stated end-use and whether that stated end-use is appropriate for the end-user;

(d) Whether the equipment, material, or related technology to be transferred is to be used in research on or development, design, manufacture, construction, operation, or maintenance of any reprocessing or enrichment facility;

(e) Whether governmental actions, statements, and policies of the recipient state are supportive of nuclear non-proliferation and whether the recipient state is in compliance with its international obligations in the field of nonproliferation;

(f) Whether the recipients have been engaged in clandestine or illegal procurement activities; and

(g) Whether a transfer has not been authorized to the end-user or whether the end-user ha-' diverted for purposes inconsistent with the Guidelines any transfer previously authorized.

CONDITIONS FOR TRANSFERS

5. In the process of determining that the transfer will not pose any unacceptable risk of diversion, in accordance with the Basic Principle and to meet the objectives of the Guidelines, the supplier should obtain, before authorizing the transfer and in a manner consistent with its national law and practices, the following:

   (a) a statement from the end-user specifying the uses and end-use locations of the proposed transfers; and

   (b) an assurance explicitly stating that the proposed transfer or any replica thereof will not be used in any nuclear explosive activity or unsafeguarded nuclear fuel-cycle activity.

CONSENT RIGHTS OVER RETRANSFERS

6. Before authorizing the transfer of equipment, material, or related technology identified in the Annex to a country not adhering to the Guidelines, suppliers should obtain assurances that their consent will be secured, in a manner consistent with their national law and practices, prior to any retransfer to a third country of the equipment, material, or related technology, or any replica thereof.

CONCLUDING PROVISIONS

7. The supplier reserves to itself discretion as to the application of the Guidelines to other items of significance in addition to those identified in the Annex, and as to the application of other conditions for transfer that it may consider necessary in addition to those provided for in paragraph 5 of the Guidelines.

8. In furtherance of the effective implementation of the Guidelines, suppliers should, as necessary and appropriate, exchange relevant information and consult with other states adhering to the Guidelines.

9. In the interest of international peace and security, the adherence of all states to the Guidelines would be welcome.

ANNEX

LIST OF NUCLEAR-RELATED DUAL-USE EQUIPMENT AND MATERIALS AND RELATED TECHNOLOGY

Note: The International System of Units (SI) is used in this Annex. In many places, the approximately equivalent physical quantity in English units is given in parentheses ( ) after the SI quantity. In all cases the physical quantity defined in SI units should be considered the official recommended control value. However, some machine tool parameters are given in their customary units, which are not SI.

Commonly used abbreviations (and their prefixes denoting size) in this Annex are as follows.
A - ampere(s)
ºC - degree(s) Celsius
Ci - curie(s)
CM^3 - cubic centimeter(s)
dB - decibel(s)
dBm - decibel referred to 1 milliwatt
g - gram(s); also, acceleration of gravity (9.81 m/seoond^2)
GBq - gigabecquerel(s)
GHz - gigahertz
Hz - hertz
J - joule(s)
K - kelvin
keV - thousand electron volt(s)
kg - kilogram(s)
kHz - kilohertz
kN - kilonewton(s)
kPa - kilopascal(s)
kW - kilowatt(s)
m - meter(s)
MeV - million electron volt(s)
MHz – megahertz
MPa - megapascal(s)
MW - megawatt(s)
μF - MICROfarad(s)
μm - micrometer(s)
μs - microsecond(s)
mm - millimeter(s)
N - newton(s)
nm - nanometer(s)
ns - nanosecond(s)
nH - nanohenry(ies)
ps - picosecond(s)
RMS - root mean square
TIR - total indicator reading
W - watt(s)

GENERAL NOTE

The following paragraphs are applied to the list of Nuclear-Related Dual-Use Equipment, Material, and Related Technology.

1. The description of any item on the List includes that item in either new or second-hand condition.

2. When the description of any item on the List contains no qualifications or specifications, it is regarded as including all varieties of that item. Category captions are only for convenience in reference and do not affect the interpretation of item definitions.

3. The object of these controls should not be defeated by the transfer of any non-controlled item (including plants) containing one or more controlled components when the controlled component or components are the principal element of the item and can feasibly be removed or used for other purposes.

   Note:
   In judging whether the controlled component or components are to be considered the principal element, governments should weigh the factors of quantity, value, and technological know-how involved and other special circumstances which might establish the controlled component or components as the principal element of the item being procured.

4. The object of these controls should not be defeated by the transfer of component parts. Each government will take such action as it can to achieve this aim and will continue to seek a workable definition for component parts, which could be used by all the suppliers.

TECHNOLOGY CONTROLS

The transfer of "technology" directly associated with any items in the list will be subject to as great a degree of scrutiny and control as will the equipment itself, to the extent permitted by national legislation.

Controls on "technology" transfer do not apply to information "in the public domain" or to "basic scientific research."

Note: - The item on machine tools contains specific controls on technology.

STATEMENT OF UNDERSTANDING

The approval of any List item for export also authorizes the export to the same end user of the minimum technology required for the installation, operation, maintenance, and repair of the item.

DEFINITIONS

“Technology” - means specific information required for the “development,” “production,” or “use” of any item contained in the List. This information may take the form of “technical data” or “technical assistance.”

“basic scientific research” - Experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena and observable facts, not primarily directed toward a specific practical aim or objective.

“development” - is related to all phases before “production” such as:

- design
- design research
- design analysis
- design concepts
- assembly and testing of prototypes
- pilot production schemes
- design data
- process of transforming design data into a product
- configuration design
- integration design
- layouts

“in the public domain” - “In the public domain,” as it applies herein, means technology that has been made available without restrictions upon its further dissemination. (Copyright restrictions do not remove technology from being in the public domain.)

“production” - means all production phases such as:

- construction
- production engineering
- manufacture
- integration
- assembly (mounting)
- inspection
- testing
- quality assurance

“Specially designed software”

The minimum “operating systems,” “diagnostic systems,” “maintenance systems,” and “application software” necessary to be executed on particular equipment to perform the

Function for which it was designed. To make other, incompatible equipment perform the same function requires:

(a) modification of this "software" or

(b) addition of "programs."

"technical assistance" - "Technical assistance" may take forms such as: instruction, skills, training working knowledge, consulting services.
NOTE: "Technical assistance" may involve transfer of "technical data."

"technical data" - "Technical data" may take forms such as blueprints, plans, diagrams, models, formulae, engineering designs and specifications, manuals and instructions written or recorded on other media or devices such as disk, tape, read-only memories.

"use" - Operation, installation (including on-site installation), maintenance (checking), repair. overhaul and refurbishing

ANNEX CONTENTS

ANNEX

LIST OF NUCLEAR-RELATED DUAL-USE EQUIPMENT AND MATERIALS AND RELATED TECHNOLOGY

1. INDUSTRIAL EQUIPMENT

1.1. Spin-forming and flow forming machines which:

a. according to the manufacturer's technical specification, can be equipped with "numerical control" units or a computer control; and

b. with two or more axes that can be coordinated simultaneously for "contouring control,"

and precision rotor-forming mandrels designed to form cylindrical rotors of inside diameter between 75 mm (3 in.) and 400 mm (16 in.) and specially designed software therefor.

Note: The only spin-forming machines controlled by this entry are those combining the function of spin-forming and flow-forming.

1.2. "Numerical control" units, specially designed "motion control boards" for "numerical control" applications on machine tools, "numerically controlled" machine tools, specially designed "software," and technology as follows.

Detailed specifications of the equipment are shown in the Appendix.

1.3. Dimensional inspection machines, devices, or systems, as follows, specially designed software therefor.

(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 millimeters) (Ref VDI/VDE 2617 parts 1 and 2);

(b) Linear and angular displacement measuring devices, as follows:
  (1) Linear measuring instruments having any of the following characteristics:
    (i) 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;
    (ii) linear variable differential transformer (LVDT) systems having both of the following characteristics:
      (A) 'linearity" equal to or less (better) than 0.1% within a measuring range up to 5 mm; *and*
      (B) drift equal to or less (better) than 0.1% per day at a standard ambient test room temperature ± K; *or*
    (iii) measuring systems that have both of the following characteristics:
      (A) contain a "laser"; *and*
      (B) maintain for at least 12 hours, over a temperature range of ± K around a standard temperature and a .standard pressure:
        (1) a "resolution" over their full scale of 01 μm or better, *and*
        (2) with a "measurement uncertainty" equal to or less (better) than (0.2 + L/2000) μm (L is the measured length in millimeters); *except* measuring interferometer systems, without dosed or open loop feedback, containing a "laser" to measure slide movement errors of machine tools, dimensional inspection machines, or similar equipment;
  (2) angular measuring instruments having an "angular position deviation" equal to or less (better) than 0.00025°;

  Note: The sub-item (b)(2) of this item does not control optical instruments, such as autocollimators, using collimated light to detect angular displacement of a mirror.

(c) Systems for simultaneously linear-angular inspection of hemishells, having both of the following characteristic:
  (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: Specially designed software for the systems described in paragraph (c) of this item includes software for simultaneous measurements of wall thickness and contour.

Technical 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.

Technical Note 2: A machine described in this section, 1.3., is controlled if it exceeds the control threshold anywhere within its operating range.

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

Technical Note 4: All parameters of measurement values in this item represent plus/minus, i.e. not total band.

"Measurement uncertainty"
The characteristic parameter which specifies in what range around the output value the correct value of the measurable variable lies with a confidence level of 95%. It includes the uncorrected systematic deviations, the uncorrected backlash, and the random deviations (Reference: VDI/DE 2617).

"Resolution"
The least increment of a measuring device; on digital instruments, the least significant bit (Reference: ANSI B-89.1.12).

"Linearity"
(Usually measured in terms of nonlinearity) is the maximum deviation of the actual characteristic (average of upscale and downscale readings), positive or negative, from a straight line so positioned as to equalize and minimize the maximum deviations.

"Angular position deviation"
The maximum difference between angular position and the actual, very accurately measured angular position after the workplace mount of the table has been turned out of its initial position. (Reference: VDI/VDE 2617. Draft: "Rotary table on coordinate measuring machines."

1.4. Vacuum or controlled environment (Inert gas) Induction furnaces capable of operation above 850° C and having induction coils 600 mm (24 in.) or less in diameter, and power supplies specially designed for induction furnaces with a power supply of 5 kW or more.

Technical Note: This entry does not control furnaces designed for the processing of semiconductor wafers.

1.5. "Isostatic presses" capable of achieving a maximum working pressure of 69 MPa (10,000 psi) or greater and having a chamber cavity with an inside diameter in excess of 152 mm (6 in.) and specially designed dies and molds, and controls and "specially designed software" therefor.

Technical Notes:

(1) 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 w h i c h of the two chambers is located inside the other

(2) "Isostatic presses"
Equipment capable of pressurizing a closed cavity through various media (gas, liquid, solid panicles, etc.) to create equal pressure in all directions within the cavity upon a workpiece or material.

1.6. "Robots" and 'end-effectors" having either of the following characteristics:

(a) Specially designed to comply with national safety standards applicable to handling high explosives (for example, meeting electrical code ratings for high explosives); or

(b) Specially designed or rated as radiation hardened to withstand greater than 5×10^4 grays (Si) (5×10^4 rad (Si)) without operational degradation;

and specially designed controllers and "specially designed software" therefor.

Technical Notes:

(1) "Robot"
A manipulation mechanism, which may be of the continuous path or of the point-to-point variety, may use "sensors," and has all of the following characteristics:

(a) is multifunctional;
(b) is capable of positioning or orienting material, parts, tools, or special devices through variable movements in three-dimensional apace;
(c) incorporates three or more dosed or open loop servo-devices which may include stepping motors; and
(d) has "user-accessible programmability" by means of teach/playback method or by means of an electronic computer which may be a programmable logic controlled, i.e., without mechanical intervention.

N.B.:
The above definition does not include the following devices:
(a) Manipulation mechanisms which are only manually/teleoperator controllable;
(b) Fixed sequence manipulation mechanisms which are automated moving devices operating according to mechanically fixed programmed motions. The program is mechanically limited by fixed stops, such as pins or cams. The sequence of motions and the selection of paths or angles are not variable or changeable by mechanical, electronic, or electrical means;
(c) Mechanically controlled variable sequence manipulation mechanisms which are automated moving devices operating according to mechanically fixed programmed motions The program is merh2nilly limited by fixed, but adjustable, stops such as pins or cams. The sequence of motions and the selection of paths or angles are variable within the faced program pattern. Variations or modifications of the program pattern (e.g., changes of pins or exchanges of cams) in one or more motion axes are accomplished only through mechanical operations;
(d) Non-servo-controlled variable sequence manipulation mechanisms which are automated moving devices, operating according to mechanically feted programmed motions. The program is variable but the sequence proceeds

only by the binary signal from mechanically fixed electrical binary devices or adjustable stops;

(e) Stacker cranes defined as Cartesian coordinate manipulator systems manufactured as an integral part of a vertical array of storage bins and designed to access the contents of those bins for storage or retrieval.

(2) "End-effectors"
"End-effectors" include grippers, "active tooling units, " and any other tooling that is attached to the baseplate on the end of a "robot" manipulator arm.

(3) The definition in (a) above is not designed to control robots specially designed for nonnuclear industrial applications such as automobile paint-spraying booths.

1.7. Vibration test equipment using digital control techniques and feedback or closed loop test equipment and software therefor capable of vibrating a system at 10 g RMS or more between 20 Hz and 2000 Hz, imparting forces of 50 kN (11,250 lbs) or greater.

1.8. Vacuum and controlled atmosphere metallurgical melting and casting furnaces as follows; and specially configured computer control and monitoring systems and "specially designed software" therefore:

(a) Arc remelt and casting furnaces with consumable electrode capacities between 1000cm^3 and capable of operating with melting temperatures above 1700ºC,

(b) Electron beam melting and plasma atomization and melting furnaces with a power of 50 kW or greater and capable of operating with melting temperatures above 1200ºC.

2. MATERIALS

2.1. Aluminum alloys capable of an ultimate tensile strength of 460 MPa (0.46×10^9 N/m^2) or more at 293 K (20ºC), in the form of tubes or solid forms (including forgings) with an outside diameter of more than 75 mm (3 in.).

Technical Note: The phrase "capable of" encompasses aluminum alloys before or after heat treatment.

2.2 Beryllium as follows: metal, alloys containing more than 50% of beryllium by weight, compounds containing beryllium, and manufactures thereof, *except:*

(a) Metal windows for X-ray machines;

(b) Chide shapes in fabricated or semi-fabricated forms specially deigned for electronic component parts or as substrates for electronic circuits.

Technical Note: This control applies to waste and scrap containing beryllium as defined here.

2.3. High-purity (99.99% or greater) bismuth with very low silver content (less than 10 parts per million).

2.4. Boron and boron compounds, mixtures, and loaded materials in which the boron-10 isotope is more than 20% by weight of the total boron content.

2.5. Calcium (high purity) containing both less than 1000 parts per million by weight of metallic impurities other than magnesium and less than 10 parts per million of boron.

2.6. Chlorine Trifluoride (CIF_3).

2.7. Crucibles made of materials resistant to liquid actinide metals, as follows:

(a) Crucibles with a volume of between 150 ml and 8 liters and made of or coated with any of the following materials having a purity of 98% or greater.

(i) Calcium fluoride (CaF_2),
(ii) Calcium zirconate (metazirconate) (Ca_2ZrO_3)
(iii) Cerium sulfide (Ce_2S_3)
(iv) Erbium oxide (erbia) (Er_2O_3),
(v) Hafnium oxide (hafnia) (HfO_2),
(vi) Magnesium oxide (MgO)

(vii) Nitrided niobium-titanium-tungsten alloy (approximately 50% Nb, 30%Ti, 20%W),
(viii) Yttrium oxide (yttria) (Y_2O_3)
(ix) Zirconium oxide (zirconia) (ZrO_2)

(b) Crucibles with a volume of between 50 ml and 2 liters and made of or lined with tantalum, having a purity of 99.9% or greater.

c) Crucibles with a volume of between 50 ml and 2 liters and made of or lined with tantalum (having a purity of 98% or greater) coated with tantalum carbide, nitride, or boride (or any combination of these).

2.8. (a) Carbon or aramid "fibrous and filamentary" materials having a "specific modulus"' of 12.7×10^6 m or greater or a "specific tensile strength" of 23.5×10^4 m or greater, or

(b) Glass "fibrous and filamentary" materials having a "specified modulus" of 3.18×10^6 m or pester and a "specific tensile strength" of 7.62×10^4 m or greater.

(c) Composite structures in the form of tubes with an inside diameter of between 75 mm (3 in.) and 400 mm (16 in.) made with "fibrous and filamentary" materials controlled in (a) above.

Technical Note:

(a) The term "fibrous and filamentary materials" includes continuous monofilaments, continuous yarns, and tapes.

(b) "Specific modulus" is the Young's modulus in N/m^2 divided by the specific weight in N/m^3 when measured at a temperature of 23 ± 2ºC and a relative humidity of 50 ± 5%;

(c) "Specific tensile strength" is the ultimate tensile strength in N/m^2 divided by the specific weight in N/m^3 when measured at a temperature of 23 ± 2ºC and a relative humidity of 50 ± 5%.

2.9. Hafnium of the following description: metal, alloys, and compounds of hafnium containing more than 60% hafnium by weight and manufactures thereof.

2.10. Lithium (isotopically enriched in lithium-6) as follows:

(a) Metal hydrides or alloys containing lithium enriched in the 6 isotope (^6Li) to a concentration higher than the one existing in nature (7.5% on an atom percentage basis);

(b) Any other materials containing lithium enriched in the 6 isotope (including compounds, mixtures, and concentrates), *except ^6Li incorporated in thermoluminescent dosimeters*.

2.11. Magnesium (high purity) containing both less than 200 parts per million by weight of metallic impurities other than calcium and less than 10 parts per million of boron.

2.12. Maraging steel capable of an ultimate tensile strength of 2050 MPa (2.050×10^9 N/m^2) (300,000 lb/in.^{2}) or more at 293 K (20 ºC) *except forms in which no linear dimension exceeds 75 mm*.

Technical Note: The phrase "capable of" encompasses maraging steel before or after heat treatment.

2.13. Radium-226 *except radium contained in medical applicators.*

2. 14. Titanium alloys capable of an ultimate tensile strength of 900 MPa (0.9×10^9 N/m^2) (130,500 lb/in.^{2}) or more at 293 K (20ºC) in the form of tubes or solid forms (including forgings) with an outside diameter of more than 75 mm (3 in.).

Technical Note: The phrase "capable of" encompasses titanium alloys before or after heat treatment.

2.15. Tungsten, as follows: parts made of tungsten, tungsten carbide, or tungsten alloys (greater than 90% tungsten) having a mass greater than 20 kg and a hollow cylindrical symmetry (including cylinder segments) with an inside diameter greater than 100 mm (4 in.) but less than 300 mm (12 in.), *except parts specifically designed for use as weights or gamma-ray collimators.*

2.16. Zirconium as follows: metal, alloys containing more than 50% zirconium by weight, and compounds in which the ratio of hafnium content to zirconium content is less than 1 part to 500 parts by weight, and manufactures wholly thereof; *except zirconium in the form of foil having a thickness not exceeding 0.10 mm (0.004 in.).*

Technical Note: This control applies to waste and soap containing zirconium as defined here.

3. URANIUM ISOTOPE SEPARATION EQUIPMENT AND COMPONENTS

3.1. Electrolytic cells for fluorine production with a production capacity greater than 250 g of fluorine per hour.

3.2. Rotor fabrication and assembly equipment and bellows-forming mandrels and dies, as follows:

(a) Rotor assembly equipment for assembly of gas centrifuge rotor tube sections, baffles, and end caps. Such equipment includes precision mandrels, clamps, and shrink fit machines.

(b) Rotor straightening equipment for alignment of gas centrifuge rotor tube sections to a common axis. (Note: Normally such equipment will consist 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 (bellows made of high-strength aluminum alloys, maraging steel, or high-strength filamentary materials). The bellows have all of the following dimensions:

(1) 75-mm to 400-mm (3-in. to 16-in.) inside diameter,
(2) 12.7 mm (0.5 in.) or more in length; and
(3) single convolution depth more than 2 mm (0.08 in.).

3.3. 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) a swing or journal diameter of 75 mm or more;
(2) mass capability of from 0.9 to 23 kg (2 to 50 lb.); and
(3) capable of balancing speed of revolution more than 5000 rpm;

(b) Centrifugal balancing machines designed for balancing hollow cylindrical rotor components and having all of the following characteristics:
(1) a journal diameter of 75 mm or more;
(2) mass capability of from 0.9 to 23 kg (2 to 50 lb.);
(3) capable of balancing to a residual imbalance of 0.010 kg mm/kg per plane or better, and
(4) belt drive type;

and “specially designed software” therefore.

3.4. Filament winding machines in which the motions for positioning, wrapping, and winding fibers are coordinated and programmed in two or more axes, specially designed to fabricate composite structures or laminates from fibrous and filamentary materials and capable of winding cylindrical rotors of diameter between 75 mm (3 in.) and 400 mm (16 in.) and lengths of 600 mm (24 in.) or greater, coordinating and programming controls therefor; precision mandrels; and "specially designed software" therefor.

3.5. Frequency changers (also known as converters or inverters) or generators having all of the following characteristics:

(a) A multiphase output capable of providing a power of 40 W or more;

(b) Capable of operating in the frequency range between 600 and 2000 Hz;

(c) Total harmonic distortion below 10%; and

(d) Frequency control better than 0.1%.

except such frequency changers specially designed or prepared to supply "motor stators" (as defined below) and having the characteristics listed in (b) and (d) above, together with a total harmonic distortion of less than 2% and an efficiency of greater than 80%.

Definition:

"Motor stators": specially designed or prepared ring-shaped stators for high-speed multiphase AC hysteresis (or reluctance) motors for synchronous operation within a vacuum in the frequency range of 600-2000 Hz and a power range of 50-1000 VA. The stators consist of multiphase windings on a laminated low-loss iron core comprising thin layers typically 2.0 mm (008 in.) thick or less.

3.6. Lasers, laser amplifiers, and oscillators as follows:

(a) Copper vapor lasers with 40 W or greater average output power operating at wavelengths between 500 nm and 600 nm;

(b) Argon son lasers with greater than 40 W average output power operating at wavelengths between 400 nm and 515 nm;

(c) Neodymium-doped (other than glass) lasers as follows:

(1) having an output wavelength between 1000 nm and 1100 nm, being pulse-excited and Q-switched with a pulse duration equal to or greater than 1 ns, and having either of the following:
(a) A single-transverse mode output having an average output power exceeding 40 W;
(b) A multiple-transverse mode output having an average output power exceeding 50 W;

(2) operating at a wavelength between 1000 am and 1100 am and incorporating frequency doubling giving an output wavelength between 500 nm and 550 nm with an average power at the doubled frequency (new wavelength) of greater than 40 W;

(d) Tunable pulsed single-mode dye oscillators capable of an average power output of greater than 1 W, a repetition rate greater than 1 kHz, a pulse less than 100 ns, and a wavelength between 300 nm and 800 nm;

(e) Tunable pulsed dye laser amplifiers and oscillators, *except single mode oscillators*, with an average power output of greater than 30 W, a repetition rate greater than 1 kHz, a pulse width less than 100 ns, and a wavelength between 300 nm and 800 nm;

(f) Alexandrite lasers with a bandwidth of 0.005 nm or less, a repetition rate of greater than 125 Hz, and an average power output greater than 30 W operating at wavelengths between 720 nm and 800 nm;

(g) Pulsed carbon dioxide lasers with a repetition rate greater than 250 Hz, an average power output of greater than 500 W, and a pulse of less than 200 ns operating at wavelengths between 9000 nm and 11,000 nm;

N.B. This specification is not intended to control the higher power (typically 1 to 5 kW) industrial CO_2 lasers used is applications such as cutting and welding, as these latter lasers are either continuous wave or are pulsed with a pulse width more than 200 ns.

(h) Pulsed excimer lasers (XeF, XeCI, KrF) with a repetition rate greater than 250 Hz and an average power output of greater than 500 W operating at wavelengths of between 240 and 360 nm;

(i) Para-hydrogen Raman shifters designed to operate at 16 μm output wavelength and at a repetition rate greater than 250 Hz.

Technical Note: Machine tools, measuring devices, and associated technology that have the potential for use in the nuclear industry are controlled under items 1.2 and 13 of this list.

3.7. Mass spectrometers capable of measuring ions of 230 atomic mass units or greater and having a resolution of better than 2 parts in 230, and ion sources therefor as follows:

(a) Inductively coupled plasma mass spectrometers (ICP/MS);

(b) Glow discharge mass spectrometers (GDMS);

(c) Thermal ionization mass spectrometers (IMS);

(d) Electron bombardment mass spectrometers which have a source chamber constructed from or lined with or plated with materials resistant to UF_6;

(e) Molecular beam mass spectrometers as follows:
  (1) which have a source chamber constructed from or lined with or plated with stainless steel or molybdenum and have a cold trap capable of cooling to 193 K (-80 ºC) or less; or
  (2) which have a source chamber constructed from or lined with or plated with materials resistant to UF_6; or

(f) Mass spectrometers equipped with a microfluorination ion source designed for use with actinides or actinide fluorides;

except

specially designed or prepared magnetic or quadrupole mass spectrometers capable of taking "on-line" samples of feed, product, or tails from UF_6 gas streams and having all of the following characteristics:
  (1) Unit resolution for mass greater than 320;
  (2) Ion sources constructed of or lined with nichrome or monel or nickel-plated;
  (3) Electron bombardment ionization sources;
  (4) Having a collector system suitable for isotopic analysis.

3.8. Instruments capable of measuring pressures up to 13 kPa (2 psi, 100 torr) to an accuracy of better than 1% (full-scale), with corrosion-resistant pressure-sensing elements constructed of nickel, nickel alloys, phosphor bronze, stainless steel, aluminum, or aluminum alloys.

3.9. Valves 5 mm (0.2 in.) or greater in diameter, with a bellows seal, wholly made of or lined with aluminum, aluminum alloy, nickel, or alloy containing 60% or more nickel, either manually or automatically operated.

3.10. Superconducting solenoidal electromagnets with all of the following characteristics:

(a) capable of creating magnetic fields of more than 2 teslas (20 kilogauss);

(b) with an L/D (length divided by inner diameter) greater than 2;

(c) with an inner diameter of more than 300 mm; and

(d) with a magnetic field uniform to better than 1% over the central 50% of the inner volume.

Note:

The item does not cover magnets specially designed for and exported as parts of medical nuclear magnetic resonance (NMR) imaging systems. It is understood that the wording "as part of" does not necessarily mean physical part in the same shipment. Separate shipments from different sources are allowed, provided the related export documents clearly specify the "part of" relationship.

3.11. Vacuum pumps with an input throat size of 38 cm (15 in.) or greater with a pumping speed of 15,000 liters/second or greater and capable of producing an ultimate vacuum better than 10^{-4} Torr (0.76×10^{-4} mbar).

Technical Note: The ultimate vacuuum is determined at the input of the pump with the input of the pump blocked off.

3.12. Direct current high-power supplies capable of continuously producing, over a time period of 8 hours, 100 V or greater with current output of 500 amps or greater and with current or voltage regulation better than 0.1%.

3.13. High-voltage direct current power supplies capable of continuously producing, over a time period of 8 hours, 20,000 V or greater with current output of 1 amp or greater and with current or voltage regulation better than 0.1%.

3.14. Electromagnetic isotope separators, designed for or equipped with, single or multiple ion sources capable of providing a total ion beam current of 50 mA or greater.

Notes:

1. This entry will control separators capable of enriching stable isotopes as well as those for uranium. A separator capable of separating the isotopes of lead with a one-mass unit difference is inherently capable of enriching the isotopes of uranium with a three-unit mass difference.
2. This entry includes separators with the ion sources and collectors both in the magnetic field and those configurations in which they are external to the field.
3. A single 50-mA ion source will produce less than 3 g of separated HEU per year from natural abundance feed

4. HEAVY WATER PRODUCTION PLANT RELATED EQUIPMENT
(Other Than Trigger List Items)

4.1. Specialized packings for use in separating heavy water from ordinary water and made of phosphor bronze mesh or copper (both chemically treated to improve wettability) and designed for use in vacuum distillation towers.

4.2. Pumps circulating solutions of diluted or concentrated potassium amide catalyst in liquid ammonia (KNH_2/NH_3), with all of the following characteristics:

(a) airtight (i.e., hermetically sealed);

(b) for concentrated potassium amide solutions (1% or greater), operating pressure of 1.5-60 MPa [15-600 atmospheres (atm)]; for dilute potassium amide solutions (less than 1%), operating pressure of 20-60 MPa (200-600 atm); *and*

(c) a capacity greater than 8.5 m^3/h (5 cubic feet per minute).

4.3. Water-hydrogen sulfide exchange tray columns constructed from fine carbon steel (such as ASTM A516) with a diameter of 1.8 m (6 ft.) or grater to operate at a nominal pressure of 2 MPa (300 psi) or greater, except columns which are specially designed or prepared for the production of heavy water. Internal contactors of the columns are segmented trays with an effective assembled diameter of 1.8 m (6 ft.) or greater, such as sieve trays, valve trays, bubble cap trays, and turbogrid trays designed to facilitate countercurrent contacting and constructed of materials resistant to corrosion by hydrogen sulfide/water mixtures, such as 304L or 316 stainless steel

4.4. Hydrogen-cryogenic distillation columns having all of the following applications:

(a) designed to operate with internal temperatures of -238ºC (35 K) or less;

(b) designed to operate at internal pressure of 0.5 to 5 MPa (5 to 50 atmospheres);

(c) constructed of fine-grain stainless steels of the 300 series with low sulfur content or equivalent cryogenic and H_2-compatible materials; and

(d) with internal diameters of 1 m or greater and effective lengths of 5 m or greater

4.5. Ammonia synthesis convertors, ammonia synthesis units in which the synthesis gas (nitrogen and hydrogen) is withdrawn from an ammonia/hydrogen high-pressue exchange column and the synthesized ammonia is returned to said column.

5. IMPLOSION SYSTEMS DEVELOPMENT EQUIPMENT

5.1. Flash x-ray generators or pulsed electron accelerators with peak energy of 500 keV or greater, as follows, *except accelerators that are component parts of devices designed for purposes other than electron beam or x-ray radiation (electron microscopy. For example) and those designed for medical purposes*:

(a) Having an accelerator peak electron energy of 500 keV or greater but less than 25 MeV and with a figure of merit (K) of 0.25 or greater, where K is defined as:

$$K = 1.7 \text{ x } 10^{3} V^{2.65} Q,$$

where V is the peak electron energy in million electron wilts and Q is the total accelerated charge in coulombs if the accelerator beam pulse duration is less than or equal to $1 \mu s$, if the accelerator beam pulse duration is greater than $1 \mu s$, Q is the maximum accelerated charge in $1 \mu s$ [Q equals the integral of i with respect to t, over the lesser of $1 \mu s$ or the time duration of the beam pulse ($Q = \int i dt$), where i is beam current in amperes and t is time in seconds] *or*,

(b) Having an accelerator peak electron energy of 25 MeV or greater and a peak power greater than 50 MW. [Peak power = (peak potential in volts) x (peak beam current in amperes).]

Technical Note:

Time duration of the beam pulse - In machines, based on microwave accelerating cavities, the time duration of the beam pulse is the lesser of $1 \mu s$ or the duration of the bunched beam packet resulting from one microwave modulator pulse.

Peak beam current - In machines based on microwave accelerating cavities, the peak beam current is the average current in the time duration of a bunched beam packet.

5.2. Multistage light gas guns or other high-velocity gun systems (coil, electromagnetic, electrothermal, or other advanced systems) capable of accelerating projectiles to 2 km per second or greater.

5.3. Mechanical rotating mirror cameras

Mechanical framing cameras with recording rates greater than 225,000 frames per second; streak cameras with writing speeds greater than 0.5 mm per microsecond; and parts, including specially designed synchronizing electronics and specially designed rotor assemblies (consisting of turbines, mirrors, and bearings).

5.4. Electronic streak and framing cameras and tubes as follows:

(a) Electronic streak cameras capable of 50 ns or less time resolution and streak tubes therefor;

(b) Electronic (or electronically shuttered) framing cameras capable of 50 ns or less frame exposure time;

(c) Framing tubes and solid-state imaging devices for use with cameras controlled in sub-item (b) above, as follows:

(1) proximity focused image intensifier tubes having the photocathode deposited on a transparent conductive coating to decrease photocathode sheet resistance;
(2) gate silicon intensifier target (SIT) vidicon tubes, where a fast system allows gating the photoelectrons from the photocathode before they impinge on the SIT plate;
(3) Kerr or pockel cell electro-optical shuttering; or
(4) Other framing tubes and solid-state imaging devices having a fast-image gating time of less than 50 ns specially designed for cameras controlled by sub-item (b) above.

5.5 Specialized instrumentation for hydrodynamic experiments as follows:

(a) Velocity interferometers for measuring velocities in excess of 1 km per second during time intervals less than 10 μs. (VISARS, Doppler laser interferometers, DLIs, etc);

(a) manganin gauges for pressures greater than 100 kilobars; or

(c) quartz pressure transducers for pressures greater than 100 kilobars

6. EXPLOSIVES AND RELATED EQUIPMENT

6.1. Detonators and multipoint initiation systems (exploding bridge wire, dapper, etc.)

(a) Electrically driven explosive detonators as follows:

(1) exploding bridge (EB);
(2) exploding bridge wire (EBW);
(3) slapper; and
(4) exploding foil initiators (EFI).

(b) Arrangements using single or multiple detonators designed to nearly simultaneously initiate an explosive surface (over greater than 5000 mm^2) from a single firing signal (with an initiation timing spread over the surface of less than 2.5 μs).

Description clarification: The detonators of concern all utilize a small electrical conductor (bridge, bridge wire, or foil) that explosively vaporises when a fast, high-current electrical pulse is passed through it. In nonslapper types, the exploding conductor starts a chemical detonation in a contacting high-explosive material such as PETN (pentaerythritoltetranitrate). In slapper detonators, the explosive vaporization of the electrical conductor drives a “flyer” or “slapper” across a gap, and the impact of the stopper or an explosive starts a chemical detonation. The slapper in some designs is driven by magnetic force. The term “exploding foil” detonator may refer to either an EB or a slapper-type detonator. Also, the word “initiator” is sometimes used in place of the word “detonator.”

Detonators using only primary explosives, such as lead azide, are not subject to control

6.2. Electronic components for firing sets (switching devices and pulse discharge capacitors)

6.2.1. Switching devices

(a) Cold-cathode tubes (including gas krytron tubes and vacuum sprytron tubes), whether gas filled or not, operating similarly to a spark gap, containing three or more electrodes, and having all of the following characteristics:

(1) Anode peak voltage rating of 2500 V or more,
(2) Anode peak current rating of 100 A or more,
(3) Anode delay time of 10 μs or less, and

(b) Triggered spark-gaps having an anode delay time of 15 μs or less and rated for a peak current of 500 A or more;

(c) Modules or assemblies with a fast switching function having all of the following characteristics:

(1) Anode peak voltage rating greater than 2000 V;
(2) anode peak current rating of 500 A or more; and
(3) turn-on time of 1 μs or less.

6.2.2. Capacitors with the following characteristics:

(a) Voltage rating greater than 1.4 kV, energy storage grater than 10 J, capacitance greater than 0.5 μF, and series inductance less than 50 nH, *or*

(b) Voltage rating greater than 750 V, capacitance greater than 0.25 μF, and series inductance less than 10 nH.

6.3. Firing sets and equivalent high-current pulse generators (for controlled detonators), as follows:

(a) Explosive detonator firing sets designed to drive multiple controlled detonators covered under item 6.1. above;

(b) Modular electrical pulse generators (pulsars) designed for portable, mobile, or ruggedized use (including xenon flash-lamp driven) having all the following characteristics:

(1) capable of delivering their energy in less than 15 μs;

(2) having an output greater than 100 A;

(3) having a rise time of less than 10 μs into loads of less than 40 ohms. (Rise time is defined as the time interval from 10% to 90% current amplitude when driving a resistive load);

(4) enclosed in a dust-tight enclosure;

(5) no dimension greater than 25.4 cm (10 in.);

(6) weight less than 25 kg (55 lb.); and

(7) specified for use over an extended temperature range (-50 ºC to 100ºC) or specified as suitable for aerospace use.

6.4. High explosives or substances or mixtures containing more than 2% of any of the following:

(a) Cyclotetramethylenetetranitramine (HMX);

(b) Cyclotrimethylenetrinitramine (RDX);

(c) Triaminotrinitrobenzene (TATB);

(d) Any explosive with a crystal density greater than L8 g/cm^3 and having a detonation velocity greater than 8000 m/s; or

(e) Hexanitrostilbene (HNS).

7. NUCLEAR TESTING EQUIPMENT AND COMPONENTS

7.1 Oscilloscopes and transient recorders and specially designed components as follows: plug-in units, external amplifiers, pre-amplifiers, sampling devices, and cathode ray tubes for analog oscilloscopes.

(a) Non-modular analog oscilloscopes having a “bandwidth” of 1 GHz or greater,

(b) Modular analog oscilloscope systems having either of the following characteristics:

(i) a mainframe with a 'bandwidth" of 1 GHz or grater; or

(ii) Plug-in modules with an individual “bandwidth” of 4 GHz or greater,

(c) Analog sampling oscilloscopes for the analysis of recurring phenomena with an effective “bandwidth” greater than 4 GHz;

(d) Digital oscilloscopes and transient recorders, using analog-to-digital conversion techniques, capable of storing transients by sequentially sampling single-shot inputs at successive intervals of less than 1 ns (greater than 1 giga-sample per second), digitizing to 8 bits or greater resolution and storing 256 or more samples.

Technical Note: “Bandwidth” is defined as the band of frequencies over which the deflection on the cathode ray tube does not fall below 70.7% of that at the maximum point measured with a constant input voltage to the oscilloscope amplifier.

7.2. Photomultiplier tubes with a photocathode area of greater than 20 cm^2 having an anode pulse rise time of less than 1 ns.

7.3. High-speed pulse generators with output voltages greater than 6 V into a less than 55-ohm resistive load, and with pulse transition times less than 500 ps (defined as the time interval between 10% and 90% voltage amplitude).

8. OTHER

8.1. Neutron generator systems, including tubes, designed for operation without an external vacuum system and utilizing electrostatic acceleration to induce a tritium-deuterium nuclear reaction.

8.2. Equipment related to nuclear material handling and processing and to nuclear reactors as follows:

8.2.1. Remote manipulators that provide mechanical translation of human operator actions by electrical, hydraulic, or mechanical means to an operating arm and terminal fixture that can be used to provide remote actions in radiochemical separation operations and "hot cells." The manipulators have a capability to penetrate 0.6 m or more (2 ft. or more) of cell wall or, alternatively, bridge over the top of a cell wall with a thickness of 0.6 m or more (2 ft. or more);

8.2.2. High-density (lead glass or other) radiation shielding windows greater than 0.3 m (1 ft.) on a side and with a density greater than 3 g/cm^3 and a thickness of 100 mm or greater; and specially designed frames therefor,

8.2.3. Radiation-hardened TV cameras specially designed or rated as radiation hardened to withstand greater than 5×10^4 grays (Si) (5×10^4 rad (SI)) without operational degradation and specially designed lenses used therein.

8.3. Tritium, tritium compounds, and mixtures containing tritium in which the ratio of tritium to hydrogen by atoms exceeds 1 part in 1000 *except a product or device containing not note than 40 Ci of tritium in any chemical or physical form*.

8.4. Facilities or plants for the production, recovery, extraction, concentration, or handling of tritium, and equipment as follows:

(a) Hydrogen or helium refrigeration units capable of cooling to -250ºC (23 K) or less, with heat removal capacity greater than 150 watts or

(b) Hydrogen isotope storage and purification systems using metal hydrides as the storage, or purification medium.

8.5. Platinized catalysts specially designed or prepared for promoting the hydrogen isotope exchange reaction between hydrogen and water for the recovery of tritium from heavy water or for the production of heavy water.

8.6. Helium in any form isotopically enriched in the helium-3 isotope, whether or not mixed with other materials or contained in any equipment or device, *except products or devices containing less than 1 g of helium-3*.

8.7. Alpha-emitting radionuclides and equipment containing such radionuclides as follows:

All alpha-emitting radionuclides having an alpha half-life of 10 days or greater but less than 200 years, including compounds and mixtures containing these radionuclides with a total alpha activity of 1 curie per kilogram (37 GBq/kg) or greater *except for devices containing less than 100 millicuries (3.7 GBq) of alpha activity per device*.

ANNEX APPENDIX: Detailed Specifications for Machine Tools
(Item 1.2. in List of Nuclear Dual-Use Export Controls)

1.2. "Numerical control" units, specially designed "motion control boards" for "numerical control" applications on machine tools, "numerically controlled" machine tools, specially designed "software," and technology as follows:

(a) "Numerical control" units for machine tools, as follows:

(1) Having more than four interpolating axes that can be coordinated simultaneously for "contouring control" *or*
(2) Having two, three, or four interpolating axes that can be coordinated simultaneously for "contouring control" and one or more of the following conditions are fulfilled:
(i) Capable of "real-time processing" of data to modify the tool path during the machining operation by automatic calculation and modification of "part program" data for machining in two or more axes by means of measuring cycles and access to source data;
(ii) Capable of receiving directly (on-line) and processing computer-aided design (CAD) data for internal preparation of machine instructions; or
(iii) Capable, without modification, according to the manufacturer's technical specifications, of accepting additional boards that would permit increasing the number of interpolating axes that can be coordinated simultaneously for "contouring control," above the control levels, even if they do not contain these additional boards.

(b) "Motion control boards" specially designed for machine tools having one or more of the following characteristics:
(1) Providing interpolation in more than four axes;
(2) Capable of "real time processing" described in (a)(2)(i); *or*
(3) Capable of receiving and processing CAD data as described in (a)(2)(ii) above.

Note 1: Subitems (a) and (b) do not control "numerical control" units and "motion control boards" if

(a) Modified for and incorporated in uncontrolled machines; *or*
(b) Specially designed for uncontrolled machines.

Note 2: "Software" (including documentation) for "numerical control" units that may be exported must be:

(a) In machine executable form only; and

(b) Limited to the minimum necessary for the use (i.e., installation, operation, and maintenance) of these units.

(c) Machine tools, as follows, for removing or cutting metals, ceramics, or composites, which, according to the manufacturer's technical specifications, can be equipped with electronic devices for simultaneous "contouring control" in two or more axes:

Technical Note:

1. The c-axis on jig grinders used to maintain grinding wheels normal to the work surfaces is not considered a contouring rotary axis.
2. Not counted in the total number of contouring axes are secondary parallel contouring axes, e.g., a secondary rotary axis, the center line of which is parallel to the primary rotary axis.
3. Axis nomenclature shall be in accordance with International Standard ISO 841, "Numerical Control Machines Axis and Motion Nomenclature."
4. Rotary axes do not necessarily have to rotate over 360º. A rotary axis can be driven by a linear device, e.g., screw or a rack-and-pinion.

(1) Machine tools for turning, grinding, milling, or any combination thereof that:
  (i) Have two or more axes that can be coordinated simultaneously for "contouring control"; *and*
  (ii) Have any of the following characteristics:
    (A) Two or more contouring rotary axes;
    (B) One or more contouring "tilting spindles";

Note: (c)(1)(ii)(B) applies to machine tools for grinding or milling only.

    (C) "Camming" (axial displacement) in one revolution of the spindle less (better) than 0.0006 mm total indicator reading (TIR);

Note: (c)(1)(ii)(C) applies to machine tools for turning only.

    (D) "Run out" (out-of-true running) in one revolution of the spindle less (better) than 0.0006 TIR.
    (E) The "positioning accuracies," which all compensations available, are less (better) than:
      (1) 0.001º on any rotary axis
      (2) (a) 0.004 mm along any linear axis (overall positioning) for grinding machines)
        (b) 0.006 mm along any linear axis (overall positioning) for milling or turning machines

Note: (c)(1)(ii)(E)(2)(b) does not control milling or turning machine tools with a positioning accuracy along one linear axis, with all compensations available, equal to or greater (worse) than 0.005 mm.

Notes: 1. Sub-item (c) does not control cylindrical external, internal, and external-internal grinding machines having all of the following characteristics:
(a) Not centerless (shoe-type) grinding machines;
(b) Limited to cylindrical grinding;
(c) A maximum workpiece outside diameter or length of 150 mm;
(d) Only two axes that can be coordinated simultaneously for "contouring control"; *and*
(e) No contouring c axis.

2. Sub-item (c) does not control machines designed specifically as jig grinders having both of the following characteristics:
(a) Axes limited to x, y, c, and a, where the c axis is used to maintain the grinding wheel normal to the work surface, and the a axis is configured to grind barrel cams *and*
(b) A spindle "run-out" not less (not better) than 0.0006 mm.

3. Sub-item (c) does not control tool or cutter grinding machines having all of the following characteristics:
(a) Shipped as a complete system with "software" specially designed for the production of tools or cutters;
(b) No more than two rotary axes that can be coordinated simultaneously for "contouring control";
(c) "Run-out" (out-of-true running) in one revolution of the spindle not less (not better) than 0.0006 mm TIR; *and*
(d) The "positioning accuracies," with all compensations available, are not less (not better) than:
(i) 0.004 mm along any linear axis for overall positioning; or
(ii) 0.001º for any rotary axis.

(2) Electrical discharge machines (EDM);
(i) Of the wire feed type that have five or more axes can be coordinated simultaneously for "contouring control";
(ii) Non-wire EDMs that have two or more contouring rotary axes and that can be coordinated simultaneously for "contouring control."

3. Other machine tools for removing metals, ceramics, or composites:
   (i) By means of:
      (A) Water or other liquid jets, including those employing abrasive additives:
      (B) Electron bean; *or*
      (C) "Laser" beam; *and*
   (ii) Having two or more rotary axes that:
      (A) Can be coordinated simultaneously for "contouring control"; *and*
      (B) Have a "positioning accuracy" or less (better) than 0.003º.

(d) "Software"
   (1) "Software" specially designed or modified for the "development," "production," or "use" of equipment controlled by sub-categories (a), (b) or (c) above;
   (2) Specific "software," as follows:
      (i) "Software" to provide "adaptive control" and having both of the following characteristics:
         (A) For "flexible manufacturing units" (FMUs) that consist at least of equipment described in (b)(1) and (b)(2) of the definition of "flexible manufacturing units"; *and*
         (B) Capable of generating or modifying, in "real time processing," "part program" data by using the signals obtained simultaneously by means of at least two detection techniques, such as:
            (1) Machine vision (optical ranging);
            (2) Infrared imaging;
            (3) Acoustical imaging (acoustical ranging);
            (4) Tactile measurement;
            (5) Inertial positioning;
            (6) Force measurement;
            (7) Torque measurement.

Note: This sub-item does not control "software" that only provides rescheduling of functionally identical equipment within "flexible manufacturing units" using prestored "part programs" and a prestored strategy for the distribution of the "part programs."

      (ii) "Software" for electronic devices other than those described in sub-items (a) or (b) that provides the "numerical control" capability of the equipment controlled in sub-item 1.2.

(e) Technology
   (1) "Technology" for the "development" of equipment controlled by sub-items (a), (b), or (c) above, (f) or (g) below, and of the sub-item (d).
   (2) "Technology" for the "production" of equipment controlled by sub-items (a), (b), or (c) above, (f) or (g) below;
   (3) Other "technology":
      (i) For the "development" of interactive graphics as an integrated part in "numerical control" units for preparation or modification of "part programs";
      (ii) For the "development" of integration "software" for incorporation of expert systems for advanced decision support of shop floor operations into "numerical control" units.

(f) Components and parts for machine tools controlled by sub-item (c) as follows:

(1) Spindle assemblies, consisting of spindles and bearings as a minimal assembly, with radical ("run-out") or axial ("camming") axis motion in one revolution of the spindle less (better) than 0.0006 mm TIR;

(2) Linear position feedback units (e.g. inductive-type devices, graduated scales, "laser," or infrared systems) having, with compensation, an overall "accuracy" better than $800 + (600 \times L \times 10^{-3})$ nm, where *L* equals the effective length in millimetres of the linear measurement; *except* 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;

(3) Rotary position feedback units (e.g., inductive-type devices, graduated scales, "laser," or infrared systems) having, with compensation, an "accuracy" less (better) than 0.00025º of arc, *except* measuring interferometer systems, without dosed or open loop feedback, containing a "laser" to measure slide movement errors of machine tools, dimensional inspection machines, or similar equipment;

(4) Slide way assemblies consisting of a minimal assembly of ways, bed, and slide having all of the following characteristics:

(i) A yaw, pitch, or roll of less (better) than 2 seconds of arc TIR (Ref. ISO/DIS 230-1 over full travel);

(ii) A horizontal straightness of less (better) than 2 μm per 300 mm length; *and*

(iii) A vertical straightness of less (better) than 2 μm over full travel per 300 mm length;

(5) Single-point diamond-cutting tool inserts having all of the following characteristics:

(i) A flawless and chip-free cutting edge when magnified 400 times in any direction;

(ii) A cutting radius out-of-roundness less (better) than 0.002 mm TIR (also peak-to-peak); *and*

(iii) A cutting radius between 0.1 and 5.0 mm, inclusive.

(g) Specially designed components or sub-assemblies, as follows, capable of upgrading, according to the manufacturer's specifications, "numerical control" units, motion control boards, machine tools, or feedback devices to or above the levels controlled in sub-items (a), (b), (c), (f)(2), or (f)(3):

(1) Printed circuit boards with mounted components and "software" therefor;

(2) "Compound rotary tables."

Technical Note: Definitions of Terms:

"accuracy" - Usually measured in terms of inaccuracy, defined as the maximum deviation, positive or negative, of an indicated value from an accepted standard or true value.

"adaptive control" - a control system that adjusts the response from conditions detected during the operation (Ref. ISO 2806-1980).

"camming" (axial displacement) - Axial displacement in one revolution of the main spindle measured in a plane perpendicular to the spindle faceplate at a point next to the circumference of the spindle faceplate (Ref. ISO 230 Part 1-1986, paragraph 5.63).

“compound rotary table” - A table allowing the workpiece to rotate and tilt about two non-parallel axes, which can be coordinated simultaneously for “contouring control.”

“contouring control” - Two or more “numerically controlled” motions operating in accordance with instructions that specify the next required position and the required feed rates to that position. These feed rates are varied in relation to each other so that a desired contour is generated (Ref. ISO/DIS 2806-1980).

“digital computer” - Equipment which can, in the form of one or more discrete variables:

a. Accept data;
b. Store data or instructions in fixed or alterable (writable) storage devices;
c. Process data by means of a stored sequence of instructions which is modifiable; and
d. Provide output of data.

N.B.: Modifications of a stored sequence of instructions include replacement of fixed storage devices, but not a physical change in wiring or interconnections.

“flexible manufacturing unit (FMU)” [sometimes also referred to as “flexible manufacturing system (FMS)” or “flexible manufacturing cell (FMC)”]

An entity which includes a combination of at least:

a. A “digital computer” including its own “main storage” and its own related equipment; and
b. Two or more of the following:
    1. A machine tool described in Section 1.2.;
    2. A dimensional inspection machine described in Section 1.3.;
    3. A “robot” controlled by Section 1.6.;
    4. Digitally controlled equipment controlled by Section 3.4.

“laser” - An assembly of components which produce coherent light that is amplified by stimulated emission of radiation.

“main storage” - The primary storage for data or instructions for rapid access by a central processing unit. It consists of the internal storage of a “digital computer”and any hierarchical extension thereto, such as cache storage or non-sequentially accessed mended storage.

“microprogram” - A sequence of elementary instructions, maintained in a special storage, the execution of which is initiated by the introduction of its reference instruction into an instruction register.

“motion control board” - An electronic assembly specially designed to provide a computer system with the capability to coordinate simultaneously the motion of axes of machine tools for “contouring control”

“numerical control” - The automatic control of a process performed by a device that makes use of numeric data usually introduced as the operation is in progress (Ref. ISO 2382).

“part program” - An ordered set of instructions in a language and in a format required to cause operations to be effected under automatic control, which is either written in the form

of a machine program on an input medium or prepared as input data for processing in a computer to obtain a machine program (Ref. ISO 2806-1980).

"positioning accuracy"

Of "numerically controlled" machine tools is to be determined and presented in accordance with paragraph 2.13, in conjunction with the requirements below:

(a) Test conditions (ISO/DIS/230/2, paragraph 3):
  (1) For 12 hours before and during measurements, the machine tool and accuracy measuring equipment will be kept at the same ambient temperature. During the premeasurement time, the slides of the machine will be continuously cycled identically to the way they will be cycled during the accuracy measurements;
  (2) The machine shall be equipped with any mechanical, electronic, or software compensation to be exported with the machine;
  (3) Accuracy of measuring equipment for the measurements shall be at least four times more accurate than the expected machine tool accuracy;
  (4) Power supply for slide drives shall be as follows:
    (i) Line voltage variation shall not be greater than $\pm$ 10% of nominal rated voltage;
    (ii) Frequency variation shall not be greater than $\pm$ 2 Hz of normal frequency;
    (iii) Lineouts or interrupted service are not permitted.

(b) Test Program (paragraph 4):
  (1) Feed rate (velocity of slides) during measurement shall be the rapid traverse rate;
    N.B.: In the case of machine tools which generate optical quality surfaces, the feed rate shall be equal to or less than 50 mm per minute;
  (2) Measurements shall be made in an incremental manner from one limit of the axis travel to the other without returning to the starting position for each move to the target position;
  (3) Axes not being measured shall be retained at mid-travel during test of an axis.

(c) Presentation of test results (paragraph 2):
  The results of the measurements must include:
  (1) "positioning accuracy" (A) *and*
  (2) The mean reversal error (B).

"program" - A sequence of instructions to carry out a process in, or convertible into, a form executable by an electronic computer.

"real-time processing" - Processing of data by an electronic computer in response to an external event according to time requirements imposed by the external event.

"robot" - A manipulation mechanism, which may be of the continuous path or of the point-to-point variety, may use "sensors" and has all the following characteristics:

a. Is multifunctional;
b. Is capable of positioning or orienting material, parts, tools or special devices through variable movements in three-dimensional space;

c. incorporates three or more closed or open loop servo-devices which may include stepping motors; and
d. Has "user-accessible programmability" by means of teach/playback method or by means of an electronic computer which may be a programmable logic controller, i.e., without mechanical intervention

N.B.: The above definition does not include the following devices:
a. Manipulation mechanisms which are only manually/teleoperator controllable;
b. Fixed sequence manipulation mechanisms which are automated moving devices, operating according to mechanically fixed programmed motions. The program is mechanically limited by fixed stops, such as pins or cams. The sequence of motions and the selection of paths or angles are not variable or changeable by mechanical, electronic or electrical means;
c. Mechanically controlled variable sequence manipulation mechanisms which are automated moving devices, operating according to mechanically fixed programmed motions. The program is mechanically limited by fixed, but adjustable, stops, such as pins or cams. The sequence of motions and the selection of paths or angles are variable within the fixed program pattern. Variations or modifications of the program pattern (e.g., changes of pins or exchanges of cams) in one or more motion axes are accomplished only through mechanical operations;
d. Non-servo-controlled variable sequence manipulation mechanisms which are automated moving devices, operating according to mechanically fixed programmed motions. The program is variable, but the sequence proceeds only by the binary signal from mechanically fixed electrical binary devices or adjustable stops;
e. Stacker cranes defined as Cartesian coordinate manipulator systems manufactured as an integral part of a vertical array of storage bins and designed to access the contents of those bins for storage or retrieval.

"run out" (out-of-true running) - Radial displacement in one revolution of the main spindle measured in a plane perpendicular to the spindle axis at a point on the external or internal revolving surface to be tested (Ref. ISO 230 Part 1-1986, paragraph 5.61).

"sensors" - Detectors of a physical phenomenon, the output of which (after conversion into a signal that can be interpreted by a controller) is able to generate "programs" or modify programmed instructions or numerical program data. This includes "sensors" with machine vision, infrared imaging, acoustical imaging, tactile feel, inertial position measuring, optical or acoustic ranging or force or torque measuring capabilities.

"software" - A collection of one or more "programs" or "microprograms" fixed in any tangible medium of expression.

"tilting spindle" - A tool-holding spindle that, during the machining process, alters the angular position of its center line with respect to any other axis.

“user-accessible programmability”

The facility allowing a user to insert, modify of replace “programs” by means other than:

(a) A physical change in wiring or interconnections; or

(b) The setting of function controls including entry of parameters.