NRRC Specific Regulations

National Nuclear Regulatory Controlled Items

NRRC-R-18-SR01

هيئة الرقابة النووية والإشعاعية
Nuclear and Radiological Regulatory Commission

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Specific Regulation

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Preamble

In accordance with the provisions of the Notification on and Authorization of Facilities and Activities with Radiation Sources Regulation (NRRC-R-02), and the provisions of the Authorization and Regulatory Control of Nuclear-Related Items Regulation (NRRC-R-18), approved by the NRRC's Board of Directors in resolution No. (R/1/1/2022), dated 20 April 2022, chapter (1) section (1) article (1) and chapter (1) section (2) article (2), respectively. This specific regulation classifies national nuclear regulatory controlled items that are subject to authorization (Annex A items) and notification (Annex B items), for the purpose of non-proliferation of nuclear weapons.

This specific regulation has been prepared on the basis of International Atomic Energy Agency (IAEA) standards, international best practices and the experiences of similar international regulatory bodies, and in accordance with the Kingdom's international commitments, and it has been approved by the NRRC's CEO resolution No. 1094, dated 22 March 2023.

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Chapter 1: Objective, Scope, and Definitions

Section 1: Objective

1. This specific regulation classifies national nuclear regulatory controlled items that are subject to authorization (Annex A items) and notification (Annex B items), for the purpose of non-proliferation of nuclear weapons.

Section 2: Scope

2. This specific regulation applies to the development, production, possession, use, import, export, re-export, transfer, transit, and trans-shipment of nuclear regulatory controlled items, including technology and software, and any other activities related to non-proliferation of nuclear weapons.

3. This specific regulation classifies the national nuclear regulatory controlled items that are subject to authorization (Annex A items) and notification (Annex B items), for the purpose of non-proliferation of nuclear weapons.

Section 3: Definitions

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.

Angular position deviation

The maximum difference between angular position and the actual, very accurately measured angular position after the workpiece mount of the table has been turned out of its initial position.

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 towards a specific practical aim or objective.

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. International Organization for Standardization (ISO 2806: 1994) as amended).

Fibrous or filamentary materials

Means continuous monofilaments, yarns, rovings, tows or tapes.

NOTE:

1. **Filament or monofilament:** is the smallest increment of fiber, usually several μm in diameter.
2. **Roving:** is a bundle (typically 12-120) of approximately parallel strands.
3. **Strand:** is a bundle of filaments (typically over 200) arranged approximately parallel.
4. **Tape:** is a material constructed of interlaced or unidirectional filaments, strands, rovings, tows or yarns, etc., usually preimpregnated with resin.

5. **Tow:** is a bundle of filaments, usually approximately parallel.

6. **Yarn:** is a bundle of twisted strands.

Filament

See "Fibrous or filamentary materials".

In the public domain

As it applies herein, means technology or software that has been made available without restrictions upon its further dissemination. (Copyright restrictions do not remove technology or software from being in the public domain).

Linearity

(Usually measured in terms of non-linearity) 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.

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.

Microprograms

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.

Monofilament

See "Fibrous or filamentary materials".

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: 2015).

Positioning accuracy

of numerically controlled machine tools is to be determined and presented in accordance with item 1-B-2, in conjunction with the requirements below:

A. Test conditions (ISO 230/2: 1988, paragraph-3):

1. For 12 h 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:

   - Line voltage variation shall not be greater than ± 10% of nominal rated voltage.

- Frequency variation shall not be greater than ± 2 Hz of normal frequency.
- Lineouts or interrupted service are not permitted.

B. Test program (ISO 230/2: 1988, paragraph-4):

1. Feed rate (velocity of slides) during measurement shall be the rapid traverse rate.

   NOTE:

   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 the test results (ISO 230/2: 1988, paragraph-2):

The results of the measurements must include:

1. Positioning accuracy (A); and
2. The mean reversal error (B).

Other elements

All elements other than hydrogen, uranium, and plutonium.

Program

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

Resolution

The least increment of a measuring device; on digital instruments, the least significant bit. (Ref. American National Standards Institute (ANSI) B-89.1.12).

Use

Operation, installation (including on-site installation), maintenance (checking), repair, overhaul, or refurbishing.

Ionizing radiation

Radiation capable of creating ion pairs in biological materials.

Radioisotope

The unstable form of an element that emits radiation to transform into a more stable form.

Chapter 2: National Nuclear Regulatory Controlled Items

ANNEX A: First List

ANNEX A1: Material and Equipment

This list includes nuclear materials, ores, radioactive materials, and primary nuclear related items, which are subject to an authorization from the NRRC prior to carrying out any activity, in accordance with Regulation on Notification on and Authorization of Facilities and Activities with Radiation Sources (NRRC-R-02).

Technology Control:

The transfer of technology directly associated with any item in the First List will be subject to as great a degree of scrutiny and control as will the item itself, to the extent permitted by the NRRC's regulations.

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

Software Control:

The transfer of software especially designed or prepared for the development, production or use of any item in the First List will be subject to as great a degree of scrutiny and controls as will the item itself, to the extent permitted by the NRRC's regulations.

1. **Source Material, Special Fissionable Material and Other Radioactive Materials and Isotopes**

   As defined in Article XX of the Statute of the International Atomic Energy Agency:

1-1 Source material

The term "source material" means uranium containing the mixture of isotopes occurring in nature; uranium depleted in the isotope 235; thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate; any other material containing one or more of the foregoing in such concentration as the IAEA shall from time to time determine and endorsed by the NRRC; and such other material as the IAEA shall from time to time determine and endorsed by the NRRC.

1-2 Special fissionable material

1. The term "special fissionable material" means plutonium-239 (^{239}Pu); uranium-233 (^{233}U); uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing; and such other fissionable material in any form – including the nuclear fuel, as the IAEA shall from time to time determine and endorsed by the NRRC; but the term "special fissionable material" does not include source material;

2. The term "uranium enriched in the isotopes 235 or 233" means uranium containing the isotopes 235 or 233 or both in an amount such that the abundance ratio of the sum of these isotopes to the isotope 238 is greater than the ratio of the isotope 235 to the isotope 238 occurring in nature.

1-3 Radioactive materials and isotopes, other than those mentioned in 1-1 & 1-2

Any material or isotope that emits ionizing radiation (other than those mentioned in 1-1 and 1-2).

1-4 Ore (mineral)

A mineral or a natural chemical aggregate containing any quantity of uranium or thorium in a quantity and of a quality that makes mining and extracting the uranium and thorium economically viable.

1-5 Natural calcium phosphates and natural aluminum calcium phosphates ground & unground

2- Primary Nuclear-Related Items

The designation of primary nuclear related items adopted by the NRRC is as follows:

2-1 Nuclear reactors and especially designed or prepared equipment and components therefor (see Annex A2, section 1);

2-2 Non-nuclear materials (see Annex A2, section 2);

2-3 Plants for the reprocessing of irradiated fuel elements, and equipment especially designed or prepared therefor (see Annex A2, section 3);

2-4 Plants for the fabrication of nuclear reactor fuel elements, and equipment especially designed or prepared therefor (see Annex A2, section 4);

2-5 Plants for the separation of isotopes of natural uranium, depleted uranium or special fissionable material and equipment, other than analytical instruments, especially designed or prepared therefor (see Annex A2, section 5);

2-6 Plants for the production or concentration of heavy water, deuterium and deuterium compounds and equipment especially designed or prepared therefor (see Annex A2, section 6);

2-7 Plants for the conversion of uranium and plutonium for use in the fabrication of fuel elements and the separation of uranium isotopes as defined in sections 4 and 5 respectively, and equipment especially designed or prepared therefor (see Annex A2, section 7);

2-8 Tritium facilities or plants, equipment, and components therefor (see Annex A2, section 8);

2-9 Lithium isotope separation facilities or plants, and systems and equipment therefor (see Annex A2, section 9).

ANNEX A2: Clarification of Items on the Primary Nuclear-Related Items

NOTE:

The International System of Units (SI) is used in this Annex. In all cases, the physical quantity defined in SI units should be considered the official recommended control value.

Commonly used abbreviations (and their prefixes denoting size) in the Annex are as follows:

Parameter	(SI) Unit
Electrical current	Amperes (A) Milliamperes (mA)
Length	Nanometer (nm) Micrometer (μm) Millimeter (mm) Centimeter (cm) Meter (m)
Area	Square centimeter (cm^2) Square meter (m^2)
Volume	Cubic centimeter (cm^3) Cubic meter (m^3) Milliliter (mL) Liter (L)
Angle	Degree (°)
Temperature	Degree Celsius (°C)
Mass	Gram (g) Kilogram (kg)
Acceleration	Acceleration of gravity (9.80665 m/s^2) (g_0)
Radioactive activity	Giga-becquerel (GBq)

Parameter	(SI) Unit
Pressure	Pascal (Pa) Kilopascal (kPa) Megapascal (MPa) Gigapascal (GPa)
Absorbed ionizing radiation	Gray (Gy)
Frequency	Hertz (Hz) Kilohertz (kHz)
Energy, Work, Heat	Joule (J)
Electronic energy	Kiloelectron volt (keV) Megaelectron volt (MeV)
Force	Newton (N) Kilonewton (kN)
Voltage	Volts (V) Kilovolts (kV)
Power	Kilowatts (kW) Megawatts (MW)
Thermodynamic temperature	Kelvin (K)
Time	Picosecond (ps) Nanosecond (ns) Microsecond (μs) Second (s) Minute (m) Hour (h)
Angular velocity	Revolution per minute (rpm)
Magnetic flux density	Tesla (T)
Chemical Abstracts Service	CAS
Electrical power	Volt-ampere (VA)

1- Nuclear Reactors and Especially Designed or Prepared Equipment and Components Therefor

NOTE:

Various types of nuclear reactors may be characterized by the moderator used (e.g., graphite, heavy water, light water, none), the spectrum of neutrons therein (e.g., thermal, fast), the type of coolant used (e.g., water, liquid metal, molten salt, gas), or by their function or type (e.g., power reactors, research reactors, test reactors). It is intended that all of these types of nuclear reactors are within scope of this specific regulation.

1-1 Complete nuclear reactors

Nuclear reactors capable of operation so as to maintain a controlled self-sustaining fission chain reaction.

NOTE:

A nuclear reactor basically includes the items within or attached directly to the reactor vessel, the equipment which controls the level of power in the core, and the components which normally contain or come in direct contact with or control the primary coolant of the reactor core.

1-2 Nuclear reactor vessels

Metal vessels, or major shop-fabricated parts therefor, especially designed or prepared to contain the core of a nuclear reactor as defined in item 1-1 above, as well as relevant reactor internals as defined in item 1-8 below.

NOTE:

Item 1-2 covers nuclear reactor vessels regardless of pressure rating and includes reactor pressure vessels and calandrias. The reactor vessel head is covered by item 1-2 as a major shop-fabricated part of a reactor vessel.

1-3 Nuclear reactor fuel charging and discharging machines

Manipulative equipment especially designed or prepared for inserting or removing fuel in a nuclear reactor as defined in item 1-1 above.

NOTE:

The items noted above are capable of on-load operation or at employing technically sophisticated positioning or alignment features to allow complex off-load fuelling operations such as those in which direct viewing of or access to the fuel is not normally available.

1-4 Nuclear reactor control rods and equipment

Especially designed or prepared rods, support, or suspension structures therefor, rod drive mechanisms or rod guide tubes to control the fission process in a nuclear reactor as defined in item 1-1 above.

1-5 Nuclear reactor pressure tubes

Tubes which are especially designed or prepared to contain both fuel elements and the primary coolant in a reactor as defined in item 1-1 above.

NOTE:

Pressure tubes are parts of fuel channels designed to operate at elevated pressure, sometimes in excess of 5 MPa.

1-6 Nuclear fuel cladding

Zirconium metal tubes or zirconium alloy tubes (or assemblies of tubes) especially designed or prepared for use as fuel cladding in a reactor as defined in item 1-1 above, and in quantities exceeding 10 kg.

NOTE:

For zirconium pressure tubes see item 1-5, for calandria tubes see item 1-8.

Zirconium metal tubes or zirconium alloy tubes for use in a nuclear reactor consist of zirconium in which the relation of hafnium to zirconium is typically less than 1:500 parts by weight.

1-7 Primary coolant pumps or circulators

Pumps or circulators especially designed or prepared for circulating the primary coolant for nuclear reactors as defined in item 1-1 above.

NOTE:

Especially designed or prepared pumps or circulators include pumps for water-cooled reactors, circulators for gas-cooled reactors, and electromagnetic and mechanical pumps for liquid-metal-cooled reactors. This equipment may include pumps with elaborate sealed or multi-sealed systems to prevent leakage of primary coolant, canned-driven pumps, and pumps with inertial mass systems. This definition encompasses pumps certified to Section III, Division I, Subsection NB (Class 1 components) of the American Society of Mechanical Engineers (ASME) Code, or equivalent standards.

1-8 Nuclear reactor internals

Nuclear reactor internals especially designed or prepared for use in a nuclear reactor as defined in item 1-1 above. This includes, for example, support columns for the core, fuel channels, calandria tubes, thermal shields, baffles, core grid plates, and diffuser plates.

NOTE:

Nuclear reactor internals are major structures within a reactor vessel which have one or more functions such as supporting the core, maintaining fuel alignment, directing primary coolant flow, providing radiation shields for the reactor vessel, and guiding in-core instrumentation.

1-9 Heat exchangers

A. Steam generators especially designed or prepared for the primary or intermediate coolant circuit of a nuclear reactor as defined in item 1-1 above.

B. Other heat exchangers especially designed or prepared for use in the primary coolant circuit of a nuclear reactor as defined in item 1-1 above.

NOTE:

Steam generators are especially designed or prepared to transfer the heat generated in the reactor to the feed water for steam generation. In the case of a fast reactor for which an intermediate coolant loop is also present, the steam generator is in the intermediate circuit.

In a gas-cooled reactor, a heat exchanger may be utilized to transfer heat to a secondary gas loop that drives a gas turbine.

The scope of control for this item does not include heat exchangers for the supporting systems of the reactor (e.g., the emergency cooling system or the decay heat cooling system).

1-10 Neutron detectors

Especially designed or prepared neutron detectors for determining neutron flux levels within the core of a reactor as defined in item 1-1 above.

NOTE:

The scope of this item encompasses in-core and ex-core detectors which measure flux levels in a wide range, typically from 10^4 neutrons per cm^2 per second or more. Ex-core refers to those instruments outside the core of a reactor as defined in item 1-1 above, but located within the biological shielding.

1-11 External thermal shields

External thermal shields especially designed or prepared for use in a nuclear reactor as defined in item 1-1 for reduction of heat loss and also for containment vessel protection.

NOTE:

External thermal shields are major structures placed over the reactor vessel which reduce heat loss from the reactor and reduce temperature within the containment vessel.

2- Non-Nuclear Materials

2-1 Deuterium and heavy water

Deuterium, heavy water (deuterium oxide) and any other deuterium compound in which the ratio of deuterium to hydrogen atoms exceeds 1:5000 for use in a nuclear reactor as defined in item 1-1 above.

2-2 Nuclear grade graphite

Graphite having a purity level better than 5 ppm (parts per million) boron equivalent and with a density greater than 1.50 g/cm^3 for use in a nuclear reactor as defined in item 1-1 above.

NOTE:

For the purpose of export and import control, the NRRC will determine whether or not the exports and imports of graphite meeting the above specifications are for nuclear reactor use. Graphite having a purity level better than 5 ppm boron equivalent and with a density greater than

1.50 g/cm^3 not for use in a nuclear reactor as defined in item 1-1 above is not covered by this item.

Boron Equivalent (BE) may be determined experimentally or is calculated as the sum of BE_z for impurities (excluding BE_{carbon} since carbon is not considered an impurity) including boron, where:

BE_z ppm = CF × concentration of element Z (in ppm);

CF is the conversion factor: $(\sigma_z \times A_B)$ divided by $(\sigma_B \times A_z)$;

σ_B and σ_z are the thermal neutron capture cross sections (in barns) for naturally occurring boron and element Z respectively; and

A_B and A_z are the atomic masses of naturally occurring boron and element Z respectively.

2-3 Maraging steel capable of an ultimate tensile strength of 1950 MPa or more at 293 K (20°C)

NOTE:

Item 2-3 does not control forms in which all linear dimensions are 75 mm or less.

In item 2-3, the phrase "capable of" encompasses maraging steel before or after heat treatment.

2-4 Radium-226 (^{226}Ra), radium-226 alloys, radium-226 compounds, mixtures containing radium-226, manufactures thereof, and products or devices containing any of the foregoing

NOTE:

Item 2-4 does not control the following:

1. Medical applicators;
2. A product or device containing less than 0.37 GBq of radium-226.

2-5 Titanium alloys having both of the following characteristics:

- Capable of an ultimate tensile strength of 900 MPa or more at 293 K (20°C); and
- In the form of tubes or cylindrical solid forms (including forgings) with an outside diameter of more than 75 mm.

NOTE:

In item 2-5, the phrase "capable of" encompasses titanium alloys before or after heat treatment.

2-6 Tungsten, tungsten carbide, and alloys containing more than 90% tungsten by weight, having both of the following characteristics:

- In forms with a hollow cylindrical symmetry (including cylinder segments) with an inside diameter between 100 and 300 mm; and
- A mass greater than 20 kg.

NOTE:

Item 2-6 does not control manufactures specially designed as weights or gamma-ray collimators.

2-7 **Hafnium metal, alloys containing more than 60% hafnium by weight, hafnium compounds containing more than 60% hafnium by weight, manufactures thereof, and waste or scrap of any of the foregoing**

2-8 **Tritium, tritium compounds, mixtures containing tritium in which the ratio of tritium to hydrogen atoms exceeds 1 part in 1000, and products or devices containing any of the foregoing**

NOTE:

Item 2-8 does not control a product or device containing less than 1.48×10^3 GBq of tritium.

2-9 **Helium-3 (^{3}He), mixtures containing helium-3, and products or devices containing any of the foregoing**

NOTE:

Item 2-9 does not control a product or device containing less than 1 g of helium-3.

2-10 **Radionuclides appropriate for making neutron sources based on alpha-n reaction:**

Actinium-225 (^{225}Ac)	Curium-244 (^{244}Cm)	Polonium-209 (^{209}Po)
Actinium-227 (^{227}Ac)	Einsteinium-253 (^{253}Es)	Polonium-210 (^{210}Po)
Californium-253 (^{253}Cf)	Einsteinium-254 (^{254}Es)	Radium-223 (^{223}Ra)
Curium-240 (^{240}Cm)	Gadolinium-148 (^{148}Gd)	Thorium-227 (^{227}Th)
Curium-241 (^{241}Cm)	Plutonium-236 (^{236}Pu)	Thorium-228 (^{228}Th)
Curium-242 (^{242}Cm)	Plutonium-238 (^{238}Pu)	Uranium-230 (^{230}U)
Curium-243 (^{243}Cm)	Polonium-208 (^{208}Po)	Uranium-232 (^{232}U)

In the following forms:

A. Elemental;

B. Compounds having a total activity of 37 GBq per kg or greater;

C. Mixtures having a total activity of 37 GBq per kg or greater;

D. Products or devices containing any of the foregoing.

NOTE:

Item 2-10 does not control a product or device containing less than 3.7 GBq of activity

2-11 Fibrous or filamentary materials, and prepregs, as follows:

A. Carbon or aramid fibrous or filamentary materials having either of the following characteristics:

- A specific modulus of 12.7×10^6 m or greater; or
- A specific tensile strength of 23.5×10^4 m or greater.

NOTE:

Item 2-11-A does not control aramid fibrous or filamentary materials having 0.25% or more by weight of an ester based fibre surface modifier.

B. Glass fibrous or filamentary materials having both of the following characteristics:

- A specific modulus of 3.18×10^6 m or greater; and
- A specific tensile strength of 7.62×10^4 m or greater.

C. Thermoset resin impregnated continuous yarns, rovings, tows or tapes with a width of 15 mm or less (prepregs), made from carbon or glass fibrous or filamentary materials specified in item 2-11-A or item 2-11-B.

NOTE:

The resin forms the matrix of the composite.

In item 2-11, 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 296 ± 2K (23 ± 2 °C) and a relative humidity of 50 ± 5%.

In item 2-11, 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 296 ± 2K (23 ± 2°C) and a relative humidity of 50 ± 5%.

2-12 Composite structures in the form of tubes having both of the following characteristics:

- An inside diameter of between 75 and 400 mm; and
- Made with any of the fibrous or filamentary materials specified in item 2-11-A or carbon prepreg materials specified in item 2-11-C.

3- Plants for the Reprocessing of Irradiated Fuel Elements, and Equipment Especially Designed or Prepared Therefor

Reprocessing irradiated nuclear fuel separates plutonium and uranium from intensely radioactive fission products and other transuranic elements. Different technical processes can accomplish this separation. However, over the years Purex has become the most commonly used and accepted process. Purex involves the dissolution of irradiated nuclear fuel in nitric acid, followed by separation of the uranium, plutonium, and fission products by solvent extraction using a mixture of tributyl phosphate in an organic diluent.

Purex facilities have process functions similar to each other, including irradiated fuel element decladding and/or chopping, fuel dissolution, solvent extraction, and process liquor storage. There may also be equipment for thermal denitration of uranium nitrate, conversion of plutonium nitrate to oxide or metal, and treatment of fission product waste liquor to a form suitable for long term storage or disposal. However, the specific type and configuration of the equipment performing these functions may differ between Purex facilities for several reasons, including the type and quantity of irradiated nuclear fuel to be reprocessed and the intended disposition of the recovered materials, and the safety and maintenance philosophy incorporated into the design of the facility.

A plant for the reprocessing of irradiated fuel elements includes the equipment and components which normally come in direct contact with and directly control the irradiated fuel and the major nuclear material and fission product processing streams.

These processes, including the complete systems for plutonium conversion and plutonium metal production, may be identified by the measures taken to avoid criticality (e.g., by geometry), radiation exposure (e.g., by shielding), and toxicity hazards (e.g., by containment).

Items of equipment that are considered to fall within the meaning of the phrase "and equipment especially designed or prepared" for the reprocessing of irradiated fuel elements include:

3-1 Irradiated fuel element decladding equipment and chopping machines

Remotely operated equipment especially designed or prepared for use in a reprocessing plant as identified above and intended to expose or prepare the irradiated nuclear material in fuel assemblies, bundles, or rods for processing.

NOTE:

This equipment cuts, chops, shears, or otherwise breaches the cladding of the fuel to expose the irradiated nuclear material for processing or prepares the fuel for processing. Especially designed cutting shears are most commonly employed, although advanced equipment, such as lasers, peeling machines, or other techniques, may be used. Decladding involves removing the cladding of the irradiated nuclear fuel prior to its dissolution.

3-2 Dissolvers

Dissolver vessels or dissolvers employing mechanical devices especially designed or prepared for use in a reprocessing plant as identified above, intended for dissolution of irradiated nuclear fuel and which are capable of withstanding hot, highly corrosive liquid, and which can be remotely loaded, operated, and maintained.

NOTE:

Dissolvers normally receive the solid, irradiated nuclear fuel. Nuclear fuels with cladding made of material including zirconium, stainless steel, or alloys of such materials must be decladded and/or sheared or chopped prior to being charged to the dissolver to allow the acid to reach the fuel matrix. The irradiated nuclear fuel is typically dissolved in strong mineral acids, such as nitric acid, and any undissolved cladding removed. While certain design features, such as small diameter, annular, or slab tanks, may be used to ensure criticality safety, they are not a necessity. Administrative controls, such as small batch size or low fissile material content, may be used instead. Dissolver vessels and dissolvers employing mechanical devices are normally fabricated of material such as low carbon stainless steel, titanium or zirconium, or other high-quality materials. Dissolvers may include systems for the removal of cladding or cladding waste and systems for the control and treatment of radioactive off-gases. These dissolvers may have features for remote placement since they are normally loaded, operated, and maintained behind thick shielding.

3-3 Solvent extractors and solvent extraction equipment

Especially designed or prepared solvent extractors (such as packed or pulse columns, mixer settlers or centrifugal contactors) for use in a plant for the reprocessing of irradiated fuel. Solvent extractors must be resistant to the corrosive effect of nitric acid. Solvent extractors are normally fabricated to extremely high standards (including special welding and inspection and quality assurance and quality control techniques) out of low carbon stainless steels, titanium, zirconium, or other high quality materials.

NOTE:

Solvent extractors both receive the solution of irradiated fuel from the dissolvers and the organic solution which separates the uranium, plutonium, and fission products. Solvent extraction equipment is normally designed to meet strict operating parameters, such as long operating lifetimes with no maintenance requirements or adaptability to easy replacement, simplicity of operation and control, and flexibility for variations in process conditions.

3-4 Chemical holding or storage vessels

Especially designed or prepared holding or storage vessels for use in a plant for the reprocessing of irradiated fuel. The holding or storage vessels must be resistant to the corrosive effect of nitric acid. The holding or storage vessels are normally fabricated of materials such as low carbon stainless steels, titanium or zirconium, or other high quality materials. Holding or storage vessels may be designed for remote operation and maintenance and may have the following features for control of nuclear criticality:

1. Walls or internal structures with a boron equivalent of at least 2%;
2. A maximum diameter of 175 mm for cylindrical vessels; or
3. A maximum width of 75 mm for either a slab or annular vessel.

NOTE:

Three main process liquor streams result from the solvent extraction step. Holding or storage vessels are used in the further processing of all three streams, as follows:

A. The pure uranium nitrate solution is concentrated by evaporation and passed to a denitration process where it is converted to uranium oxide. This oxide is re-used in the nuclear fuel cycle.

B. The intensely radioactive fission products solution is normally concentrated by evaporation and stored as a liquor concentrate. This concentrate may be subsequently evaporated and converted to a form suitable for storage or disposal.

C. The pure plutonium nitrate solution is concentrated and stored pending its transfer to further process steps. In particular, holding or storage vessels for plutonium solutions are designed to avoid criticality problems resulting from changes in concentration and form of this stream.

3-5 Neutron measurement systems for process control

Neutron measurement systems especially designed or prepared for integration and use with automated process control systems in a plant for the reprocessing of irradiated fuel elements.

NOTE:

These systems involve the capability of active and passive neutron measurement and discrimination in order to determine the fissile material quantity and composition. The complete system is composed of a neutron generator, a neutron detector, amplifiers, and signal processing electronics.

4- Plants for the Fabrication of Nuclear Reactor Fuel Elements, and Equipment Especially Designed or Prepared Therefor

NOTE:

Nuclear fuel elements are manufactured from one or more of the source or special fissionable materials mentioned in Material and Equipment of this Annex. For oxide fuels, the most common type of fuel, equipment for pressing pellets, sintering, grinding, and grading will be present. Mixed oxide fuels are handled in glove boxes (or equivalent containment) until they are sealed in the cladding. In all cases, the fuel is hermetically sealed inside a suitable cladding which is designed to be the primary envelope encasing the fuel so as to provide suitable performance and safety during reactor operation. Also, in all cases, precise control of processes, procedures and equipment to extremely high standards is necessary in order to ensure predictable and safe fuel performance.

Items of equipment that are considered to fall within the meaning of the phrase "and equipment especially designed or prepared" for the fabrication of fuel elements include equipment which:

A. Normally comes in direct contact with, or directly processes, or controls, the production flow of nuclear material;

B. Seals the nuclear material within the cladding;

C. Checks the integrity of the cladding or the seal;

D. Checks the finish treatment of the sealed fuel; or

E. Is used for assembling reactor fuel elements.

Such equipment or systems of equipment may include, for example:

1. Fully automatic pellet inspection stations especially designed or prepared for checking final dimensions and surface defects of the fuel pellets;

2. Automatic welding machines especially designed or prepared for welding end caps onto the fuel pins (or rods);

3. Automatic test and inspection stations especially designed or prepared for checking the integrity of completed fuel pins (or rods);

4. Systems especially designed or prepared to manufacture nuclear fuel cladding.

Item 3 typically includes equipment for:

A. X-ray examination of pin (or rod) end cap welds;

B. Helium leak detection from pressurized pins (or rods);

C. Gamma-ray scanning of the pins (or rods) to check for correct loading of the fuel pellets inside.

5- Plants for the Separation of Isotopes of Natural Uranium, Depleted Uranium or Special Fissionable Material and Equipment, other than Analytical Instruments, Especially Designed or Prepared Therefor

NOTE:

Plants, equipment, and technology for the separation of uranium isotopes have, in many instances, a close relationship to plants, equipment and technology for isotope separation of other elements. In particular cases, the controls under section 5 also apply to plants and equipment that are intended for isotope separation of other elements. These controls of plants and equipment for isotope separation of other elements are complementary to controls on plants and equipment especially designed or prepared for the processing, use or production of special fissionable material covered by Annex A1.

Processes for which the controls in section 5 equally apply whether the intended use is uranium isotope separation or isotope separation of other elements are: gas centrifuge, gaseous diffusion, the plasma separation process, and aerodynamic processes.

For some processes, the relationship to uranium isotope separation depends on the element being separated. These processes are: laser-based processes (e.g., molecular laser isotope separation and atomic vapor laser isotope separation), chemical exchange, and ion exchange. For this purpose, the NRRC will evaluate based on these processes on a case-by-case basis to apply section 5 controls for uses involving other elements accordingly.

Items of equipment that are considered to fall within the meaning of the phrase "equipment, other than analytical instruments, especially designed or prepared" for the separation of isotopes of uranium include:

5-1 Gas centrifuges and assemblies and components especially designed or prepared for use in gas centrifuges

NOTE:

The gas centrifuge normally consists of a thin-walled cylinder of between 75 mm and 650 mm diameter contained in a vacuum environment and spun at high peripheral speed of the order of 300 m/s or more with its central axis vertical. In order to achieve high speed the materials of construction for the rotating components have to be of a high strength to density ratio and the rotor assembly, and hence its individual components, have to be manufactured to very close tolerances in order to minimize the unbalance. In contrast to other centrifuges, the gas centrifuge for uranium enrichment is characterized by having within the rotor chamber a rotating disc-shaped baffle (or baffles) and a stationary tube arrangement for feeding and extracting the uranium hexafluoride (UF_6) gas and featuring at least three separate channels, of which two are connected to scoops extending from the rotor axis towards the periphery of the rotor chamber. Also contained within the vacuum environment are a number of critical items which do not rotate and, which although they are especially designed, are not difficult to fabricate nor are they fabricated out of unique materials. A centrifuge facility however requires a large number of these components, so that quantities can provide an important indication of end use.

5-1-1 Rotating components

A. Complete rotor assemblies

Thin-walled cylinders, or a number of interconnected thin-walled cylinders, manufactured from one or more of the high strength to density ratio materials described in the NOTE to this section. If interconnected, the cylinders are joined together by flexible bellows or rings as described in item 5-1-1-C following. The rotor is fitted with an internal baffle (or baffles) and end caps, as described in item 5-1-1-D and E following, if in final form. However, the complete assembly may be delivered only partly assembled.

B. Rotor tubes

Especially designed or prepared thin-walled cylinders with thickness of 12 mm or less, a diameter of between 75 mm and 650 mm, and manufactured from one or more of the high strength to density ratio materials described in the NOTE to this section.

C. Rings or Bellows

Components especially designed or prepared to give localized support to the rotor tube or to join together a number of rotor tubes. The bellows is a short cylinder of wall thickness 3 mm or less, a diameter of between 75 mm and 650 mm, having a convolute, and manufactured from one of the high strength to density ratio materials described in the NOTE to this section.

D. Baffles

Disc-shaped components of between 75 mm and 650 mm diameter especially designed or prepared to be mounted inside the centrifuge rotor tube, in order to isolate the take-off chamber from the main separation chamber and, in some cases, to assist the UF_6 gas circulation within the main separation chamber of the rotor tube, and manufactured from one of the high strength to density ratio materials described in the NOTE to this section.

E. Top caps/Bottom caps

Disc-shaped components of between 75 mm and 650 mm diameter especially designed or prepared to fit to the ends of the rotor tube, and so contain the UF_6 within the rotor tube, and in some cases to support, retain or contain as an integrated part an element of the upper bearing (top cap) or to carry the rotating elements of the motor and lower bearing (bottom cap), and manufactured from one of the high strength to density ratio materials described in the NOTE to this section.

NOTE:

The materials used for centrifuge rotating components include the following:

A. Maraging steel capable of an ultimate tensile strength of 1.95 GPa or more;

B. Aluminum alloys capable of an ultimate tensile strength of 0.46 GPa or more;

C. Filamentary materials suitable for use in composite structures and having a specific modulus of 3.18×10^6 m or greater and a specific ultimate tensile strength of 7.62×10^4 m or greater. (specific modulus is the Young's modulus in N/m^2 divided by the specific weight in N/m^3; specific ultimate tensile strength is the ultimate tensile strength in N/m^2 divided by the specific weight in N/m^3).

5-1-2 Static components

A. Magnetic suspension bearings

1. Especially designed or prepared bearing assemblies consisting of an annular magnet suspended within a housing containing a damping medium. The housing will be manufactured from a UF_6-resistant material (see NOTE to section 5-2). The magnet couples with a pole piece or a second magnet fitted to the top cap described in item 5-1-1-E. The magnet may be ring-shaped with a relation between outer and inner diameter smaller or equal to 1.6:1. The magnet may be in a form having an initial permeability of 0.15 H/m or more, or a remanence of 98.5% or more, or an energy product of greater than 80 kJ/m^3. In addition to the usual material properties, it is a prerequisite that the deviation of the magnetic axes from the geometrical axes is limited to very small tolerances (lower than 0.1 mm) or that homogeneity of the material of the magnet is specially called for.

2. Active magnetic bearings especially designed or prepared for use in gas centrifuges.

NOTE:

These bearings usually have the following characteristics:

- Designed to keep centered a rotor spinning at 600 Hz or more; and
- Associated to a reliable electrical power supply and/or to an uninterruptible power supply (UPS) unit in order to function for more than one hour.

B. Bearings/Dampers

Especially designed or prepared bearings comprising a pivot/cup assembly mounted on a damper. The pivot is normally a hardened steel shaft with a hemisphere at one end with a means of attachment to the bottom cap described in item 5-1-1-E at the other. The shaft may however have a hydrodynamic bearing attached. The cup is pellet-shaped with a hemispherical indentation in one surface. These components are often supplied separately to the damper.

C. Molecular pumps

Especially designed or prepared cylinders having internally machined or extruded helical grooves and internally machined bores. Typical dimensions are as follows: 75 mm to 650 mm internal diameter, 10 mm or more wall thickness, with the length equal to or greater than the diameter. The grooves are typically rectangular in cross-section and 2 mm or more in depth.

D. Motor stators

Especially designed or prepared ring-shaped stators for high speed multiphase AC hysteresis (or reluctance) motors for synchronous operation within a vacuum at a frequency of 600 Hz or greater and a power of 40 VA or greater. The stators may consist of multi-phase windings on a laminated low loss iron core comprised of thin layers typically 2 mm thick or less.

E. Centrifuge housing/recipients

Components especially designed or prepared to contain the rotor tube assembly of a gas centrifuge. The housing consists of a rigid cylinder of wall thickness up to 30 mm with precision machined ends to locate the bearings and with one or more flanges for mounting. The machined ends are parallel to each other and perpendicular to the cylinder's longitudinal axis to within 0.05° or less. The housing may also be a honeycomb type structure to accommodate several rotor assemblies.

F. Scoops

Especially designed or prepared tubes for the extraction of UF_6 gas from within the rotor tube by a Pitot tube action (that is, with an aperture facing into the circumferential gas flow within the rotor tube, for example by bending the end of a radially disposed tube) and capable of being fixed to the central gas extraction system.

5-2 Especially designed or prepared auxiliary systems, equipment and components for gas centrifuge enrichment plants

NOTE:

The auxiliary systems, equipment and components for a gas centrifuge enrichment plant are the systems of plant needed to feed UF_6 to the centrifuges, to link the individual centrifuges to each other to form cascades (or stages) to allow for progressively higher enrichments and to extract the product and tails UF_6 from the centrifuges, together with the equipment required to drive the centrifuges or to control the plant.

Normally UF_6 is evaporated from the solid using heated autoclaves and is distributed in gaseous form to the centrifuges by way of cascade header pipework. The product and tails UF_6 gas streams flowing from the centrifuges are also passed by way of cascade header pipework to cold traps (operating at about 203 K (-70°C)) where they are condensed prior to onward transfer into suitable containers for transportation or storage. Because an enrichment plant consists of many thousands of centrifuges arranged in cascades there are many kilometers of cascade header pipework, incorporating thousands of welds with a substantial amount of repetition of layout. The equipment, components and piping systems are fabricated to very high vacuum and cleanliness standards.

Some of the items listed below either come into direct contact with the UF_6 process gas or directly control the centrifuges and the passage of the gas from centrifuge to centrifuge and cascade to cascade. Materials resistant to corrosion by UF_6 include copper, copper alloys, stainless steel, aluminum, aluminum oxide, aluminum alloys, nickel or alloys containing 60% by weight or more nickel and fluorinated hydrocarbon polymers.

5-2-1 Feed systems/product and tails withdrawal systems

Especially designed or prepared process systems or equipment for enrichment plants, made of or protected by materials resistant to corrosion by UF_6, including:

A. Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process.

B. Desublimers, cold traps or pumps used to remove UF_6 from the enrichment process for subsequent transfer upon heating.

C. Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form.

D. Product or tails stations used for transferring UF_6 into containers.

5-2-2 Machine header piping systems

Especially designed or prepared piping systems and header systems for handling UF_6 within the centrifuge cascades. The piping network is normally of the triple header system with each centrifuge connected to each of the headers. There is thus a substantial amount of repetition in its form. It is wholly made of or protected by UF_6-resistant materials (see

NOTE to this section) and is fabricated to very high vacuum and cleanliness standards.

5-2-3 Special shut-off and control valves

A. Shut-off valves especially designed or prepared to act on the feed, product, or tails UF_6 gas streams of an individual gas centrifuge.

B. Bellows-sealed valves, manual or automated, shut-off or control, made of or protected by materials resistant to corrosion by UF_6, with an inside diameter of 10 to 160 mm, especially designed or prepared for use in main or auxiliary systems of gas centrifuge enrichment plants.

NOTE:

Typical especially designed or prepared valves include bellow-sealed valves, fast acting closure-types, fast acting valves, and others.

5-2-4 UF_6 mass spectrometers/ion sources

Especially designed or prepared mass spectrometers capable of taking on-line samples from UF_6 gas streams and having all of the following characteristics:

- Capable of measuring ions of 320 atomic mass units or greater and having a resolution of better than 1 part in 320;

- Ion sources constructed of or protected by nickel, nickel-copper alloys with a nickel content of 60% by weight or more, or nickel-chrome alloys;

- Electron bombardment ionization sources; and
- Having a collector system suitable for isotopic analysis.

5-2-5 Frequency changers

Frequency changers (also known as converters or inverters) especially designed or prepared to supply motor stators as defined under item 5-1-2-D, or parts, components and sub-assemblies of such frequency changers having both of the following characteristics:

- A multiphase frequency output of 600 Hz or greater; and
- High stability (with frequency control better than 0.2%).

5-3 Especially designed or prepared assemblies and components for use in gaseous diffusion enrichment

NOTE:

In the gaseous diffusion method of uranium isotope separation, the main technological assembly is a special porous gaseous diffusion barrier, heat exchanger for cooling the gas (which is heated by the process of compression), seal valves and control valves, and pipelines. Inasmuch as gaseous diffusion technology uses UF_6, all equipment, pipeline, and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with UF_6. A gaseous diffusion facility requires a number of these assemblies, so that quantities can provide an important indication of end use.

5-3-1 **Gaseous diffusion barriers and barrier materials**

A. Especially designed or prepared thin, porous filters, with a pore size of 10-100 nm, a thickness of 5 mm or less, and for tubular forms, a diameter of 25 mm or less, made of metallic, polymer or ceramic materials resistant to corrosion by UF_6 (see NOTE to section 5-4).

B. Especially prepared compounds or powders for the manufacture of such filters. Such compounds and powders include nickel or alloys containing 60% by weight or more nickel, aluminum oxide, or UF_6-resistant fully fluorinated hydrocarbon polymers having a purity of 99.9% by weight or more, a particle size less than 10 μm, and a high degree of particle size uniformity, which are especially prepared for the manufacture of gaseous diffusion barriers.

5-3-2 **Diffuser housings**

Especially designed or prepared hermetically sealed vessels for containing the gaseous diffusion barrier, made of or protected by UF_6-resistant materials (see NOTE to section 5-4).

5-3-3 **Compressors and gas blowers**

Especially designed or prepared compressors or gas blowers with a suction volume capacity of 1 m^3 per minute or more of UF_6, with a discharge pressure of up to 500 kPa, and designed for long-term operation in the UF_6 environment, as well as separate assemblies of such compressors and gas blowers. These compressors and gas blowers have a pressure ratio of 10:1 or less and are made of, or protected by, materials resistant to UF_6 (see NOTE to section 5-4).

5-3-4 Rotary shaft seals

Especially designed or prepared vacuum seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor or the gas blower rotor with the driver motor so as to ensure a reliable seal against in-leaking of air into the inner chamber of the compressor or gas blower which is filled with UF_6. Such seals are normally designed for a buffer gas in-leakage rate of less than 1000 cm^3 per minute.

5-3-5 Heat exchangers for cooling UF_6

Especially designed or prepared heat exchangers made of or protected by UF_6-resistant materials (see NOTE to section 5-4), and intended for a leakage pressure change rate of less than 10 Pa/h under a pressure difference of 100 kPa.

5-4 Especially designed or prepared auxiliary systems, equipment and components for use in gaseous diffusion enrichment

NOTE:

The auxiliary systems, equipment and components for gaseous diffusion enrichment plants are the systems of plant needed to feed UF_6 to the gaseous diffusion assembly, to link the individual assemblies to each other to form cascades (or stages) to allow for progressively higher enrichments and to extract the product and tails UF_6 from the diffusion cascades. Because of the high inertial properties of diffusion cascades, any interruption in their operation, and especially their shut-down, leads to serious consequences. Therefore, a strict and constant maintenance of vacuum in all technological systems, automatic protection from accidents, and precise automated regulation of the gas flow is of importance in a gaseous diffusion plant. All this leads to a need to equip the plant with a large number of special measuring, regulating and controlling systems.

Normally UF_6 is evaporated from cylinders placed within autoclaves and is distributed in gaseous form to the entry point by way of cascade header pipework. The product and tails UF_6 gas streams flowing from exit points are passed by way of cascade header pipework to either cold traps or to compression stations where the UF_6 gas is liquefied prior to onward transfer into suitable containers for transportation or storage. Because a gaseous diffusion enrichment plant consists of a large number of gaseous diffusion assemblies arranged in cascades, there are many kilometers of cascade header pipework, incorporating thousands of welds with substantial amounts of repetition of layout. The equipment, components and piping systems are fabricated to very high vacuum and cleanliness standards.

The items listed below either come into direct contact with the UF_6 process gas or directly control the flow within the cascade. Materials resistant to corrosion by UF_6 include copper, copper alloys, stainless steel, aluminum, aluminum oxide, aluminum alloys, nickel or alloys containing 60% by weight or more nickel and fluorinated hydrocarbon polymers.

5-4-1 Feed systems/product and tails withdrawal systems

Especially designed or prepared process systems or equipment for enrichment plants made of or protected by materials resistant to corrosion by UF_6, including:

A. Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process.

B. Desublimers, cold traps or pumps used to remove UF_6 from the enrichment process for subsequent transfer upon heating.

C. Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form.

D. Product or tails stations used for transferring UF_6 into containers.

5-4-2 Header piping systems

Especially designed or prepared piping systems and header systems for handling UF_6 within the gaseous diffusion cascades.

NOTE:

This piping network is normally of the double header system with each cell connected to each of the headers.

5-4-3 Vacuum systems

A. Especially designed or prepared vacuum manifolds, vacuum headers and vacuum pumps having a suction capacity of 5 m^3/min or more.

B. Vacuum pumps especially designed for service in UF_6-bearing atmospheres made of, or protected by, materials resistant to corrosion by UF_6 (see NOTE to this section). These pumps may be either rotary or positive, may have displacement and fluorocarbon seals, and may have special working fluids present.

5-4-4 Special shut-off and control valves

Especially designed or prepared bellows-sealed valves, manual or automated, shut-off or control, made of or protected by materials resistant to corrosion by UF_6, for installation in main and auxiliary systems of gaseous diffusion enrichment plants.

5-4-5 UF_6 mass spectrometers/ion sources

Especially designed or prepared mass spectrometers capable of taking on-line samples from UF_6 gas streams and having all of the following:

- Capable of measuring ions of 320 atomic mass units or greater and having a resolution of better than 1 part in 320;
- Ion sources constructed of or protected by nickel, nickel-copper alloys with a nickel content of 60% by weight or more, or nickel-chrome alloys;
- Electron bombardment ionization sources; and
- Having a collector system suitable for isotopic analysis.

5-5 Especially designed or prepared systems, equipment, and components for use in aerodynamic enrichment plants

NOTE:

In aerodynamic enrichment processes, a mixture of gaseous UF_6 and light gas (hydrogen or helium) is compressed and then passed through separating elements wherein isotopic separation is accomplished by the generation of high centrifugal forces over a curved-wall geometry. Two processes of this type have been successfully developed: the separation nozzle process and the vortex tube process. For both processes the main components of a separation stage include cylindrical vessels housing the special separation elements (nozzles or vortex tubes), gas compressors and heat exchangers to remove the heat of compression. An aerodynamic plant requires a number of these stages, so that quantities can provide an important indication of end use. Since aerodynamic processes use UF_6, all equipment, pipeline, and instrumentation surfaces (that come in contact with the gas) must be made of or protected by materials that remain stable in contact with UF_6.

The items listed in this section either come into direct contact with the UF_6 process gas or directly control the flow within the cascade. All surfaces which come into contact with the process gas are wholly made of or protected by UF_6-resistant materials. For the purposes of the section relating to aerodynamic enrichment items, the materials resistant to corrosion by UF_6 include copper, copper alloys, stainless steel, aluminum, aluminum oxide, aluminum alloys, nickel or alloys containing 60% by weight or more nickel and fluorinated hydrocarbon polymers.

5-5-1 Separation nozzles

Especially designed or prepared separation nozzles and assemblies thereof. The separation nozzles consist of slit-shaped, curved channels having a radius of curvature less than 1 mm, resistant to corrosion by UF_6 and having a knife-edge within the nozzle that separates the gas flowing through the nozzle into two fractions.

5-5-2 Vortex tubes

Especially designed or prepared vortex tubes and assemblies thereof. The vortex tubes are cylindrical or tapered, made of or protected by materials resistant to corrosion by UF_6, and with one or more tangential inlets. The tubes may be equipped with nozzle-type appendages at either or both ends.

NOTE:

The feed gas enters the vortex tube tangentially at one end, or through swirl vanes, or at numerous tangential positions along the periphery of the tube.

5-5-3 Compressors and gas blowers

Especially designed or prepared compressors or gas blowers made of or protected by materials resistant to corrosion by the UF_6/carrier gas (hydrogen or helium) mixture.

5-5-4 Rotary shaft seals

Especially designed or prepared rotary shaft seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor rotor or the gas blower rotor with the driver motor so as to ensure a reliable seal against out-leakage of process gas or in-leakage of air or seal gas into the inner chamber of the compressor or gas blower which is filled with a UF_6/carrier gas mixture.

5-5-5 Heat exchangers for gas cooling

Especially designed or prepared heat exchangers made of or protected by materials resistant to corrosion by UF_6.

5-5-6 Separation element housings

Especially designed or prepared separation element housings, made of or protected by materials resistant to corrosion by UF_6, for containing vortex tubes or separation nozzles.

5-5-7 Feed systems/product and tails withdrawal systems

Especially designed or prepared process systems or equipment for enrichment plants, made of or protected by materials resistant to corrosion by UF_6, including:

A. Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process.

B. Desublimers (or cold traps) used to remove UF_6 from the enrichment process for subsequent transfer upon heating.

C. Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form.

D. Product or tails stations used for transferring UF_6 into containers.

5-5-8 Header piping systems

Especially designed or prepared header piping systems, made of or protected by materials resistant to corrosion by UF_6, for handling UF_6 within the aerodynamic cascades. This piping network is normally of the double header design with each stage or group of stages connected to each of the headers.

5-5-9 Vacuum systems and pumps

A. Especially designed or prepared vacuum systems consisting of vacuum manifolds, vacuum headers and vacuum pumps, and designed for service in UF_6-bearing atmospheres.

B. Vacuum pumps especially designed or prepared for service in UF_6-bearing atmospheres and made of or protected by materials resistant to corrosion by UF_6. These pumps may use fluorocarbon seals and special working fluids.

5-5-10 Special shut-off and control valves

Especially designed or prepared bellows-sealed valves, manual or automated, shut-off or control, made of or protected by materials resistant to corrosion by $UF_{6,}$ with a diameter of 40 mm or greater, for installation in main and auxiliary systems of aerodynamic enrichment plants.

5-5-11 UF_6 mass spectrometers/ion sources

Especially designed or prepared mass spectrometers capable of taking on-line samples from UF_6 gas streams and having all of the following:

- Capable of measuring ions of 320 atomic mass units or greater and having a resolution of better than 1 part in 320;
- Ion sources constructed of or protected by nickel, nickel-copper alloys with a nickel content of 60% by weight or more, or nickel-chrome alloys;
- Electron bombardment ionization sources; and
- Having a collector system suitable for isotopic analysis.

5-5-12 UF_6/carrier gas separation systems

Especially designed or prepared process systems for separating UF_6 from carrier gas (hydrogen or helium).

NOTE:

These systems are designed to reduce the UF_6 content in the carrier gas to 1 ppm or less and may incorporate equipment such as:

- Cryogenic heat exchangers and cryoseparators capable of temperatures of 153 K (-120°C) or less.
- Cryogenic refrigeration units capable of temperatures of 153 K (-120°C) or less.

- Separation nozzle or vortex tube units for the separation of UF_6 from carrier gas.
- UF_6 cold traps capable of freezing out UF_6.

5-6 Especially designed or prepared systems, equipment, and components for use in chemical exchange or ion exchange enrichment plants

NOTE:

The slight difference in mass between the isotopes of uranium causes small changes in chemical reaction equilibria that can be used as a basis for separation of the isotopes. Two processes have been successfully developed: liquid-liquid chemical exchange and solid-liquid ion exchange.

In the liquid-liquid chemical exchange process, immiscible liquid phases (aqueous and organic) are countercurrently contacted to give the cascading effect of thousands of separation stages. The aqueous phase consists of uranium chloride in hydrochloric acid solution; the organic phase consists of an extractant containing uranium chloride in an organic solvent. The contactors employed in the separation cascade can be liquid-liquid exchange columns (such as pulsed columns with sieve plates) or liquid centrifugal contactors. Chemical conversions (oxidation and reduction) are required at both ends of the separation cascade in order to provide for the reflux requirements at each end. A major design concern is to avoid contamination of the process streams with certain metal ions. Plastic, plastic-lined (including use of fluorocarbon polymers) and/or glass-lined columns and piping are therefore used.

In the solid-liquid ion-exchange process, enrichment is accomplished by uranium adsorption/desorption on a special, very fast-acting, ion-exchange resin or adsorbent. A solution of uranium in hydrochloric acid and other chemical agents is passed through cylindrical enrichment columns containing packed beds of the adsorbent. For a continuous process, a reflux system is necessary to release the uranium from the adsorbent back into the liquid flow so that product and tails can be collected. This is accomplished with the use of suitable reduction/oxidation chemical agents that are fully regenerated in separate external circuits and that may be partially regenerated within the isotopic separation columns themselves. The presence of hot concentrated hydrochloric acid solutions in the process requires that the equipment be made of or protected by special corrosion-resistant materials.

5-6-1 Liquid-liquid exchange columns (Chemical exchange)

Countercurrent liquid-liquid exchange columns having mechanical power input, especially designed or prepared for uranium enrichment using the chemical exchange process. For corrosion resistance to concentrated hydrochloric acid solutions, these columns and their internals are normally made of or protected by suitable plastic materials (such as fluorinated hydrocarbon polymers) or glass. The stage residence time of the columns is normally designed to be 30 s or less.

5-6-2 Liquid-liquid centrifugal contactors (Chemical exchange)

Liquid-liquid centrifugal contactors especially designed or prepared for uranium enrichment using the chemical exchange process. Such contactors use rotation to achieve dispersion of the organic and aqueous streams and then centrifugal force to separate the phases. For corrosion resistance to concentrated hydrochloric acid solutions, the contactors are normally made of or protected by suitable plastic materials (such as fluorinated hydrocarbon polymers) or glass. The stage residence time of the centrifugal contactors is normally designed to be 30 s or less.

5-6-3 Uranium reduction systems and equipment (Chemical exchange)

A. Especially designed or prepared electrochemical reduction cells to reduce uranium from one valence state to another for uranium enrichment using the chemical exchange process. The cell materials in contact with process solutions must be corrosion resistant to concentrated hydrochloric acid solutions.

NOTE:

The cell cathodic compartment must be designed to prevent re-oxidation of uranium to its higher valence state. To keep the uranium in the cathodic compartment, the cell may have an impervious diaphragm membrane constructed of special cation exchange material. The cathode consists of a suitable solid conductor such as graphite.

B. Especially designed or prepared systems at the product end of the cascade for taking the U^{+4} out of the organic stream, adjusting the acid concentration and feeding to the electrochemical reduction cells.

NOTE:

These systems consist of solvent extraction equipment for stripping the U^{+4} from the organic stream into an aqueous solution, evaporation and/or other equipment to accomplish solution pH adjustment and control, and pumps or other transfer devices for feeding to the electrochemical reduction cells. A major design concern is to avoid contamination of the aqueous stream with certain metal ions. Consequently, for those parts in contact with the process stream, the system is constructed of equipment made of or protected by suitable materials (such as glass, fluorocarbon polymers, polyphenol sulphate, polyether sulphone, and resin-impregnated graphite).

5-6-4 Feed preparation systems (Chemical exchange)

Especially designed or prepared systems for producing high-purity uranium chloride feed solutions for chemical exchange uranium isotope separation plants.

NOTE:

These systems consist of dissolution, solvent extraction and/or ion exchange equipment for purification and electrolytic cells for reducing the uranium U^{+6} or U^{+4} to U^{+3}. These systems produce uranium chloride solutions having only a few parts per million of metallic impurities such as chromium, iron, vanadium, molybdenum and other bivalent or higher multi-valent cations. Materials of construction for portions of the system processing high-purity U^{+3} include glass, fluorinated hydrocarbon polymers, polyphenol sulphate or polyether sulphone plastic-lined and resin-impregnated graphite.

5-6-5 Uranium oxidation systems (Chemical exchange)

Especially designed or prepared systems for oxidation of U^{+3} to U^{+4} for return to the uranium isotope separation cascade in the chemical exchange enrichment process.

NOTE:

These systems may incorporate equipment such as:

A. Equipment for contacting chlorine and oxygen with the aqueous effluent from the isotope separation equipment and extracting the resultant U^{+4} into the stripped organic stream returning from the product end of the cascade.

B. Equipment that separates water from hydrochloric acid so that the water and the concentrated hydrochloric acid may be reintroduced to the process at the proper locations.

5-6-6 Fast-reacting ion exchange resins/adsorbents (Ion exchange)

Fast-reacting ion exchange resins or adsorbents especially designed or prepared for uranium enrichment using the ion exchange process, including porous macroreticular resins, and/or pellicular structures in which the active chemical exchange groups are limited to a coating on the surface of an inactive porous support structure, and other composite structures in any suitable form including particles or fibers. These ion exchange resins/adsorbents have diameters of 0.2 mm or less and must be chemically resistant to concentrated hydrochloric acid solutions as well as physically strong enough so as not to degrade in the exchange columns. The resins/adsorbents are especially designed to achieve very fast uranium isotope exchange kinetics (exchange rate half-time of less than 10 s) and are capable of operating at a temperature in the range of 373 K (100°C) to 473 K (200°C).

5-6-7 Ion exchange columns (Ion exchange)

Cylindrical columns greater than 1000 mm in diameter for containing and supporting packed beds of ion exchange resin/adsorbent, especially designed or prepared for uranium enrichment using the ion exchange process. These columns are made of or protected by materials (such as titanium or fluorocarbon plastics) resistant to corrosion by concentrated hydrochloric acid solutions and are capable of operating at a temperature in the range of 373 K (100°C) to 473 K (200°C) and pressures above 0.7 MPa.

5-6-8 Ion exchange reflux systems (Ion exchange)

A. Especially designed or prepared chemical or electrochemical reduction systems for regeneration of the chemical reducing agent used in ion exchange uranium enrichment cascades.

B. Especially designed or prepared chemical or electrochemical oxidation systems for regeneration of the chemical oxidizing agent (agents) used in ion exchange uranium enrichment cascades.

NOTE:

The ion exchange enrichment process may use, for example, trivalent titanium (Ti^{+3}) as a reducing cation in which case the reduction system would regenerate Ti^{+3} by reducing Ti^{+4}.

The process may use, for example, trivalent iron (Fe^{+3}) as an oxidant in which case the oxidation system would regenerate Fe^{+3} by oxidizing Fe^{+2}.

5-7 Especially designed or prepared systems, equipment, and components for use in laser-based enrichment plants

NOTE:

Present systems for enrichment processes using lasers fall into two categories: those in which the process medium is atomic uranium vapor and those in which the process medium is the vapor of a uranium compound, sometimes mixed with another gas or gases. Common nomenclature for such processes include:

First category - atomic vapor laser isotope separation.

Second category - molecular laser isotope separation, including chemical reaction by isotope selective laser activation.

The systems, equipment and components for laser enrichment plants include:

A. Devices to feed uranium-metal vapor (for selective photo-ionization) or devices to feed the vapor of a uranium compound (for selective photo-dissociation or selective excitation/activation).

B. Devices to collect enriched and depleted uranium metal as product and tails in the first category, and devices to collect enriched and depleted uranium compounds as product and tails in the second category.

C. Process laser systems to selectively excite the uranium-235 (^{235}U) species.

D. Feed preparation and product conversion equipment. The complexity of the spectroscopy of uranium atoms and compounds may require incorporation of any of a number of available laser and laser optics technologies.

Many of the items listed in this section come into direct contact with uranium metal vapor or liquid or with process gas consisting of UF_6 or a mixture of UF_6 and other gases. All surfaces that come into direct contact with the uranium or UF_6 are wholly made of or protected by corrosion-resistant materials. For the purposes of the section relating to laser-based enrichment items, the materials resistant to corrosion by the vapor or liquid of uranium metal or uranium alloys include yttria-coated graphite and tantalum; and the materials resistant to corrosion by UF_6 include copper, copper alloys, stainless steel, aluminum, aluminum oxide, aluminum alloys, nickel or alloys containing 60% by weight or more nickel and fluorinated hydrocarbon polymers.

5-7-1 Uranium vaporization systems (Atomic vapor based methods)

Especially designed or prepared uranium metal vaporization systems for use in laser enrichment.

NOTE:

These systems may contain electron beam guns and are designed to achieve a delivered power (1 kW or greater) on the target sufficient to generate uranium metal vapor at a rate required for the laser enrichment function.

5-7-2 Liquid or vapor uranium metal handling systems and components (Atomic vapor based methods)

Especially designed or prepared systems for handling molten uranium, molten uranium alloys or uranium metal vapor for use in laser enrichment, or especially designed or prepared components therefor.

NOTE:

The liquid uranium metal handling systems may consist of crucibles and cooling equipment for the crucibles. The crucibles and other parts of this system that come into contact with molten uranium, molten uranium alloys or uranium metal vapor are made of or protected by materials of suitable corrosion and heat resistance. Suitable materials may include tantalum, yttria-coated graphite, graphite coated with other rare earth oxides (see Annex B) or mixtures thereof.

5-7-3 Uranium metal product and tails collector assemblies (Atomic vapor based methods)

Especially designed or prepared product and tails collector assemblies for collecting uranium metal in liquid or solid form.

NOTE:

Components for these assemblies are made of or protected by materials resistant to the heat and corrosion of uranium metal vapor or liquid (such as yttria-coated graphite or tantalum) and may include pipes, valves, fittings, gutters, feed-throughs, heat exchangers and collector plates for magnetic, electrostatic or other separation methods.

5-7-4 Separator module housings (Atomic vapor based methods)

Especially designed or prepared cylindrical or rectangular vessels for containing the uranium metal vapor source, the electron beam gun, and the product and tails collectors.

NOTE:

These housings have multiplicity of ports for electrical and water feed-throughs, laser beam windows, vacuum pump connections and instrumentation diagnostics and monitoring. They have provisions for opening and closing to allow refurbishment of internal components.

5-7-5 Supersonic expansion nozzles (Molecular based methods)

Especially designed or prepared supersonic expansion nozzles for cooling mixtures of UF_6 and carrier gas to 150 K (-123°C) or less and which are corrosion resistant to UF_6.

5-7-6 Product or tails collectors (Molecular based methods)

Especially designed or prepared components or devices for collecting uranium product material or uranium tails material following illumination with laser light.

NOTE:

In one example of molecular laser isotope separation, the product collectors serve to collect enriched uranium pentafluoride (UF_5) solid material. The product collectors may consist of filter, impact, or cyclone-type collectors, or combinations thereof, and must be corrosion resistant to the UF_5/UF_6 environment.

5-7-7 UF_6/carrier gas compressors (Molecular based methods)

Especially designed or prepared compressors for UF_6/carrier gas mixtures, designed for long term operation in a UF_6 environment. The components of these compressors that come into contact with process gas are made of or protected by materials resistant to corrosion by UF_6.

5-7-8 Rotary shaft seals (Molecular based methods)

Especially designed or prepared rotary shaft seals, with seal feed and seal exhaust connections, for sealing the shaft connecting the compressor rotor with the driver motor so as to ensure a reliable seal against out-leakage of process gas or in-leakage of air or seal gas into the inner chamber of the compressor which is filled with a UF_6/carrier gas mixture.

5-7-9 Fluorination systems (Molecular based methods)

Especially designed or prepared systems for fluorinating UF_5 (solid) to UF_6 (gas).

NOTE:

These systems are designed to fluorinate the collected UF_5 powder to UF_6 for subsequent collection in product containers or for transfer as feed for additional enrichment. In one approach, the fluorination reaction may be accomplished within the isotope separation system to react and recover directly off the product collectors. In another approach, the UF_5 powder may be removed/transferred from the product collectors into a suitable reaction vessel (e.g., fluidized-bed reactor, screw reactor or flame tower) for fluorination. In both approaches, equipment for storage and transfer of fluorine (or other suitable fluorinating agents) and for collection and transfer of UF_6 are used.

5-7-10 UF_6 mass spectrometers/ion sources (Molecular based methods)

Especially designed or prepared mass spectrometers capable of taking on-line samples from UF_6 gas streams and having all of the following:

- Capable of measuring ions of 320 atomic mass units or greater and having a resolution of better than 1 part in 320;
- Ion sources constructed of or protected by nickel, nickel-copper alloys with a nickel content of 60% by weight or more, or nickel-chrome alloys;

- Electron bombardment ionization sources; and
- Having a collector system suitable for isotopic analysis.

5-7-11 Feed systems/product and tails withdrawal systems (Molecular based methods)

Especially designed or prepared process systems or equipment for enrichment plants made of or protected by materials resistant to corrosion by UF_6, including:

A. Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process.

B. Desublimers (or cold traps) used to remove UF_6 from the enrichment process for subsequent transfer upon heating.

C. Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form.

D. Product or tails stations used for transferring UF_6 into containers.

5-7-12 UF_6/carrier gas separation systems (Molecular based methods)

Especially designed or prepared process systems for separating UF_6 from carrier gas.

NOTE:

These systems may incorporate equipment such as:

A. Cryogenic heat exchangers or cryoseparators capable of temperatures of 153 K (-120°C) or less.

B. Cryogenic refrigeration units capable of temperatures of 153 K (-120°C) or less.

C. UF_6 cold traps capable of freezing out UF_6.

The carrier gas may be nitrogen, argon, or other gas.

5-7-13 Laser systems

Lasers or laser systems especially designed or prepared for the separation of uranium isotopes.

NOTE:

The lasers and laser components of importance in laser-based enrichment processes include those identified in Annex B. The laser system typically contains both optical and electronic components for the management of the laser beam (or beams) and the transmission to the isotope separation chamber. The laser system for atomic vapor based methods usually consists of tunable dye lasers pumped by another type of laser (e.g., copper vapor lasers or certain solid-state lasers). The laser system for molecular based methods may consist of carbon dioxide lasers or excimer lasers and a multi-pass optical cell. Lasers or laser systems for both methods require spectrum frequency stabilization for operation over extended periods of time.

5-8 Especially designed or prepared systems, equipment, and components for use in plasma separation enrichment plants

NOTE:

In the plasma separation process, a plasma of uranium ions passes through an electric field tuned to the ^{235}U ion resonance frequency so that they preferentially absorb energy and increase the diameter of their corkscrew-like orbits. Ions with a large-diameter path are trapped to produce a product enriched in ^{235}U. The plasma, which is made by ionizing uranium vapor, is contained in a vacuum chamber with a high-strength magnetic field produced by a superconducting magnet. The main technological systems of the process include the uranium plasma generation system, the separator module with superconducting magnet (Annex B), and metal removal systems for the collection of product and tails.

5-8-1 Microwave power source and antennae

Especially designed or prepared microwave power sources and antennae for producing or accelerating ions and having the following characteristics: greater than 30 GHz frequency and greater than 50 kW mean power output for ion production.

5-8-2 Ion excitation coils

Especially designed or prepared radio frequency ion excitation coils for frequencies of more than 100 kHz and capable of handling more than 40 kW mean power.

5-8-3 Uranium plasma generation systems

Especially designed or prepared systems for the generation of uranium plasma for use in plasma separation plants.

5-8-4 Uranium metal product and tails collector assemblies

Especially designed or prepared product and tails collector assemblies for uranium metal in solid form. These collector assemblies are made of or protected by materials resistant to the heat and corrosion of uranium metal vapor, such as yttria-coated graphite or tantalum.

5-8-5 Separator module housings

Cylindrical vessels especially designed or prepared for use in plasma separation enrichment plants for containing the uranium plasma source, radio-frequency drive coil and the product and tails collectors.

NOTE:

These housings have a multiplicity of ports for electrical feed-throughs, diffusion pump connections and instrumentation diagnostics and monitoring. They have provisions for opening and closing to allow for refurbishment of internal components and are constructed of a suitable non-magnetic material such as stainless steel.

5-9 Especially designed or prepared systems, equipment, and components for use in electromagnetic enrichment plants

NOTE:

In the electromagnetic process, uranium metal ions produced by ionization of a salt feed material (typically uranium tetrachloride (UCl_4)) are accelerated and passed through a magnetic field that has the effect of causing the ions of different isotopes to follow different paths. The major components of an electromagnetic isotope separator include: a magnetic field for ion-beam diversion/separation of the isotopes, an ion source with its acceleration system, and a collection system for the separated ions. Auxiliary systems for the process include the magnet power supply system, the ion source high-voltage power supply system, the vacuum system, and extensive chemical handling systems for recovery of product and cleaning/recycling of components.

5-9-1 Electromagnetic isotope separators

Electromagnetic isotope separators especially designed or prepared for the separation of uranium isotopes, and equipment and components therefor, including:

A. Ion sources

Especially designed or prepared single or multiple uranium ion sources consisting of a vapor source, ionizer, and beam accelerator, constructed of suitable materials such as graphite, stainless steel, or copper, and capable of providing a total ion beam current of 50 mA or greater.

B. Ion collectors

Collector plates consisting of two or more slits and pockets especially designed or prepared for collection of enriched and depleted uranium ion beams and constructed of suitable materials such as graphite or stainless steel.

C. Vacuum housings

Especially designed or prepared vacuum housings for uranium electromagnetic separators, constructed of suitable non-magnetic materials such as stainless steel and designed for operation at pressures of 0.1 Pa or lower.

NOTE:

The housings are specially designed to contain the ion sources, collector plates and water-cooled liners and have provision for diffusion pump connections and opening and closing for removal and reinstallation of these components.

D. Magnet pole pieces

Especially designed or prepared magnet pole pieces having a diameter greater than 2 m and used to maintain a constant magnetic field within an electromagnetic isotope separator and to transfer the magnetic field between adjoining separators.

5-9-2 High voltage power supplies

Especially designed or prepared high-voltage power supplies for ion sources, having both of the following characteristics:

- Capable of continuous operation, output voltage of 20,000 V or greater, output current of 1 A or greater; and

- Voltage regulation of better than 0.01% over a time period of 8 h.

5-9-3 Magnet power supplies

Especially designed or prepared high-power, direct current magnet power supplies having both of the following characteristics:

- Capable of continuously producing a current output of 500 A or greater at a voltage of 100 V or greater; and
- Current or voltage regulation better than 0.01% over a time period of 8 h.

5-9-4 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

NOTE:

1. Item 5-9-4 includes separators capable of enriching stable isotopes as well as those for uranium.
2. 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.
3. Item 5-9-4 includes separators with the ion sources and collectors both in the magnetic field and those configurations in which they are external to the field.
4. A single 50 mA ion source cannot produce more than 3 g of separated highly enriched uranium (HEU) per year from natural abundance feed.

6- Plants for the Production or Concentration of Heavy Water, Deuterium and Deuterium Compounds and Equipment Especially Designed or Prepared Therefor

NOTE:

Heavy water can be produced by a variety of processes. However, the two processes that have proven to be commercially viable are the water-hydrogen sulfide exchange process (GS process) and the ammonia-hydrogen exchange process.

The GS process is based upon the exchange of hydrogen and deuterium between water and hydrogen sulfide within a series of towers which are operated with the top section cold and the bottom section hot. Water flows down the towers while the hydrogen sulfide gas circulates from the bottom to the top of the towers. A series of perforated trays are used to promote mixing between the gas and the water. Deuterium migrates to the water at low temperatures and to the hydrogen sulfide at high temperatures. Gas or water, enriched in deuterium, is removed from the first stage towers at the junction of the hot and cold sections and the process is repeated in subsequent stage towers. The product of the last stage, water enriched up to 30% by weight in deuterium, is sent to a distillation unit to produce reactor grade heavy water; i.e., 99.75% by weight deuterium oxide (D_2O).

The ammonia-hydrogen exchange process can extract deuterium from synthesis gas through contact with liquid ammonia (NH_3) in the presence of a catalyst. The synthesis gas is fed into exchange towers and to an ammonia converter. Inside the towers the gas flows from the bottom to the top while the liquid NH_3 flows from the top to the bottom. The deuterium is stripped from the hydrogen in the synthesis gas and concentrated in the NH_3. The NH_3 then flows into an ammonia cracker at the bottom of the tower while the gas flows into an ammonia converter at the top. Further enrichment takes place in subsequent stages and reactor grade heavy water is produced through final distillation. The synthesis gas feed can be provided by an ammonia plant that, in turn, can be constructed in association with a heavy water ammonia-hydrogen exchange plant. The ammonia-hydrogen exchange process can also use ordinary water as a feed source of deuterium.

Many of the key equipment items for heavy water production plants using GS or the ammonia-hydrogen exchange processes are common to several segments of the chemical and petroleum industries. This is particularly so for small plants using the GS process. The GS and ammonia-hydrogen processes require the handling of large quantities of flammable, corrosive and toxic fluids at elevated pressures. Accordingly, in establishing the design and operating standards for plants and equipment using these processes, careful attention to the materials selection and specifications is required to ensure long service life with high safety and reliability factors. The choice of scale is primarily a function of economics and need.

Finally, it should be noted that, in both the GS and the ammonia-hydrogen exchange processes, items of equipment which individually are not especially designed or prepared for heavy water production can be assembled into systems which are especially designed or prepared for producing heavy water. The catalyst production system used in the ammonia-hydrogen exchange process and water distillation systems used for the final concentration of heavy water to reactor-grade in either process are examples of such systems. The items of equipment which are especially designed or prepared for the production of heavy water utilizing either the water-hydrogen sulfide exchange process or the ammonia-hydrogen exchange process include the following:

6-1 Water-hydrogen sulfide exchange towers

Exchange towers with diameters of 1.5 m or greater and capable of operating at pressures greater than or equal to 2 MPa, especially designed or prepared for heavy water production utilizing the water-hydrogen sulfide exchange process.

6-2 Blowers and compressors

Single stage, low head (i.e., 0.2 MPa) centrifugal blowers or compressors for hydrogen-sulfide gas circulation (i.e., gas containing more than 70% by weight hydrogen sulfide, H_2S) especially designed or prepared for heavy water production utilizing the water-hydrogen sulfide exchange process. These blowers or compressors have a throughput capacity greater than or equal to 56 m^3/s while operating at pressures greater than or equal to 1.8 MPa suction and have seals designed for wet H_2S service.

6-3 Ammonia-hydrogen exchange towers

Ammonia-hydrogen exchange towers greater than or equal to 35 m in height with diameters of 1.5 m to 2.5 m capable of operating at pressures greater than 15 MPa especially designed or prepared for heavy water production utilizing the ammonia- hydrogen exchange process. These towers also have at least one flanged, axial opening of the same diameter as the cylindrical part through which the tower internals can be inserted or withdrawn.

6-4 **Tower internals and stage pumps**

Tower internals and stage pumps especially designed or prepared for towers for heavy water production utilizing the ammonia-hydrogen exchange process. Tower internals include especially designed stage contactors which promote intimate gas/liquid contact. Stage pumps include especially designed submersible pumps for circulation of liquid NH_3 within a contacting stage internal to the stage towers.

6-5 **NH_3 crackers**

NH_3 crackers with operating pressures greater than or equal to 3 MPa especially designed or prepared for heavy water production utilizing the ammonia-hydrogen exchange process.

6-6 **Infrared absorption analyzers**

Infrared absorption analyzers capable of on-line hydrogen/deuterium ratio analysis where deuterium concentrations are equal to or greater than 90% by weight.

6-7 **Catalytic burners**

Catalytic burners for the conversion of enriched deuterium gas into heavy water especially designed or prepared for heavy water production utilizing the ammonia-hydrogen exchange process.

6-8 **Complete heavy water upgrade systems or columns therefor**

Complete heavy water upgrade systems, or columns therefor, especially designed or prepared for the upgrade of heavy water to reactor-grade deuterium concentration.

NOTE:

These systems, which usually employ water distillation to separate heavy water from light water, are especially designed or prepared to produce reactor-grade heavy water (i.e., typically 99.75% by weight D_2O) from heavy water feedstock of lesser concentration.

6-9 NH_3 synthesis converters or synthesis units

NH_3 synthesis converters or synthesis units especially designed or prepared for heavy water production utilizing the ammonia-hydrogen exchange process.

NOTE:

These converters or units take synthesis gas (nitrogen and hydrogen) from an NH_3/hydrogen high-pressure exchange column (or columns), and the synthesized NH_3 is returned to the exchange column (or columns).

6-10 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

6-11 Specialized packings which may be used in separating heavy water from ordinary water, having both of the following characteristics:

- Made of phosphor bronze mesh chemically treated to improve wettability; and
- Designed to be used in vacuum distillation towers.

7- Plants for the Conversion of Uranium and Plutonium for Use in the Fabrication of Fuel Elements and the Separation of Uranium Isotopes as Defined in Sections 4 and 5 Respectively, and Equipment Especially Designed or Prepared Therefor

7-1 Plants for the conversion of uranium and equipment especially designed or prepared therefor

NOTE:

Uranium conversion plants and systems may perform one or more transformations from one uranium chemical species to another, including: conversion of uranium ore concentrates to uranium trioxide (UO_3), conversion of UO_3 to uranium dioxide (UO_2), conversion of uranium oxides to uranium tetrafluoride (UF_4), UF_6, or UCl_4, conversion of UF_4 to UF_6, conversion of UF_6 to UF_4, conversion of UF_4 to uranium metal, and conversion of uranium fluorides to UO_2. Many of the key equipment items for uranium conversion plants are common to several segments of the chemical process industry. For example, the types of equipment employed in these processes may include: furnaces, rotary kilns, fluidized bed reactors, flame tower reactors, liquid centrifuges, distillation columns and liquid-liquid extraction columns. Most would be prepared according to the requirements and specifications of the customer. In some instances, special design and construction considerations are required to address the corrosive properties of some of the chemicals handled (hydrogen fluoride (HF), fluorine (F_2), chlorine trifluoride (ClF_3), and uranium fluorides) as well as nuclear criticality concerns. Finally, it should be noted that, in all of the uranium conversion processes, items of equipment which individually are not especially designed or prepared for uranium conversion can be assembled into systems which are especially designed or prepared for use in uranium conversion.

7-1-1 Especially designed or prepared systems for the conversion of uranium ore concentrates to UO_3

NOTE:

Conversion of uranium ore concentrates to UO_3 can be performed by first dissolving the ore in nitric acid and extracting purified uranyl nitrate ($UO_2(NO_3)_2$) using a solvent such as tributyl phosphate (TBP). Next, the uranyl nitrate is converted to UO_3 either by concentration and denitration or by neutralization with gaseous NH_3 to produce ammonium diuranate with subsequent filtering, drying, and calcining.

7-1-2 Especially designed or prepared systems for the conversion of UO_3 to UF_6

NOTE:

Conversion of UO_3 to UF_6 can be performed directly by fluorination. The process requires a source of F_2 or ClF_3.

7-1-3 Especially designed or prepared systems for the conversion of UO_3 to UO_2

NOTE:

Conversion of UO_3 to UO_2 can be performed through reduction of UO_3 with cracked gaseous NH_3 or hydrogen.

7-1-4 Especially designed or prepared systems for the conversion of UO_2 to UF_4

NOTE:

Conversion of UO_2 to UF_4 can be performed by reacting UO_2 with gaseous HF at 573-773 K (300-500°C).

7-1-5 Especially designed or prepared systems for the conversion of UF_4 to UF_6

NOTE:

Conversion of UF_4 to UF_6 is performed by exothermic reaction with fluorine in a tower reactor. UF_6 is condensed from the hot effluent gases by passing the effluent stream through a cold trap cooled to 263 K (-10°C). The process requires a source of gaseous F_2.

7-1-6 Especially designed or prepared systems for the conversion of UF_4 to uranium metal

NOTE:

Conversion of UF_4 to uranium metal is performed by reduction with magnesium (large batches) or calcium (small batches). The reaction is carried out at temperatures above the melting point of uranium (1403 K (1130°C)).

7-1-7 Especially designed or prepared systems for the conversion of UF_6 to UO_2

NOTE:

Conversion of UF_6 to UO_2 can be performed by one of three processes. In the first, UF_6 is reduced and hydrolyzed to UO_2 using hydrogen and steam. In the second, UF_6 is hydrolyzed by solution in water, NH_3 is added to precipitate ammonium diuranate, and the diuranate is reduced to UO_2 with hydrogen at 1093 K (820°C). In the third process, gaseous UF_6, CO_2, and NH_3 are combined in water, precipitating ammonium uranyl carbonate. The ammonium uranyl carbonate is combined with steam and hydrogen at 773-873 K (500-600°C) to yield UO_2. UF_6 to UO_2 conversion is often performed as the first stage of a fuel fabrication plant.

7-1-8 Especially designed or prepared systems for the conversion of UF_6 to UF_4

NOTE:

Conversion of UF_6 to UF_4 is performed by reduction with hydrogen.

7-1-9 Especially designed or prepared systems for the conversion of UO_2 to UCl_4

NOTE:

Conversion of UO_2 to UCl_4 can be performed by one of two processes. In the first, UO_2 is reacted with carbon tetrachloride (CCl_4) at approximately 673 K (400°C).

In the second, UO_2 is reacted at approximately 973 K (700°C) in the presence of carbon black (CAS 1333-86-4), carbon monoxide, and chlorine to yield UCl_4.

7-2 Plants for the conversion of plutonium and equipment especially designed or prepared therefor

NOTE:

Plutonium conversion plants and systems perform one or more transformations from one plutonium chemical species to another, including: conversion of plutonium nitrate (PuN) to plutonium dioxide (PuO_2), conversion of PuO_2 to plutonium tetrafluoride (PuF_4), and conversion of PuF_4 to plutonium metal. Plutonium conversion plants are usually associated with reprocessing facilities, but may also be associated with plutonium fuel fabrication facilities. Many of the key equipment items for plutonium conversion plants are common to several segments of the chemical process industry. For example, the types of equipment employed in these processes may include: furnaces, rotary kilns, fluidized bed reactors, flame tower reactors, liquid centrifuges, distillation columns and liquid- liquid extraction columns. Hot cells, glove boxes and remote manipulators may also be required. Most would be prepared according to the requirements and specifications of the customer. Particular care in designing for the special radiological, toxicity and criticality hazards associated with plutonium is essential. In some instances, special design and construction considerations are required to address the corrosive properties of some of the chemicals handled (e.g., HF).

7-2-1 Especially designed or prepared systems for the conversion of plutonium nitrate to oxide

NOTE:

The main functions involved in this process are: process feed storage and adjustment, precipitation and solid/liquor separation, calcination, product handling, ventilation, waste management, and process control. The process systems are particularly adapted so as to avoid criticality and radiation effects and to minimize toxicity hazards. In most reprocessing facilities, this process involves the conversion of PuN to PuO_2. Other processes can involve the precipitation of plutonium oxalate or plutonium peroxide.

7-2-2 Especially designed or prepared systems for plutonium metal production

NOTE:

This process usually involves the fluorination of PuO_2, normally with highly corrosive HF, to produce plutonium fluoride which is subsequently reduced using high purity calcium metal to produce metallic plutonium and a calcium fluoride slag. The main functions involved in this process are fluorination (e.g., involving equipment fabricated or lined with a precious metal), metal reduction (e.g., employing ceramic crucibles), slag recovery, product handling, ventilation, waste management and process control. The process systems are particularly adapted so as to avoid criticality and radiation effects and to minimize toxicity hazards. Other processes include the fluorination of plutonium oxalate or plutonium peroxide followed by a reduction to metal.

8- Tritium Facilities or Plants, Equipment, and Components Therefor

8-1 Tritium facilities or plants, and equipment therefor, as follows:

A. Facilities or plants for the production, recovery, extraction, concentration or handling of tritium;

B. Equipment for tritium facilities or plants, as follows:

- Hydrogen or helium refrigeration units capable of cooling to 23 K (-250 °C) or less, with heat removal capacity greater than 150 W;

- Hydrogen isotope storage or hydrogen isotope purification systems using metal hydrides as the storage or purification medium.

8-2 Target assemblies and components for the production of tritium as follows:

A. Target assemblies made of or containing lithium enriched in the lithium-6 isotope specially designed for the production of tritium through irradiation, including insertion in a nuclear reactor;

B. Components specially designed for the target assemblies specified in item 8-2-A.

NOTE:

Components specially designed for target assemblies for the production of tritium may include lithium pellets, tritium getters, and specially-coated cladding.

9- Lithium Isotope Separation Facilities or Plants, and Systems and Equipment Therefor

NOTE:

Certain lithium isotope separation equipment and components for the plasma separation process (PSP) are also directly applicable to uranium isotope separation and are controlled under this Annex.

A. Facilities or plants for the separation of lithium isotopes;

B. Equipment for the separation of lithium isotopes based on the lithium-mercury amalgam process, as follows:

1. Packed liquid-liquid exchange columns specially designed for lithium amalgams;
2. Mercury or lithium amalgam pumps;
3. Lithium amalgam electrolysis cells;
4. Evaporators for concentrated lithium hydroxide solution.

C. Ion exchange systems specially designed for lithium isotope separation, and specially designed component parts therefor;

D. Chemical exchange systems (employing crown ethers, cryptands, or lariat ethers) specially designed for lithium isotope separation, and specially designed component parts therefor.

ANNEX B: Second List

General Notes:

This list includes dual-use materials and components, related technology and software, and radiation generating items, which are subject to notification requirements, in accordance with Regulation on Authorization and Regulatory Control of Nuclear-Related Items (NRRC-R-18).

The following paragraphs are applied to this list:

1. The description of any item includes that item in either new or second-hand condition.
2. When the description of any item contains no qualifications or specifications, it is regarded as including all varieties of that item.
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, the NRRC will 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 imported, exported or re-exported.

Technology Control:

The transfer of technology directly associated with any Annex B item will be subject to as great a degree of scrutiny and control as will the item itself, to the extent permitted by the NRRC's regulations.

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

> **NOTE:**
>
> Controls on technology transfer do not apply to information in the public domain or to basic scientific research.

Software Control:

The transfer of software directly associated with any Annex B item will be subject to as great a degree of scrutiny and control as will the item itself, to the extent permitted by the NRRC's regulation.

Controls on software transfers do not apply to software as follows:

1. Generally available to the public by being:

   A. Sold from stock at retail selling points without restriction.

   B. Designed for installation by the user without further substantial support by the supplier.

2. In the public domain.

NOTE:

The International System of Units (SI) is used in this Annex. 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.

Parameter	(SI) Unit
Electrical current	Amperes (A) Milliamperes (mA)
Length	Nanometer (nm) Micrometer (µm) Millimeter (mm) Centimeter (cm) Meter (m)
Area	Square centimeter (cm^2) Square meter (m^2)
Volume	Cubic centimeter (cm^3) Cubic meter (m^3) Milliliter (mL) Liter (L)
Angle	Degree (°)
Temperature	Degree Celsius (°C)
Mass	Gram (g) Kilogram (kg)
Acceleration	Acceleration of gravity (9.80665 m/s^2) (g_0)
Radioactive activity	Giga-becquerel (GBq)

Parameter	(SI) Unit
Pressure	Pascal (Pa) Kilopascal (KPa) Megapascal (MPa) Gigapascal (GPa)
Absorbed ionizing radiation	Gray (Gy)
Frequency	Hertz (Hz) Kilohertz (kHz)
Energy, Work, Heat	Joule (J)
Electronic energy	Kiloelectron volt (keV) Megaelectron volt (MeV)
Force	Newton (N) Kilonewton (kN)
Voltage	Volts (V) Kilovolts (kV)
Power	Kilowatts (kW) Megawatts (MW)
Thermodynamic temperature	Kelvin (K)
Time	Picosecond (ps) Nanosecond (ns) Microsecond (µs) Second (s) Minute (m) Hour (h)
Angular velocity	Revolution per minute (rpm)
Magnetic flux density	Tesla (T)
Electrical power	Volt-ampere (VA)

1- Industrial Equipment

1-A Equipment, Assemblies and Components

1-A-1 High-density (lead glass or other) radiation shielding windows, having all of the following characteristics, and specially designed frames therefor:

a. A cold area greater than 0.09 m^2;

b. A density greater than 3 g/cm^3; and

c. A thickness of 100 mm or greater.

NOTE:

In item 1-A-1-a, the term "cold area" means the viewing area of the window exposed to the lowest level of radiation in the design application.

1-A-2 Radiation-hardened TV cameras, or lenses therefor, specially designed or rated as radiation hardened to withstand a total radiation dose greater than 5 × 104 Gy (silicon) without operational degradation

NOTE:

The term "Gy (silicon)" refers to the energy in Joules per kilogram absorbed by an unshielded silicon sample when exposed to ionizing radiation.

1-A-3 Robots, end-effectors and control units as follows:

A. Robots or 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 a total radiation dose greater than 5×10^4 Gy (silicon) without operational degradation.

B. Control units specially designed for any of the robots or end-effectors specified in item 1-A-3-A.

NOTE:

Item 1-A-3 does not control robots specially designed for non-nuclear industrial applications such as automobile paint-spraying booths.

In item 1-A-3, "robot" means 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:

- is multifunctional;
- is capable of positioning or orienting material, parts, tools, or special devices through variable movements in three-dimensional space;
- incorporates three or more closed or open loop servo-devices which may include stepping motors; and
- 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.

NOTE:

In the above definition "sensors" means detectors of a physical phenomenon, the output of which (after conversion into a signal that can be interpreted by a control unit) 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.

In the above definition "user-accessible programmability" means the facility allowing a user to insert, modify or 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.

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.

In item 1-A-3, "end-effectors" are grippers, active tooling units, and any other tooling that is attached to the base plate on the end of a robot manipulator arm.

NOTE:

In the above definition "active tooling units" is a device for applying motive power, process energy or sensing to the workpiece.

1-A-4 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).

NOTE:

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

1-B Test and Production Equipment

1-B-1 Flow-forming machines, spin-forming machines capable of flow-forming functions, and mandrels, as follows:

A. Machines having both of the following characteristics:

- Three or more rollers (active or guiding); and
- 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 and 650 mm.

NOTE:

Item 1-B-1-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.

1-B-2 Machine tools, as follows, and any combination thereof, 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:

NOTE:

For numerical control units controlled by their associated software, see item 1-D-3.

A. Machine tools for turning, that have positioning accuracies with all compensations available better (less) than 6 µm according to (ISO 230/2: 1988) along any linear axis (overall positioning) for machines capable of machining diameters greater than 35 mm;

NOTE:

Item 1-B-2-A does not control bar machines (Swissturn), limited to machining only bar feed thru, if maximum bar diameter is equal to or less than 42 mm and there is no capability of mounting chucks. Machines may have drilling and/or milling capabilities for machining parts with diameters less than 42 mm.

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

    1. Positioning accuracies with all compensations available better (less) than 6 µm according to (ISO 230/2: 1988) along any linear axis (overall positioning);

    2. Two or more contouring rotary axes; or

    3. Five or more axes which can be coordinated simultaneously for contouring control.

    NOTE:

    Item 1-B-2-B does not control milling machines having both of the following characteristics:

    1. X-axis travel greater than 2 m; and

    2. Overall positioning accuracy on the x-axis worse (more) than 30 µm according to (ISO 230/2: 1988).

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

    1. Positioning accuracies with all compensations available better (less) than 4 µm according to (ISO 230/2: 1988) along any linear axis (overall positioning);

    2. Two or more contouring rotary axes; or

    3. Five or more axes which can be coordinated simultaneously for contouring control.

NOTE:

Item 1-B-2-C does not control grinding machines as follows:

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

    - Limited to a maximum workpiece capacity of 150 mm outside diameter or length; and

    - Axes limited to x, z and c.

2. 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).

D. Non-wire type Electrical Discharge Machines (EDM) that have two or more contouring rotary axes and that can be coordinated simultaneously for contouring control.

NOTE:

1. Stated positioning accuracy levels derived under the following procedures from measurements made according to (ISO 230/2: 1988) or national equivalents may be used for each machine tool model if provided to, and accepted by, national authorities instead of individual machine tests.

    Stated positioning accuracy levels are to be derived as follows:

A. Select five machines of a model to be evaluated;

B. Measure the linear axis accuracies according to (ISO 230/2: 1988);

C. Determine the accuracy values (A) for each axis of each machine. The method of calculating the accuracy value is described in the (ISO 230/2: 1988) standard;

D. Determine the average accuracy value of each axis. This average value becomes the stated positioning accuracy of each axis for the model (Âx, Ây);

E. Since item 1-B-2 refers to each linear axis, there will be as many stated positioning accuracy values as there are linear axes;

F. If any axis of a machine tool not controlled by items 1-B-2-A, 1-B-2-B or 1-B-2-C has a stated positioning accuracy of 6 µm or better (less) for grinding machines, and 8 µm or better (less) for milling and turning machines, both according to (ISO 230/2: 1988), then the builder should be required to reaffirm the accuracy level once every eighteen months.

2. Item 1-B-2 does not control special purpose machine tools limited to the manufacture of any of the following parts:

   A. Gears;

   B. Crankshafts or cam shafts;

   C. Tools or cutters;

   D. Extruder worms.

NOTE:

1. Axis nomenclature shall be in accordance with (ISO 841: 2001), "Numerical Control Machines-Axis and Motion Nomenclature".

2. Not counted in the total number of contouring axes are secondary parallel contouring axes (e.g., the w-axis on horizontal boring mills or a secondary rotary axis the centerline of which is parallel to the primary rotary axis).

3. Rotary axes do not necessarily have to rotate over 360°. A rotary axis can be driven by a linear device, e.g., a screw or a rack-and-pinion.

4. For the purposes of item 1-B-2, the number of axes which can be coordinated 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 motions 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.

5. A machine tool having at least 2 of the 3 turning, milling, or grinding capabilities (e.g., a turning machine with milling capability) must be evaluated against each applicable item, 1-B-2-A, 1-B-2-B and 1-B-2-C.

6. Items 1-B-2-B-3 and 1-B-2-C-3 include machines based on a parallel linear kinematic design (e.g., hexapods) that have 5 or more axes none of which is a rotary axis.

1-B-3 Dimensional inspection machines, instruments, or sys tems, as follows:

A. Computer controlled or numerically controlled coordinate measuring machines (CMM) having either of the following characteristics:

- Having only two axes and having a maximum permissible error of length measurement along any axis (one dimensional), identified as any combination of $E_{0x\ MPE}$, $E_{0y\ MPE}$ or $E_{0z\ MPE}$, equal to or less (better) than (1.25 + L/1000) µm (where L is the measured length in mm) at any point within the operating range of the machine (i.e., within the length of the axis), according to (ISO 10360-2: 2009); or

- Three or more axes and having a three-dimensional (volumetric) maximum permissible error of length measurement ($E_{0,\ MPE}$ equal to or less (better) than (1.7 + L/800) µm (where L is the measured length in mm) at any point within the operating range of the machine (i.e., within the length of the axis), according to (ISO 10360-2: 2009).

NOTE:

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

B. Linear displacement measuring instruments, as follows:

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

- Linear variable differential transformer (LVDT) systems having both of the following characteristics:

  a.

  - Linearity equal to or less (better) than 0.1% measured from 0 to the full operating range, for LVDTs with an operating range up to 5 mm; or

  - Linearity equal to or less (better) than 0.1% measured from 0 to 5 mm for LVDTs with an operating range greater than 5 mm; and

  b. Drift equal to or better (less) than 0.1% per day at a standard ambient test room temperature ± 1 K (± 1°C);

- Measuring systems having both of the following characteristics:

a. Containing a laser; and

b. Capable of maintaining for at least 12 h, over a temperature range of ± 1 K (± 1°C) around a standard temperature and a standard pressure:

- A resolution over their full scale of 0.1 µm or better; and

- With a measurement uncertainty equal to or better (less) than (0.2 + L/2000) µm (L is the measured length in mm);

NOTE:

Measuring systems in item 1-B-3 do not include 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.

In item 1-B-3-B, "linear displacement" means the change of distance between the measuring probe and the measured object.

C. Angular displacement measuring instruments having an angular position deviation equal to or better (less) than 0.00025°;

NOTE:

Item 1-B-3-C does not control optical instruments, such as autocollimators, using collimated light (e.g., laser light) to detect angular displacement of a mirror.

D. Systems for simultaneous linear-angular inspection of hemishells, having both of the following characteristics:

- Measurement uncertainty along any linear axis equal to or better (less) than 3.5 µm per 5 mm; and
- Angular position deviation equal to or less than 0.02°.

NOTE:

1. Item 1-B-3 includes machine tools, other than those specified by item 1-B-2, that can be used as measuring machines if they meet or exceed the criteria specified for the measuring machine function.
2. Machines described in item 1-B-3 are controlled if they exceed the threshold specified anywhere within their operating range.
3. All parameters of measurement values in this item represent plus/minus, i.e., not total band.

1-B-4 Controlled atmosphere (vacuum or inert gas) induction furnaces, and power supplies therefor, as follows:

A. Furnaces having all of the following characteristics:

- Capable of operation at temperatures above 1123 K (850 °C);
- Induction coils 600 mm or less in diameter; and
- Designed for power inputs of 5 kW or more.

NOTE:

Item 1-B-4-A does not control furnaces designed for the processing of semiconductor wafers.

B. Power supplies, with a specified output power of 5 kW or more, specially designed for furnaces specified in item 1-B-4-A.

1-B-5 Isostatic presses, and related equipment, as follows:

A. Isostatic presses having both of the following characteristics:

- Capable of achieving a maximum working pressure of 69 MPa or greater; and
- A chamber cavity with an inside diameter in excess of 152 mm.

B. Dies, moulds, and controls specially designed for the isostatic presses specified in item 1-B-5-A.

NOTE:

1. In item 1-B-5, "isostatic presses" means equipment capable of pressurizing a closed cavity through various media (gas, liquid, solid particles, etc.) to create equal pressure in all directions within the cavity upon a workpiece or material.
2. In item 1-B-5, 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.

1-B-6 Vibration test systems, equipment, and components as follows:

A. Electrodynamic vibration test systems, having all of the following characteristics:

- Employing feedback or closed loop control techniques and incorporating a digital control unit;
- Capable of vibrating at 10 g_0 root mean square (RMS) or more between 20 and 2000 Hz; and
- Capable of imparting forces of 50 kN or greater measured bare table.

B. Digital control units, combined with software specially designed for vibration testing, with a real-time bandwidth greater than 5 kHz and being designed for a system specified in item 1-B-6-A;

C. Vibration thrusters (shaker units), with or without associated amplifiers, capable of imparting a force of 50 kN or greater measured bare table, which are usable for the systems specified in item 1-B-6-A;

D. Test piece support structures and electronic units designed to combine multiple shaker units into a complete shaker system capable of providing an effective combined force of 50 kN or greater, measured bare table, which are usable for the systems specified in item 1-B-6-A.

NOTE:

In item 1-B-6, "bare table" means a flat table, or surface, with no fixtures or fittings.

1-B-7 Vacuum or other controlled atmosphere metallurgical melting and casting furnaces and related equipment, as follows:

A. Arc remelt furnaces, arc melt furnaces and arc melt and casting furnaces having both of the following characteristics:

- Consumable electrode capacities between 1000 and 20000 cm^3; and
- Capable of operating with melting temperatures above 1973 K (1700°C).

B. Electron beam melting furnaces, plasma atomization furnaces and plasma melting furnaces having both of the following characteristics:

- A power of 50 kW or greater; and
- Capable of operating with melting temperatures above 1473 K (1200°C).

C. Computer control and monitoring systems specially configured for any of the furnaces specified in item 1-B-7-A or 1-B-7-B.

D. Plasma torches specially designed for the furnaces specified in 1-B-7-B having both of the following characteristics:

- Operating at a power greater than 50 kW; and
- Capable of operating above 1473 K (1200°C).

E. Electron beam guns specially designed for the furnaces specified in item 1-B-7-B operating at a power greater than 50 kW.

1-C Materials

None.

1-D Software

1-D-1 Software specially designed or modified for the use of equipment specified in items 1-A-3, 1-B-1, 1-B-3, 1-B-5, 1-B-6-A, 1-B-6-B, 1-B-6-D or 1-B-7

NOTE:

Software specially designed or modified for systems specified in item 1-B-3-D includes software for simultaneous measurements of wall thickness and contour.

1-D-2 Software specially designed or modified for the development, production, or use of equipment specified in item 1-B-2

NOTE:

Item 1-D-2 does not control part programming software that generates numerical control command codes but does not allow direct use of equipment for machining various parts.

1-D-3 Software for any combination of electronic devices or system enabling such a device or such devices to function as a numerical control unit for machine tools, that is capable of controlling five or more interpolating axes that can be coordinated simultaneously for contouring control

NOTE:

1. Software is controlled whether exported separately or residing in a numerical control unit or any electronic device or system.
2. Item 1-D-3 does not control software specially designed or modified by the manufacturers of the control unit or machine tool to operate a machine tool that is not specified in item 1-B-2.

1-E Technology

1-E-1 Technology according to the Technology Control for the development, production or use of equipment, material or software specified in 1-A through 1-D

2- Materials

2-A Equipment, Assemblies and Components

2-A-1 Crucibles made of materials resistant to liquid actinide metals, as follows:

A. Crucibles having both of the following characteristics:

- A volume of between 150 cm^3 (150 mL) and 8000 cm^3 (8 L); and

- Made of or coated with any of the following materials, or combination of the following materials, having an overall impurity level of 2% or less by weight:

    a. Calcium fluoride (CaF_2);

    b. Calcium zirconate (metazirconate) ($CaZrO_3$);

    c. Cerium sulfide (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:

- A volume of between 50 cm^3 (50 mL) and 2000 cm^3 (2 L); and
- Made of or lined with tantalum, having a purity of 99.9% or greater by weight.

C. Crucibles having all of the following characteristics:

- A volume of between 50 cm^3 (50 mL) and 2000 cm^3 (2 L);
- Made of or lined with tantalum, having a purity of 98% or greater by weight; and

- Coated with tantalum carbide, nitride, boride, or any combination thereof.

2-B Test and Production Equipment

None.

2-C Materials

2-C-1 Aluminum alloys having both of the following characteristics:

- Capable of an ultimate tensile strength of 460 MPa or more at 293 K (20 °C); and
- In the form of tubes or cylindrical solid forms (including forgings) with an outside diameter of more than 75 mm.

NOTE:

In item 2-C-1, the phrase "capable of" encompasses aluminum alloys before or after heat treatment.

2-C-2 Beryllium metal, alloys containing more than 50% beryllium by weight, beryllium compounds, manufactures thereof, and waste or scrap of any of the foregoing

NOTE:

Item 2-C-2 does not control the following:

1. Metal windows for X-ray machines or for bore-hole logging devices;
2. Oxide shapes in fabricated or semi-fabricated forms

specially designed for electronic component parts or as substrates for electronic circuits;

3. Beryl (silicate of beryllium and aluminum) in the form of emeralds or aquamarines.

2-C-3 Bismuth having both of the following characteristics:

- A purity of 99.99% or greater by weight; and
- Containing less than 10 ppm by weight of silver.

2-C-4 Boron enriched in the boron-10 (^{10}B) isotope to greater than its natural isotopic abundance, as follows: elemental boron, compounds, mixtures containing boron, manufactures thereof, waste or scrap of any of the foregoing

NOTE:

In item 2-C-4, mixtures containing boron include boron loaded materials.

The natural isotopic abundance of boron-10 is approximately 18.5 weight percent (20 atom percent).

2-C-5 Calcium having both of the following characteristics:

- Containing less than 1000 ppm by weight of metallic impurities other than magnesium; and
- Containing less than 10 ppm by weight of boron.

2-C-6 Chlorine trifluoride (ClF_3)

2-C-7 Lithium enriched in the lithium-6 (^{6}Li) isotope to greater than its natural isotopic abundance and products or devices containing enriched lithium, as follows: elemental lithium, alloys, compounds, mixtures containing lithium, manufactures thereof, waste or scrap of any of the foregoing

NOTE:

1. Item 2-C-7 does not control thermoluminescent dosimeters.
2. The natural isotopic abundance of lithium-6 is approximately 6.5 weight percent (7.5 atom percent).

2-C-8 Magnesium having both of the following characteristics:

- Containing less than 200 ppm by weight of metallic impurities other than calcium; and
- Containing less than 10 ppm by weight of boron.

2-C-9 Zirconium with a hafnium content of less than 1 part hafnium to 500 parts zirconium by weight, as follows: metal, alloys containing more than 50% zirconium by weight, compounds, manufactures thereof, waste or scrap of any of the foregoing

NOTE:

Item 2-C-9 does not control zirconium in the form of foil having a thickness of 0.10 mm or less.

2-C-10 Nickel powder and porous nickel metal, as follows:

NOTE:

For nickel powders which are especially prepared for the manufacture of gaseous diffusion barriers see Annex A2.

A. Nickel powder having both of the following characteristics:

- A nickel purity content of 99.0% or greater by weight; and
- A mean particle size of less than 10 μm measured by the American Society for Testing and Materials (ASTM) B330 standard.

B. Porous nickel metal produced from materials specified in item 2-C-10-A.

NOTE:

Item 2-C-10 does not control the following:

1. Filamentary nickel powders;
2. Single porous nickel metal sheets with an area of 1000 cm^2 per sheet or less.

Item 2-C-10-B refers to porous metal formed by compacting and sintering the material in item 2-C-10-A to form a metal material with fine pores interconnected throughout the structure.

2-C-11 Rhenium, and alloys containing 90% by weight or more rhenium; and alloys of rhenium and tungsten containing 90% by weight or more of any combination of rhenium and tungsten, having both of the following characteristics:

- In forms with a hollow cylindrical symmetry (including cylinder segments) with an inside diameter between 100 and 300 mm; and
- A mass greater than 20 kg.

2-D Software

None.

2-E Technology

2-E-1 Technology according to the Technology Control for the development, production or use of equipment, material or software specified in 2-A through 2-D

3- Uranium Isotope Separation Equipment and Components (other than Annex A items)

3-A Equipment, Assemblies and Components

3-A-1 Frequency changers or generators, usable as a variable frequency or fixed frequency motor drive, having all of the following characteristics:

- Multiphase output providing a power of 40 VA or greater;
- Operating at a frequency of 600 Hz or more; and
- Frequency control better (less) than 0.2%.

NOTE:

Frequency changers and generators especially designed or prepared for the gas centrifuge process are controlled under Annex A.

Software specially designed to enhance or release the performance of frequency changers or generators to meet the characteristics below is controlled in 3-D-2 and 3-D-3.

Item 3-A-1 only controls frequency changers intended for specific industrial machinery and/or consumer goods (machine tools, vehicles, etc.) if the frequency changers can meet the characteristics above when removed, and subject to the General Notes (paragraph-3).

Frequency changers in item 3-A-1 are also known as converters or inverters.

The characteristics specified in item 3-A-1 may be met by certain equipment marketed such as: generators, Electronic test equipment, AC power supplies, variable speed motor drives, Variable Speed Drives (VSDs), Variable Frequency Drives (VFDs), Adjustable Frequency Drives (AFDs), or Adjustable Speed Drives (ASDs).

3-A-2 Lasers, laser amplifiers and oscillators as follows:

A. Copper vapor lasers having both of the following characteristics:

- Operating at wavelengths between 500 and 600 nm; and
- An average output power equal to or greater than 30 W.

B. Argon ion lasers having both of the following characteristics:

- Operating at wavelengths between 400 and 515 nm; and

- An average output power greater than 40 W.

C. Neodymium-doped (other than glass) lasers with an output wavelength between 1000 and 1100 nm having either of the following:

  1. Pulse-excited and Q-switched with a pulse duration equal to or greater than 1 ns, and having either of the following:

  - A single-transverse mode output with an average output power greater than 40 W; or

  - A multiple-transverse mode output with an average output power greater than 50 W; or

  2. Incorporating frequency doubling to give an output wavelength between 500 and 550 nm with an average output power of greater than 40 W.

D. Tunable pulsed single-mode dye laser oscillators having all of the following characteristics:

  - Operating at wavelengths between 300 and 800 nm;

  - An average output power greater than 1 W;

  - A repetition rate greater than 1 kHz; and

  - Pulse width less than 100 ns.

E. Tunable pulsed dye laser amplifiers and oscillators having all of the following characteristics:

  - Operating at wavelengths between 300 and 800 nm;

- An average output power greater than 30 W;
- A repetition rate greater than 1 kHz; and
- Pulse width less than 100 ns.

NOTE:

Item 3-A-2-E does not control single mode oscillators.

F. Alexandrite lasers having all of the following characteristics:

- Operating at wavelengths between 720 and 800 nm;
- A bandwidth of 0.005 nm or less;
- A repetition rate greater than 125 Hz; and
- An average output power greater than 30 W.

G. Pulsed carbon dioxide (CO_2) lasers having all of the following characteristics:

- Operating at wavelengths between 9000 and 11000 nm;
- A repetition rate greater than 250 Hz;
- An average output power greater than 500 W; and
- Pulse width of less than 200 ns.

NOTE:

Item 3-A-2-G does not control the higher power (typically 1 to 5 kW) industrial CO_2 lasers used in applications such as cutting and welding, as these latter lasers are either continuous wave or are pulsed with a pulse width greater than 200 ns.

H. Pulsed excimer lasers (XeF, XeCl, KrF) having all of the following characteristics:

- Operating at wavelengths between 240 and 360 nm;
- A repetition rate greater than 250 Hz; and
- An average output power greater than 500 W.

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

J. Pulsed carbon monoxide (CO) lasers having all of the following characteristics:

- Operating at wavelengths between 5000 and 6000 nm;
- A repetition rate greater than 250 Hz;
- An average output power greater than 200 W; and
- Pulse width of less than 200 ns.

NOTE:

Item 3-A-2-J does not control the higher power (typically 1 to 5 kW) industrial CO lasers used in applications such as cutting and welding, as these latter lasers are either continuous wave or are pulsed with a pulse width greater than 200 ns.

3-A-3 Superconducting solenoidal electromagnets having-all of the following characteristics:

- Capable of creating magnetic fields greater than 2 T;
- A ratio of length to inner diameter greater than 2;
- Inner diameter greater than 300 mm; and
- Magnetic field uniform to better than 1% over the central 50% of the inner volume.

NOTE:

Item 3-A-3 does not control magnets specially designed for and exported as part of medical nuclear magnetic resonance (NMR) imaging systems.

3-A-4 High-power direct current power supplies having both of the following characteristics:

- Capable of continuously producing, over a time period of 8 h, 100 V or greater with current output of 500 A or greater; and
- Current or voltage stability better than 0.1% over a time period of 8 h.

3-A-5 High-voltage direct current power supplies having both of the following characteristics:

- Capable of continuously producing, over a time period of 8 h, 20 kV or greater with current output of 1 A or greater; and
- Current or voltage stability better than 0.1% over a time period of 8 h.

3-A-6 All types of pressure transducers capable of measuring absolute pressures and having all of the following characteristics:

- Pressure sensing elements made of or protected by aluminum, aluminum alloy, aluminum oxide (alumina or sapphire), nickel, nickel alloy with more than 60% nickel by weight, or fully fluorinated hydrocarbon polymers;
- Seals, if any, essential for sealing the pressure sensing element, and in direct contact with the process medium, made of or protected by aluminum, aluminum alloy, aluminum oxide (alumina or sapphire), nickel, nickel alloy with more than 60% nickel by weight, or fully fluorinated hydrocarbon polymers; and
- 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 when measuring at 13 kPa.

NOTE:

1. In item 3-A-6, pressure transducers are devices that convert pressure measurements into a signal.
2. In item 3-A-6, accuracy includes non-linearity, hysteresis, and repeatability at ambient temperature.

3-A-7 Vacuum pumps having all of the following characteristics:

- Input throat size equal to or greater than 380 mm;
- Pumping speed equal to or greater than 15 m^3/s; and
- Capable of producing an ultimate vacuum better than 13.3 mPa.

NOTE:

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.

3-A-8 Bellows-sealed scroll-type compressors and bellows-sealed scroll-type vacuum pumps having all of the following characteristics:

- Capable of an inlet volume flow rate of 50 m^3/h or greater;
- Capable of a pressure ratio of 2:1 or greater; and
- Having all surfaces that come in contact with the process gas made from any of the following materials:
    1. Aluminum or aluminum alloy;
    2. Aluminum oxide;
    3. Stainless steel;
    4. Nickel or nickel alloy;

5. Phosphor bronze; or

6. Fluoropolymers.

NOTE:

1. In a scroll compressor or vacuum pump, crescent-shaped pockets of gas are trapped between one or more pairs of intermeshed spiral vanes, or scrolls, one of which moves while the other remains stationary. The moving scroll orbits the stationary scroll; it does not rotate. As the moving scroll orbits the stationary scroll, the gas pockets diminish in size (i.e., they are compressed) as they move toward the outlet port of the machine.

2. In a bellows-sealed scroll compressor or vacuum pump, the process gas is totally isolated from the lubricated parts of the pump and from the external atmosphere by a metal bellows. One end of the bellows is attached to the moving scroll and the other end is attached to the stationary housing of the pump.

3. Fluoropolymers include, but are not limited to, the following materials:

   a. Polytetrafluoroethylene (PTFE),

   b. Fluorinated Ethylene Propylene (FEP),

   c. Perfluoroalkoxy (PFA),

   d. Polychlorotrifluoroethylene (PCTFE); and

   e. Vinylidene fluoride-hexafluoropropylene copolymer.

3-A-9 Valves having all of the following characteristics:

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

NOTE:

For valves with different inlet and outlet diameter, the nominal size parameter in item 3-A-9 refers to the smallest diameter.

3-B Test and Production Equipment

3-B-1 Electrolytic cells for fluorine production with an output capacity greater than 250 g of fluorine per hour

3-B-2 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:

Item 3-B-2-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;

NOTE:

In item 3-B-2-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.

NOTE:

The bellows referred to in item 3-B-2-C have all of the following characteristics:

- Inside diameter between 75 and 400 mm;
- Length equal to or greater than 12.7 mm;
- Single convolution depth greater than 2 mm; and
- Made of high-strength aluminium alloys, maragin steel, or high strength fibrous or filamentary materials.

3-B-3 Filament winding machines and related equipment, as follows:

A. Filament winding machines having all of the following characteristics:

- Having motions for positioning, wrapping, and winding fibres coordinated and programmed in two or more axes;
- Specially designed to fabricate composite structures or laminates from fibrous or filamentary materials; and

- Capable of winding cylindrical tubes with an internal diameter between 75 and 650 mm and lengths of 300 mm or greater.

B. Coordinating and programming controls for the filament winding machines specified in item 3-B-3-A;

C. Precision mandrels for the filament winding machines specified in item 3-B-3-A.

3-B-4 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 following characteristics:

- Swing or journal diameter greater than 75 mm;
- Mass capability of from 0.9 to 23 kg; and
- Capable of balancing speed of revolution greater than 5000 rpm.

B. Centrifugal balancing machines designed for balancing hollow cylindrical rotor components and having all of the following characteristics:

- Journal diameter greater than 75 mm;
- Mass capability of from 0.9 to 23 kg;
- A minimum achievable residual specific unbalance equal to or less than 10 g mm/kg per plane; and
- Belt drive type.

3-B-5 Mass spectrometers capable of measuring ions of 230 u or greater and having a resolution of better than 2 parts in 230, as follows, and ion sources therefor:

NOTE:

Mass spectrometers especially designed or prepared for analyzing on-line samples of uranium hexafluoride (UF_6) are controlled under Annex A.

A. Inductively coupled plasma mass spectrometers (ICP/MS).

B. Glow discharge mass spectrometers (GDMS).

C. Thermal ionization mass spectrometers (TIMS).

D. Electron bombardment mass spectrometers having both of the following features:

- A molecular beam inlet system that injects a collimated beam of analyte molecules into a region of the ion source where the molecules are ionized by an electron beam; and
- One or more cold traps that can be cooled to a temperature of 193 K (-80°C) or less in order to trap analyte molecules that are not ionized by the electron beam.

E. Mass spectrometers equipped with a microfluorination ion source designed for actinides or actinide fluorides.

NOTE:

1. Item 3-B-5-D describes mass spectrometers that are typically used for isotopic analysis of UF_6 gas samples.
2. Electron bombardment mass spectrometers in item 3-B-5-D are also known as electron impact mass spectrometers or electron ionization mass spectrometers.
3. In item 3-B-5-D, "cold trap" is a device that traps gas molecules by condensing or freezing them on cold surfaces. For the purposes of this item, a closed-loop gaseous helium cryogenic vacuum pump is not a cold trap.

3-C Materials

None.

3-D Software

3-D-1 Software specially designed for the use of equipment specified in items 3-A-1, 3-B-3 or 3-B-4

3-D-2 Software or encryption keys/codes specially designed to enhance or release the performance characteristics of equipment not controlled in item 3-A-1 so that it meets or exceeds the characteristics specified in item 3-A-1

3-D-3 Software specially designed to enhance or release the performance characteristics of equipment controlled in item 3-A-1

3-E Technology

3-E-1 Technology according to the Technology Control for the development, production or use of equipment, material or software specified in 3-A through 3-D

4- Heavy Water Production Plant Related Equipment (other than Annex A items)

4-A Equipment, Assemblies and Components

4-A-1 Pumps capable of circulating solutions of concentrated or dilute potassium amide catalyst in liquid ammonia (KNH2/ NH3), having all of the following characteristics:

- Airtight (i.e., hermetically sealed);
- A capacity greater than 8.5 m^3/h; and
- Either of the following characteristics:
    1. For concentrated potassium amide solutions (1% or greater), an operating pressure of 1.5 to 60 MPa; or
    2. For dilute potassium amide solutions (less than 1%), an operating pressure of 20 to 60 MPa.

4-A-2 Turboexpanders or turboexpander-compressor sets having both of the following characteristics:

- Designed for operation with an outlet temperature of 35 K (-238°C) or less; and
- Designed for a throughput of hydrogen gas of 1000 kg/h or greater.

4-B Test and Production Equipment

4-B-1 Hydrogen-cryogenic distillation columns having all of the following characteristics:

- Designed for operation at internal temperatures of 35 K (-238°C) or less;
- Designed for operation at internal pressures of 0.5 to 5 MPa;
- Constructed of either:
    1. Stainless steel of the Society of Automotive Engineers International (SAE) 300 series with low sulfur content and with an austenitic ASTM (or equivalent standard) grain size number of 5 or greater; or
    2. Equivalent materials which are both cryogenic and hydrogen (H_2)-compatible.
- With internal diameters of 30 cm or greater and effective lengths of 4 m or greater.

NOTE:

The term "effective length" means the active height of packing material in a packed-type column, or the active height of internal contactor plates in a plate-type column.

4-C Materials

None.

4-D Software

None.

4-E Technology

4-E-1 Technology according to the Technology Control for the development, production or use of equipment, material or software specified in 4-A through 4-D

5- Test and Measurement Equipment for the Development of Nuclear Explosive Devices

5-A Equipment, Assemblies and Components

5-A-1 Photomultiplier tubes having both of the following characteristics:

- Photocathode area of greater than 20 cm^2; and
- Anode pulse rise time of less than 1 ns.

5-B Test and Production Equipment

5-B-1 Flash X-ray generators or pulsed electron accelerators having either of the following sets of characteristics:

A. First Group:

- An accelerator peak electron energy of 0.5 MeV or greater but less than 25 MeV; and
- With a figure of merit (K) of 0.25 or greater; or

B. Second Group:

- An accelerator peak electron energy of 25 MeV or greater; and
- A peak power greater than 50 MW.

NOTE:

1. Item 5-B-1 does not control accelerators that are component parts of devices designed for purposes other than electron beam or X-ray radiation (electron microscopy, for example) nor those designed for medical purposes.

2. The figure of merit K is defined as:

$$K=1.7 \times 10^{3} V^{2.65} Q$$

   V is the peak electron energy in million electron volts. If the accelerator beam pulse duration is less than or equal to 1 μs, then Q is the total accelerated charge in Coulombs. If the accelerator beam pulse duration is greater than 1 μs, then Q is the maximum accelerated charge in 1μs. Q equals the integral of i with respect to t, over the lesser of 1 μs or the time duration of the beam pulse ($Q=\int idt$) where i is beam current in amperes and t is the time in seconds.

3. Peak power = (peak potential in volts) × (peak beam current in amperes).

4. In machines based on microwave accelerating cavities, the time duration of the beam pulse is the lesser of 1 μs or the duration of the bunched beam packet resulting from one microwave modulator pulse.

5. 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-B-2 High-velocity gun systems (propellant, gas, coil, electromagnetic, and electrothermal types, and other advanced systems) capable of accelerating projectiles to 1.5 km/s or greater

NOTE:

This item does not control guns specially designed for high velocity weapon systems.

5-B-3 High-speed cameras and imaging devices and components therefor, as follows:

NOTE:

Software specially designed to enhance or release the performance of cameras or imaging devices to meet the characteristics below is controlled in items 5-D-1 and 5-D-2

A. Streak cameras, and specially designed components therefor, as follows:

1. Streak cameras with writing speeds greater than 0.5 mm/μs;
2. Electronic streak cameras capable of 50 ns or less time resolution;
3. Streak tubes for cameras specified in item 5-B-3-A-2;
4. Plug-ins specially designed for use with streak cameras which have modular structures and that enable the performance specifications in item 5-B-3-A-1 or 5-B-3-A-2;

5. Synchronizing electronics units, rotor assemblies consisting of turbines, mirrors and bearings specially designed for cameras specified in item 5-B-3-A-1.

B. Framing cameras and specially designed components therefor as follows:

1. Framing cameras with recording rates greater than 225,000 frames per second;

2. Framing cameras capable of 50 ns or less frame exposure time;

3. Framing tubes and solid-state imaging devices having a fast image gating (shutter) time of 50 ns or less specially designed for cameras specified in item 5-B-3-B-1 or 5-B-3-B-2;

4. Plug-ins specially designed for use with framing cameras which have modular structures and that enable the performance specifications in item 5-B-3-B-1 or 5-B-3-B-2;

5. Synchronizing electronics units, rotor assemblies consisting of turbines, mirrors and bearings specially designed for cameras specified in item 5-B-3-B-1 or 5-B-3-B-2.

C. Solid state or electron tube cameras and specially designed components therefor as follows:

1. Solid-state cameras or electron tube cameras with a fast image gating (shutter) time of 50 ns or less;

2. Solid-state imaging devices and image intensifiers tubes having a fast image gating (shutter) time of 50 ns or less specially designed for cameras specified in item 5-B-3-C-1;

3. Electro-optical shuttering devices (Kerr or Pockels cells) with a fast image gating (shutter) time of 50 ns or less;

4. Plug-ins specially designed for use with cameras which have modular structures and that enable the performance specifications in item 5-B-3-C-1.

NOTE:

High speed single frame cameras can be used alone to produce a single image of a dynamic event, or several such cameras can be combined in a sequentially-triggered system to produce multiple images of an event.

5-B-4 Specialized instrumentation for hydrodynamic experiments, as follows:

A. Velocity interferometers for measuring velocities exceeding 1 km/s during time intervals of less than 10 μs;

B. Shock pressure gauges capable of measuring pressures greater than 10 GPa, including gauges made with manganin, ytterbium, and polyvinylidene fluoride (PVDF)/ polyvinyl difluoride (PVF_2);

C. Quartz pressure transducers for pressures greater than 10 GPa.

NOTE:

Item 5-B-5-A includes velocity interferometers such as VISARs (Velocity Interferometer Systems for Any Reflector), DLIs (Doppler Laser Interferometers) and PDV (Photonic Doppler Velocimeters) also known as Het-V (Heterodyne Velocimeters).

5-B-5 High-speed pulse generators, and pulse heads therefor, having both of the following characteristics:

- Output voltage greater than 6 V into a resistive load of less than 55 Ω; and
- Pulse transition time less than 500 ps.

NOTE:

1. In item 5-B-5, pulse transition time is defined as the time interval between 10% and 90% voltage amplitude.
2. Pulse heads are impulse forming networks designed to accept a voltage step function and shape it into a variety of pulse forms that can include rectangular, triangular, step, impulse, exponential, or monocycle types. Pulse heads can be an integral part of the pulse generator, they can be a plug-in module to the device, or they can be an externally connected device.

5-B-6 High explosive containment vessels, chambers, containers, and other similar containment devices designed for the testing of high explosives or explosive devices and having both of the following characteristics:

- Designed to fully contain an explosion equivalent to 2 kg of trinitrotoluene (TNT) or greater; and
- Having design elements or features enabling real time or delayed transfer of diagnostic or measurement information.

5-C Materials

None.

5-D Software

5-D-1 Software or encryption keys/codes specially designed to enhance or release the performance characteristics of equipment not controlled in item 5-B-3 so that it meets or exceeds the characteristics specified in item 5-B-3

5-D-2 Software or encryption keys/codes specially designed to enhance or release the performance characteristics of equipment controlled in item 5-B-3

5-E Technology

5-E-1 Technology according to the Technology Control for the development, production or use of equipment, material or software specified in 5-A through 5-D

6- Components for Nuclear Explosive Devices

6-A Equipment, Assemblies and Components

6-A-1 Detonators and multipoint initiation systems, as follows:

A. Electrically driven explosive detonators, as follows:

1. Exploding bridge (EB);
2. Exploding bridge wire (EBW);
3. Slapper;
4. Exploding foil initiators (EFI).

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

NOTE:

Item 6-A-1 does not control detonators using only primary explosives, such as lead azide.

In item 6-A-1, the detonators of concern all utilize a small electrical conductor (bridge, bridge wire, or foil) that explosively vaporizes 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 (pentaerythritol tetranitrate). In slapper detonators, the explosive vaporization of the electrical conductor drives a flyer or slapper across a gap, and the impact of the slapper on 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.

6-A-2 Firing sets and equivalent high-current pulse generators, as follows:

A. Detonator firing sets (initiation systems, firesets), including electronically-charged, explosively-driven and optically-driven firing sets designed to drive multiple controlled detonators specified by item 6-A-1 above.

B. Modular electrical pulse generators (pulsers) having all of the following characteristics:

- Designed for portable, mobile, or ruggedised-use;
- Capable of delivering their energy in less than 15 μs into loads of less than 40 Ω;
- Having an output greater than 100 A;
- No dimension greater than 30 cm;
- Weight less than 30 kg; and
- Specified to operate over an extended temperature range of 223 to 373 K (-50 to 100°C) or specified as suitable for aerospace applications.

C. Micro-firing units having all of the following characteristics:

- No dimension greater than 35 mm;
- Voltage rating of equal to or greater than 1 kV; and
- Capacitance of equal to or greater than 100 nF.

NOTE:

Optically driven firing sets include both those employing laser initiation and laser charging. Explosively-driven firing sets include both explosive ferroelectric and explosive ferromagnetic firing set types. Item 6-A-2-B includes xenon flashlamp drivers.

6-A-3 Switching devices as follows:

A. Cold-cathode tubes, whether gas filled or not, operating similarly to a spark gap, having all of the following characteristics:

- Containing three or more electrodes;
- Anode peak voltage rating of 2.5 kV or more;
- Anode peak current rating of 100 A or more; and
- Anode delay time of 10 µs or less.

NOTE:

Item 6-A-3-A includes gas krytron tubes and vacuum sprytron tubes.

B. Triggered spark-gaps having both of the following characteristics:

- 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:

- Anode peak voltage rating greater than 2 kV;
- Anode peak current rating of 500 A or more; and
- Turn-on time of 1 µs or less.

6-A-4 Pulse discharge capacitors having either of the following sets of characteristics:

A. First Group:

- Voltage rating greater than 1.4 kV;
- Energy storage greater than 10 J;
- Capacitance greater than 0.5 µF; and
- Series inductance less than 50 nH; or

B. Second Group:

- Voltage rating greater than 750 V;
- Capacitance greater than 0.25 µF; and
- Series inductance less than 10 nH.

6-A-5 Neutron generator systems, including tubes, having both of the following characteristics:

A. First Group:

- Designed for operation without an external vacuum system; and

B. Second Group:

- Utilizing electrostatic acceleration to induce a tritium-deuterium nuclear reaction; or

- Utilizing electrostatic acceleration to induce a deuterium-deuterium nuclear reaction and capable of an output of 3×10^9 neutrons/s or greater.

6-A-6 Striplines to provide low inductance path to detonators with the following characteristics:

- Voltage rating greater than 2 kV; and

- Inductance of less than 20 nH.

6-B Test and Production Equipment

None.

6-C Materials

6-C-1 High explosive substances or mixtures, containing more than 2% by weight of any of the following:

A. Cyclotetramethylenetetranitramine (HMX) (CAS 2691-41-0);

B. Cyclotrimethylenetrinitramine (RDX) (CAS 121-82-4);

C. Triaminotrinitrobenzene (TATB) (CAS 3058-38-6);

D. Aminodinitrobenzo-furoxan or 7-amino-4,6 nitrobenzo-furazane-1-oxide (ADNBF) (CAS 97096-78-1);

E. 1,1-diamino-2,2-dinitroethylene (DADE or FOX7) (CAS 145250-81-3);

F. 2,4-dinitroimidazole (DNI) (CAS 5213-49-0);

G. Diaminoazoxyfurazan (DAAOF or DAAF) (CAS 78644-89-0);

H. Diaminotrinitrobenzene (DATB) (CAS 1630-08-6);

I. Dinitroglycoluril (DNGU or DINGU) (CAS 55510-04-8);

J. 2,6-Bis (picrylamino)-3,5-dinitropyridine (PYX) (CAS 38082-89-2);

K. 3,3'-diamino-2,2',4,4',6,6'-hexanitrobiphenyl or dipicramide (DIPAM) (CAS 17215-44-0);

L. Diaminoazofurazan (DAAzF) (CAS 78644-90-3);

M. 1,4,5,8-tetranitro-pyridazino[4,5-d] pyridazine (TNP) (CAS 229176-04-9);

N. Hexanitrostilbene (HNS) (CAS 20062-22-0); or

O. Any explosive with a crystal density greater than 1.8 g/cm^3 and having a detonation velocity greater than 8000 m/s.

6-D Software

None.

6-E Technology

6-E-1 Technology according to the Technology Control for the development, production or use of equipment, material or software

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