ANNEX 3

List of items to be reported to IAEA

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GENERAL PROVISIONS

Introduction

In paragraph 12 of resolution 687 (1991), the Security Council decided, inter alia, that Iraq shall unconditionally agree not to acquire or develop nuclear weapons or nuclear-weapon-usable material or any subsystems or components or any research, development, support or manufacturing facilities related thereto; to declare to the IAEA the locations, amounts and types of such items, and to accept the destruction, removal, or rendering harmless of all such items. In paragraph 13 of that resolution, the Security Council also asked the IAEA to develop a plan for the future ongoing monitoring and verification of Iraq's compliance with paragraph 12. An additional restriction, specified in paragraph 3. iv) of resolution 707 (1991), currently prohibits Iraq from carrying out nuclear activities of any kind, except for the use of isotopes for medical, agricultural or industrial purposes.

The IAEA's "Plan for Ongoing Monitoring and Verification (OMV) of Iraq's Compliance with Paragraph 12 of Part C of Security Council Resolution 687 (1991) and with the Requirements of Paragraphs 3 and 5 of Resolution 707 (1991)" (hereinafter referred to as the "OMV Plan") was approved by the Security Council in resolution 715 (1991). The Security Council approved the OMV Plan in resolution 715 (1991). Annex 3 of the IAEA's OMV Plan[1] sets out a list of nuclear and nuclear-related items which are either prohibited to Iraq or are subject to certain controls (including reporting to the IAEA by Iraq and reporting by any State exporting such items to Iraq).[2]

In resolution 715 (1991), the Security Council also requested the Committee established under resolution 661 (1990) (hereinafter referred to as the Sanctions Committee), the IAEA and the United Nations Special Commission (UNSCOM) to develop "a mechanism for monitoring any future sales or supplies by other countries to Iraq of items relevant to the implementation of section C of resolution 687 (1991) and other relevant resolutions". The provisions for the export/import monitoring mechanism developed by the Sanctions Committee, UNSCOM and the IAEA were transmitted to the Security Council in document S/1995/1017 (7 December 1995. They included the establishment of a Joint Unit to which relevant exports to, and imports by, Iraq must be reported. That mechanism (hereinafter referred to as the Export/Import Mechanism) was approved by the Security Council in resolution 1051 (1996).

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[1] The OMV Plan, including Annex 3 thereto, was originally published as S/22872/Rev.1 and Corr. 1 (20 September 1991 and 10 October 1991, respectively), and was approved by the United Nations Security Council on 11 October 1991 in Security Council resolution 715 (1991). A first update and revision was issued as S/24300 (16 July 1992). Annex 3 was subsequently revised and re-issued as S/1995/215 (23 March 1995), S/1995/215/Corr. 1 (7 April 1995) and S/1995/215/Corr. 2 (2 August 1995).

[2] See also, for example, paragraphs 22(c), 25, 26, 30(a) and 30(b) of the OMV Plan.

As provided for in the Export/Import Mechanism, Annex 3 of the IAEA's OMV Plan (hereinafter referred to as Annex 3) serves as the list of those nuclear and nuclear-related items which are subject to reporting, under that mechanism, to the Joint Unit, by Iraq and by any State exporting such items to Iraq. Items related to the chemical, biological and missile aspects of the relevant Security Council resolutions are set out in Annexes II, III and IV to the OMV Plans of UNSCOM.[3]

In resolution 1284 (1999), the Security Council requested UNMOVIC (which replaced UNSCOM)[4] and the IAEA to resume the revision and updating of the lists of items and technology to which the Export/Import Mechanism applies. In paragraph 19 of resolution 1330 (2000), the Security Council established 5 June 2001 as the date by which this revision should be completed. This document reflects the results of the revision and updating of Annex 3 with respect to nuclear and nuclear-related items and technology.

Purpose

Annex 3 of the IAEA's OMV Plan lists nuclear material, equipment and technology and nuclear-related materials, equipment, software and related technology, which are subject to the OMV Plan as well to the Export/Import Mechanism. It is designed to assist all organizations, agencies and personnel responsible for ensuring compliance with the OMV and/or the Export/Import Mechanism. These include exporters, customs and other officials in exporting States and in Iraq, personnel in the Joint Unit responsible for the Export/Import Mechanism, and staff of the IAEA and UNMOVIC at Headquarters and in the field.

In addition to certain nuclear materials, the items listed in Annex 3 include those considered to be "especially designed or prepared for the processing, use or production of special fissionable material"[5] (i.e., items for use exclusively in nuclear activities, whether military or civilian). Such items are, for ease of reference, termed, "single-use". Furthermore, Annex 3 lists items considered to be "dual-use" items[6] (i.e., items that may have non-nuclear applications as well as nuclear applications).

Prohibitions and Restrictions

Items prohibited pursuant to resolution 687

Those items which are prohibited to Iraq pursuant to resolution 687 (1991), i.e., those related to weapons development or use, are indicated in Annex 3 by shading and an asterisk. Iraq is required to declare the existence in Iraq of such items to the

[3] See United Nations document S/22871/Rev.1, dated 2 October 1991.
[4] In resolution 1284 (1999), the Security Council established the United Nations Monitoring, Verification and Inspection Commission (UNMOVIC) as a subsidiary body of the Council to replace UNSCOM. UNMOVIC is to undertake the responsibilities mandated to UNSCOM under resolution 687 (1991) and other relevant resolutions of the Security Council.
[5] See IAEA document INFCIRC/254/Rev.4/ Part 1, dated 15 March 2000.
[6] See IAEA document INFCIRC/254/Rev.4/ Part 2, dated 9 March 2000.

IAEA so that the IAEA can arrange to destroy, remove or render such items harmless.

Iraq is also prohibited from acquiring such items; thus, the transfer to Iraq of any item indicated by shading and an asterisk (including technology directly associated with or required for the development, production or use of such item) is prohibited. It bears noting that some of the items indicated as prohibited under resolution 687 (1991) are dual-use items.

Items restricted pursuant to resolution 707

As indicated above, paragraph 3. (iv) of resolution 707 (1991) demands that Iraq "halt all nuclear activities of any kind, except for the use of isotopes for medical, agricultural or industrial purposes until the Security Council determines that Iraq is in full compliance with that resolution and paragraphs 12 and 13 of resolution 687 (1991), and the IAEA determines that Iraq is in full compliance with its safeguards agreement with that Agency." Consequently, in addition to the items prohibited pursuant to resolution 687 (1991), Annex 3 lists items that are of use in peaceful nuclear activities, including research and development, which, although not prohibited under resolution 687 (1991), are prohibited under the additional strictures imposed by resolution 707 (1991). Furthermore, in paragraph 27 of the IAEA OMV plan approved under resolution 715 (1991) requires that, at such a time as the Security Council determines that Iraq may resume nuclear activities not prohibited under resolution 687 (1991), "Iraq shall submit a request to the Security Council specifying precisely the activity, the facility, installation or site where it is to be carried out, and the material or other items involved".

Transfers of non-proscribed items for non-proscribed purposes

The transfer to Iraq of non-proscribed items for non-proscribed purposes is subject to the approval of the IAEA under the OMV Plan and is required to be reported under the Export/Import Mechanism. The list of non-proscribed applications of isotopes is found in Annex 4 of the OMV Plan and is reproduced as Appendix 3 of this document for convenience.

In addition, and in accordance with paragraphs 3 and 4 of resolution 661 (1990) and paragraphs 3 and 11 of resolution 670 (1990), the transfer of any such items is regulated by the Sanctions Committee established under resolution 660 (1990). Resolution 661 prohibits, inter alia, the sale or supply of any commodities or products to Iraq, but not including "supplies intended strictly for medical purposes, and in humanitarian circumstances, foodstuffs to any person or body in Iraq." Resolution 670 (1990) calls upon all States "to carry out their obligations to ensure strict and complete compliance with resolution 661 (1990), and in particular paragraphs 3, 4 and 5 thereof."

Definitions

Annex 3 uses many terms with specific technical meanings. Definitions of these terms are found at appropriate locations in the body of Annex 3, and in Appendix 4 to this document.

Abbreviations and Units

Annex 3 uses the International System of Units (SI). The abbreviations of such units used in Annex 3 are set out in Appendix 5 to this document.

ANNEX 3

LIST OF ITEMS TO BE REPORTED TO IAEA

*Items marked * and shaded are prohibited to Iraq under Resolution 687.*

NUCLEAR MATERIALS

NOTE:
See Appendix 4 for definitions of nuclear materials.

1. *Nuclear Materials

1.1. Uranium and Thorium

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 and any other goods containing one or more of the foregoing.

1.2. Low Enriched Uranium (LEU), or plutonium

Uranium enriched to less than 20% of the isotopes 233, 235, or both; plutonium with an isotopic concentration of Pu-238 exceeding 80%; any of the foregoing in the form of metal, alloy, chemical compound or concentrate and any other goods containing one or more of the foregoing, other than irradiated nuclear fuel (*See item 1.4*).

1.3. *Highly Enriched Uranium (HEU) or plutonium

Uranium enriched to 20% or more in isotopes 233, 235, or both; plutonium containing less than 80% plutonium 238; any of the foregoing in the form of metal, alloy, chemical compound or concentrate and any other goods containing one or more of the foregoing, other than irradiated nuclear fuel (*See item 1.4*).

NOTE
The following items are not prohibited, but are required to be reported:

i) Sub-gram amounts of the special fissionable material specified in 1.3 above in the form of:

a) Certified reference material;

b) Instrument calibration source; or

c) Sensing component in instruments.

1.4. *Irradiated nuclear fuel

EXPLANATORY NOTE
The prohibition applies only to the transfer of irradiated nuclear fuel to Iraq.

1.5. *Neptunium-237

Neptunium enriched to 20% or more in isotope 237 in the form of metal, alloy, chemical compound or concentrate and any other goods containing one or more of the foregoing.

NON-NUCLEAR MATERIALS

NOTE 1
See item for 49.11 deuterium and heavy water.

NOTE 2
See item 49.12 for nuclear grade graphite.

2. Aluminium alloys

Aluminium alloys having both of the following characteristics:

(a) 'Capable of' an ultimate tensile strength of 460 MPa or more at 293 K (20 °C); and

(b) In the form of tubes or cylindrical solid forms (including forgings) with an outside diameter of more than 75 mm.

TECHNICAL NOTE
In item 2(a), the phrase 'capable of' encompasses aluminium alloys before or after heat treatment.

3. Beryllium

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 3 does not include the following:

i) Metal windows for X-ray machines or for bore-hole logging devices;

ii) Oxide shapes in fabricated or semi-fabricated forms especially designed for electronic component parts or as substrates for electronic circuits;

iii) Beryl (silicate of beryllium and aluminium) in the form of emeralds or aquamarines.

4. Bismuth

Bismuth having both of the following characteristics:

(a) A purity of 99.99% or greater by weight; and

(b) Containing less than 10 parts per million by weight of silver.

5. Boron

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 5 mixtures containing boron include boron-loaded materials.

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

6. Calcium

Calcium having both of the following characteristics:

(a) Containing less than 2000 parts per million by weight of metallic impurities other than magnesium; and

(b) Containing less than 20 parts per million by weight of boron.

7. Chlorine trifluoride

8. 'Fibrous or filamentary materials' and prepregs

NOTE
Items 8.1 - 8.3 refer to raw materials. Item 8.4 refers to finished products.

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

(a) A 'specific modulus' of 12.7 x 10^6 m or greater; or

(b) A 'specific tensile strength' of 23.5 x 10^4 m or greater;

NOTE
Item 8.1 does not include aramid 'fibrous or filamentary materials' having 0.25% or more by weight of an ester based fibre surface modifier.

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

(a) A 'specific modulus' of 3.18 x 10^6 m or greater; and

(b) A 'specific tensile strength' of 7.62 x 10^4 m or greater;

8.3. 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 8.1 or item 8.2.

TECHNICAL NOTE
The resin forms the matrix of the composite.

8.4. *Composite structures in the form of tubes having both of the following characteristics:

(a) An inside diameter of between 75 and 400 mm; and

(b) Made with any of the materials specified in item 8.1, item 8.2 and item 8.3.

TECHNICAL NOTE

The term 'fibrous or filamentary materials' includes continuous monofilaments, yarns, rovings, tows, and tapes.

'Filament' or 'monofilament' is the smallest increment of fibre, usually several µm in diameter.

'Roving' is a bundle (typically 12-120) of approximately parallel strands.

'Strand' is a bundle of filaments (typically over 200) arranged approximately parallel.

'Tape' is a material constructed of interlaced or unidirectional filaments, strands, rovings, tows, yarns, etc. usually pre-impregnated with resin.

'Tow' is a bundle of filaments, usually approximately parallel.

'Yarn' is a bundle of twisted strands.

'Specific modulus' is the Young's modulus in N/m^2 divided by the specific weight in N/m^3 when measured at a temperature of 23±2°C and a relative humidity of 50±5%.

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

9. Hafnium

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

10. *Lithium

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

Item 10 does not include thermoluminescent dosimeters.

TECHNICAL NOTE

The natural isotopic abundance of lithium-6 is approximately 6.5 weight percent (7.5 atom percent).

11. Magnesium

Magnesium having both of the following characteristics:

(a) Containing less than 2000 parts per million by weight of metallic impurities other than calcium; and

(b) Containing less than 20 parts per million by weight of boron.

12. *Maraging steel

Maraging steel 'capable of' an ultimate tensile strength of 2050 MPa (2.050 x 10^9 N/m^2) or more at 293 K (20°C).

TECHNICAL NOTE
In item 12, the phrase 'capable of' encompasses maraging steel before or after heat treatment.

NOTE
Item 12 does not include forms in which all linear dimensions are 75 mm or less.

13. Radium-226 (^{226}Ra)

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 1
See item 20 for other alpha-emitting radioisotopes.

NOTE 2
Item 13 does not include the following:

i) Medical applicators;

ii) A product or device containing less than 0.37 GBq of radium-226.

14. Titanium

Titanium alloys capable of having both of the following characteristics:

(a) Of an ultimate tensile strength of 900 MPa or more at 293 K (20 °C); and

(b) In the form of tubes or cylindrical solid forms (including forgings) with an outside diameter of more than 75 mm.

TECHNICAL NOTE
In item 14, the phrase 'capable of' encompasses titanium alloys before or after heat treatment.

15. Tungsten

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

(a) In forms with a hollow cylindrical symmetry (including cylinder segments) with an inside diameter between 100 and 300 mm; and

(b) A mass greater than 20 kg.

16. Zirconium

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 1
Item 16 does not include zirconium in the form of foil having a thickness of 0.10 mm or less.

NOTE 2
See item 49.6 for additional zirconium controls.

17. Nickel

Nickel powder and porous nickel metal, as follows:

17.1. Nickel powder having both of the following characteristics:

(a) A nickel purity content of 99.0% or greater by weight; and

(b) A mean particle size of less than 10 microns (μm) measured by the ASTM B 330 standard;

17.2. Porous nickel metal produced from materials specified in item 17.1

NOTE 1
For nickel powders, which are especially prepared for the manufacture of gaseous diffusion barriers, see item 24.1.

NOTE 2
Item 17 does not include the following:

Filamentary nickel powders;

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

TECHNICAL NOTE
Item 17.2 refers to porous metal formed by compacting and sintering the material in item 17.1 to form a metal material with fine pores interconnected throughout the structure.

18. *Tritium

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

NOTE 1
The following are not prohibited but are required to be reported:

Tritium in luminescent devices (e.g. safety devices installed in aircraft, watches, runway lights) containing less than 40 Ci (4 mg) of tritium in any chemical or physical form. The total amount of tritium imported in any twelve month period under this exception shall not exceed 2000 Ci (0.2 g);

NOTE 2
Tritium labelled organic compounds are not prohibited and are not required to be reported.

NOTE 3
See also item 36.

19. *Helium-3

Helium-3 (^3He), mixtures containing helium-3, and products or devices containing any of the foregoing.

NOTE
Item 19 does not prohibit a product or device containing less than 1 g of helium-3.

20. Alpha sources

Alpha-emitting radionuclides having an alpha half-life of 10 days or greater but less than 200 years, in the following forms:

(a) Elemental;

(b) Compounds having a specific alpha activity of 37 GBq per kg or greater;

(c) Mixtures having a specific alpha activity of 37 GBq per kg or greater;

(d) Products or devices containing any of the foregoing.

NOTE 1
Item 20 does not include a product or device containing less than 3.7 GBq of alpha activity.

NOTE 2
See item 13 for Ra^{226}.

NOTE 3
Item 20(a) above includes, but it is not limited to, the following:

Atomic Number	Element	Half Life	
		Years	Days
147	Europium		24d
148	Europium		54.5d
148	Gadolinium	75y	
151	Gadolinium		120d
188	Platinum		10.2d
208	Polonium	2.898y	
209	Polonium	1.02y	
210(RaD)	Lead	22.3y	

Atomic Number	***Element***	***Half Life***	
		Years	***Days***
210(RaF)	*Polonium*		*138.376d*
223(AcX)	*Radium*		*11.43d*
225	*Actinium*		*10.00d*
227(Ac)	*Actinium*	*21.77y*	
227(RaAc)	*Thorium*		*18.718d*
228(RaTh)	*Thorium*	*1.913y*	
230	*Protactinium*		*17.4d*
230	*Uranium*		*20.8d*
232	*Uranium*	*68.9y*	
235	*Neptunium*	*1.085y*	
236	*Plutonium*	*2.851y*	
237	*Plutonium*		*45.17d*
238	*Plutonium*	*87.74y*	
240	*Curium*		*27d*
241	*Curium*		*32.8d*
241	*Neptunium*	*14.4y*	
242m	*Americium*	*141y*	
242	*Curium*		*162.94d*
243	*Curium*	*28.5y*	
244	*Curium*	*18.11y*	
248	*Californium*		*334d*
250	*Californium*	*13.08y*	
252	*Californium*	*2.645y*	
252	*Einsteinium*	*1.291y*	
253	*Einsteinium*		*20.4d*
254	*Californium*		*60.5d*
254	*Einsteinium*		*275.7d*
255	*Einsteinium*		*38.8d*
257	*Fermium*		*100.5d*
258	*Mendelevium*		*55d*

NOTE 4
Americium in industrial process equipment and petroleum equipment shall not exceed 20 Ci (6.16g) per device.

NOTE 5
The total amount of americium imported in any twelve month period shall not exceed 200 Ci (61.6 g).

NOTE 6
Item 20 does not apply to americium when used in smoke detectors.

21. Tantalum

Tantalum sheets with a thickness of 2.5 mm or greater from which a circle of 200 mm diameter can be obtained.

*PLANTS FOR THE SEPARATION OF ISOTOPES OF URANIUM AND EQUIPMENT, OTHER THAN ANALYTICAL INSTRUMENTS, SPECIALLY DESIGNED OR PREPARED THEREFOR

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:

22. *Gas centrifuges and assemblies and components specially designed or prepared for use in gas centrifuges

INTRODUCTORY NOTE

The gas centrifuge normally consists of a thin-walled cylinder(s) of between 75 mm and 400 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 imbalance. In contrast to other centrifuges, the gas centrifuge for uranium enrichment is characterized by having, within the rotor chamber, a rotating disc-shaped baffle(s) and a stationary tube arrangement for feeding and extracting the UF_6 *gas and featuring at least 3 separate channels, of which 2 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.*

22.1. *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 *EXPLANATORY NOTE* to this section. If interconnected, the cylinders are joined together by flexible bellows or rings as described in section (c) below. The rotor is fitted with an internal baffle(s) and end caps, as described in section (d) and (e) below, 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 400 mm and manufactured from one or more of the high strength to density ratio materials described in the *EXPLANATORY 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 400 mm, having a convolute and manufactured from one or more of the high strength to density ratio materials described in the *EXPLANATORY NOTE* to this section;

(d) Baffles:

Disc-shaped components of between 75 mm and 400 mm in 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 or more of the high strength to density ratio materials described in the *EXPLANATORY NOTE* to this section;

(e) Top caps/Bottom caps:

Disc-shaped components of between 75 mm and 400 mm in 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 *EXPLANATORY NOTE* to this section.

EXPLANATORY NOTE

The materials used for centrifuge rotating components are:

i) Maraging steel capable of an ultimate tensile strength of 2.05 x 10^9 N/m^2 or more;

ii) Aluminium alloys capable of an ultimate tensile strength of 0.46 x 10^9 N/m^2 or more; and

iii) Filamentary materials suitable for use in composite structures and having a specific modulus of 12.3 x 10^6 m or greater and a specific ultimate tensile strength of 0.3 x 10^6 m or greater ('Specific Modulus' is the Young 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.)

22.2. *Static components

(a) Magnetic suspension bearings:

Especially designed or prepared bearing assemblies consisting of an annular magnet suspended within a housing containing a damping medium. The housing is manufactured from an UF_6-resistant material (see *EXPLANATORY NOTE* to Section 22 above). The magnet couples with a pole piece or a second magnet fitted to the top cap described in Section 22.1(e) above. The magnet may be ring-shaped with a relation between the 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 (120,000 in CGS units) or more, or a remanence of 98.5% or more, or an energy product of greater than 80 kJ/m^3 (10^7 gauss-oersteds). 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;

(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 Section 22.1(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 400 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 in the frequency range of 600-2000 Hz and a power range of 50-1000 VA. The stators consist of multiphase windings on a laminated low loss iron core comprised of thin layers typically 2.0 mm thick or less;

(e) Centrifuge housings/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 degrees or less. The housing may also be a honeycomb type structure to accommodate several rotor tubes. The housings are made of, or protected by, materials resistant to corrosion by UF_6;

(f) Scoops:

Especially designed or prepared tubes of up to 12 mm internal diameter 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. The tubes are made of, or protected by, materials resistant to corrosion by UF_6.

23. *Specially designed or prepared auxiliary systems, equipment and components for gas centrifuge enrichment plants

INTRODUCTORY NOTE

The auxiliary systems, equipment, and components for a gas centrifuge enrichment plant are the systems of the plant needed to feed UF_6 to the centrifuges, to link the individual centrifuge 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 centrifuge 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 centrifuge by way of cascade header pipework. The 'product' and 'tails' UF_6 gaseous streams flowing from the centrifuge 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 kilometres 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.

23.1. *Feed systems/'product' and 'tails' withdrawal systems

Especially designed or prepared process systems including:

(a) Feed autoclaves (or stations) used for passing UF_6 to the centrifuge cascades at up to 100 kPa and at a rate of 1 kg/h or more;

(b) Desublimers (or cold traps) used to remove UF_6 from the cascades at up to 3 kPa pressure. The desublimers are capable of being chilled to 203 K (-70°C) and heated to 343 K (70°C); and

(c) 'Product' and 'tails' stations used for trapping UF_6 into containers.

This plant, equipment, and pipework is wholly made of or lined with UF_6-resistant materials (see *EXPLANATORY NOTE* at the end of this section) and is fabricated to very high vacuum and cleanliness standards.

23.2. *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 UF_6-resistant materials (see *EXPLANATORY NOTE* at the end of this section) and is fabricated to very high vacuum and cleanliness standards.

23.3. *UF_6 mass spectrometers/ion sources

Especially designed or prepared magnetic or quadrupole mass spectrometers, capable of taking 'on-line' samples of feed, 'product' or 'tails', from UF_6 gas streams and having all of the following characteristics:

(a) Unit resolution for atomic mass unit greater than 320;

(b) Ion sources constructed of or lined with nichrome or Monel or nickel plated;

(c) Electron bombardment ionization sources; and

(d) A collector system suitable for isotopic analysis.

23.4. *Frequency changers

Frequency changers (also known as converters or inverters) especially designed or prepared to supply motor stators as defined under 22.2(d), or parts, components, and sub-assemblies of such frequency changers having all of the following characteristics:

(a) A multiphase output of 600 to 2000 Hz;

(b) High stability (with frequency control better than 0.1%); and

(c) Total harmonic distortion less than 2%.

NOTE
See also item 84.

EXPLANATORY NOTE
The items listed in section 23 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 stainless steel, aluminium, aluminium alloys, nickel, or alloys containing 60% or more nickel.

24. *Specially designed or prepared assemblies or components for use in gaseous diffusion enrichment

INTRODUCTORY 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. In as much as gaseous diffusion technology uses uranium hexafluoride (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.

24.1. *Gaseous diffusion barriers

(a) Especially designed or prepared thin, porous filters, with a pore size of 100 - l000 Å (ångstroms), 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; and

(b) Specially prepared compounds or powders for the manufacture of such filters. Such compounds and powders include nickel or alloys containing 60% or more nickel, aluminium oxide, or UF_6-resistant fully fluorinated hydrocarbon polymers having a purity of 99.9% or more, a particle size less than 10 microns, and a high degree of particle size uniformity, which are specially prepared for the manufacture of gaseous diffusion barriers.

24.2. *Diffuser housings

Especially designed or prepared hermetically sealed cylindrical vessels greater than 300 mm in diameter and greater than 900 mm in length, or rectangular vessels of comparable dimensions, which have an inlet connection and two outlet connections all of which are greater than 50 mm in diameter, for containing the gaseous diffusion barrier, made of or lined with UF_6-resistant materials and designed for horizontal or vertical installation.

24.3. *Compressors and gas blowers

Especially designed or prepared axial, centrifugal, or positive displacement compressors, or gas blowers with a suction volume capacity of 1 m^3/min or more of UF_6, and with a discharge pressure of up to several hundred kPa, designed for long-term operation in the UF_6 environment with or without an electrical motor of appropriate power, as well as separate assemblies of such compressors and gas blowers. These compressors and gas blowers have a pressure ratio between 2:1 and 6:1 and are made of, or lined with, materials resistant to UF_6.

24.4. *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/min (60 in^3/min).

24.5. *Heat exchangers for cooling UF_6

Especially designed or prepared heat exchangers made of or lined with UF_6-resistant materials (except stainless steel) or with copper or any combination of those metals, and intended for a leakage pressure change rate of less than 10 Pa per hour under a pressure difference of 100 kPa.

24.6. *Porous membranes

Porous membranes, other than those specified in item 24.1, having both of the following characteristics:

(a) Mean pore diameter between 1 nm and 100 nm;

(b) Surfaces that come in contact with the process fluid made from any of the following materials: aluminium, aluminium alloy, aluminium oxide, nickel, nickel alloy, stainless steel, or fully fluorinated hydrocarbon polymers.

NOTE
This entry does not prohibit porous membranes that are component parts of devices or finished products specially designed for water purification or medical uses, and that are being supplied as part of such devices or finished products.

25. *Specially designed or prepared auxiliary systems, equipment and components for use in gaseous diffusion enrichment

INTRODUCTORY 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 specially their shut-down, leads to serious consequences. Therefore, a strict and constant maintenance of vacuum in all technological systems, automatic protection from accidents and the 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 gaseous 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 kilometres 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.

25.1. *Feed systems/'product' and 'tails' withdrawal systems

Especially designed or prepared process systems, capable of operating at pressures of 300 kPa or less, including:

(a) Feed autoclaves, or systems used for passing UF_6 to the gaseous diffusion cascade;

(b) Desublimers (or cold traps) used to remove UF_6 from diffusion cascades;

(c) Liquefaction stations where UF_6 gas from the cascade is compressed and cooled to form liquid UF_6; and

(d) 'Product' or 'tails' stations used for transferring UF_6 into containers.

25.2. *Header piping systems

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

This piping network is normally of the 'double' header system with each stage or group of stages connected to each of the headers.

25.3. *Vacuum systems

(a) Especially designed or prepared large vacuum manifolds, vacuum headers and vacuum pumps having a suction capacity of 5 m^3/min or more; and

(b) Vacuum pumps especially designed for service in UF_6-bearing atmospheres made of, or lined with, aluminium, nickel, or alloys bearing more than 60% nickel. These pumps may be either rotary or positive, may have displacement and fluorocarbon seals, and may have special working fluids present.

25.4. *Special shut-off and control valves

Especially designed or prepared manual or automated shut-off and control bellows valves made of UF_6-resistant materials with a diameter of 40 to 1500 mm for installation in main and auxiliary systems of gaseous diffusion enrichment plants.

25.5. *UF_6 mass spectrometers/ion sources

Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking 'on-line' samples of feed, 'product' or 'tails', from UF_6 gas streams and having all of the following characteristics:

(a) Unit resolution for atomic mass unit greater than 320;

(b) Ion sources constructed of or lined with nichrome or monel or nickel plated;

(c) Electron bombardment ionization sources; and

(d) Collector system suitable for isotopic analysis.

EXPLANATORY NOTE

The items listed in section 25 above either come into direct contact with the UF_6 process gas or directly control the flow within the cascade. All surfaces that come into contact with the process gas are wholly made of, or lined with, UF_6-resistant materials. For the purposes of the sections relating to gaseous diffusion items, the *materials resistant to corrosion by UF_6 include stainless steel, aluminium, aluminium alloys, aluminium oxide, nickel or alloys containing 60% or more nickel and UF_6-resistant fully fluorinated hydrocarbon polymers.*

26. *Specially designed or prepared systems, equipment and components for Aerodynamic enrichment plants

INTRODUCTORY 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 (nozzle 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 materials that are stable in contact with UF_6.

EXPLANATORY NOTE

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 that 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, stainless steel, aluminium, aluminium alloys, nickel or alloys containing 60% or more nickel and UF_6-resistant fully fluorinated hydrocarbon polymers.

26.1. *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 (typically 0.1 to 0.05 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.

26.2. *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, having a diameter of between 0.5 cm and 4 cm, a length to diameter ratio of 20:1 or less and with one or more tangential inlets. The tubes may be equipped with nozzle-type appendages at either or both ends.

EXPLANATORY 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.

26.3. *Compressors and gas blowers

Especially designed or prepared axial, centrifugal or positive displacement compressors or gas blowers made of, or protected by, materials resistant to corrosion by UF_6 and with a suction volume capacity of 2 m^3/min or more of UF_6/carrier gas (hydrogen or helium) mixture.

EXPLANATORY NOTE

These compressors and gas blowers typically have a pressure ratio between 1.2:1 and 6:1.

26.4. *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.

26.5. *Heat exchangers for gas cooling

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

26.6. *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.

EXPLANATORY NOTE

These housings may be cylindrical vessels greater than 300 mm in diameter and greater than 900 mm in length or may be rectangular vessels of comparable dimensions, and may be designed for horizontal or vertical installation.

26.7. *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; and

(d) 'Product' or 'tails' stations used for transferring UF_6 into containers

26.8. *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.

26.9. *Vacuum systems and pumps

(a) Especially designed or prepared vacuum systems having a suction capacity of 5 m^3/min or more, consisting of vacuum manifolds, vacuum headers and vacuum pumps, and designed for service in UF_6-bearing atmospheres; and

(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.

26.10. *Special shut-off and control valves

Especially designed or prepared manual or automated shut-off and control bellows valves made of, or protected by, materials resistant to corrosion by UF_6 with a diameter of 40 to 1500 mm for installation in main and auxiliary systems of aerodynamic enrichment plants.

26.11. *UF_6 mass spectrometers/ion sources

Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking 'on-line' samples of feed, 'product' or 'tails', from UF_6 gas streams and having all of the following characteristics:

(a) Unit resolution for mass greater than 320;

(b) Ion sources constructed of or lined with nichrome or monel or nickel plated;

(c) Electron bombardment ionization sources; and

(d) Collector system suitable for isotopic analysis.

26.12. *UF_6/carrier gas separation systems

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

EXPLANATORY 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:

i) Cryogenic heat exchangers and cryoseparators capable of temperatures of -120oC or less, or

ii) Cryogenic refrigeration units capable of temperatures of -120oC or less, or

iii) Separation nozzle or vortex tube units for the separation of UF6 from carrier gas, or

iv) UF6 cold traps capable of temperatures of -20oC or less.

27. *Specially designed or prepared systems, equipment and components for chemical exchange or ion exchange enrichment plants

INTRODUCTORY 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 counter currently 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 requirement 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 'products' 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 partly 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.

27.1. *Liquid-liquid exchange columns (Chemical exchange)

Countercurrent liquid-liquid exchange columns having mechanical power input (i.e., pulsed columns with sieve plates, reciprocating plate columns, and columns with internal turbine mixers), 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 made of, or protected by, suitable plastic materials (such as fluorocarbon polymers) or glass. The stage residence time of the columns is designed to be short (30 seconds or less).

27.2. *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 made of or are lined with suitable plastic materials (such as fluorocarbon polymers) or are lined with glass. The stage residence time of the centrifugal contactors is designed to be short (30 seconds or less).

27.3. *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.

EXPLANATORY 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.

EXPLANATORY 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, polyphenyl sulphate, polyether sulphone, and resin-impregnated graphite).

27.4. *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.

EXPLANATORY 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, fluorocarbon polymers, polyphenyl sulphate or polyether sulphone plastic-lined and resin-impregnated graphite*

27.5. *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.

EXPLANATORY NOTE

These systems may incorporate equipment such as:

i) 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;

ii) 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.

27.6. *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 fibres. 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 seconds) and are capable of operating at a temperature in the range of 100°C to 200°C.

27.7. *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 100°C to 200°C and pressures above 0.7 MPa.

27.8. *Ion exchange reflux systems (Ion exchange)

(a) Especially designed or prepared chemical or electrochemical reduction systems for regeneration of the chemical reducing agent(s) used in ion exchange uranium enrichment cascades; and

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

EXPLANATORY NOTE

The ion exchange enrichment process may use, for example, trivalent titanium (Ti^{+3}) as a reducing agent 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}.

28. *Systems, equipment and components for use in laser based enrichment plants.

INTRODUCTORY NOTE

Present systems for enrichment processes using lasers fall into two categories: those in which the process medium is atomic uranium vapour and those in which the process medium is the vapour of an uranium compound. Common nomenclature for such processes include:

First category - atomic vapor laser isotope separation (AVLIS or SILVA);

Second category - molecular laser isotope separation (MLIS or MOLIS); and

Chemical reaction by isotope selective laser activation (CRISLA).

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

i) Devices to feed uranium metal vapor (for selective photo-ionization) or devices to feed the vapor of a uranium compound (for photo-dissociation or chemical activation);

ii) Devices to collect enriched and depleted uranium metals as 'product' and 'tails' in the first category, and devices to collect dissociated or reacted compounds as 'products' and unaffected material as 'tails' in the second category;

iii) Process laser systems to selectively excite the uranium-235 species; and

iv) 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 technologies.

EXPLANATORY NOTE

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 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 vapor or liquid uranium metal or uranium alloys include yttria-coated graphite and tantalum; and the materials resistant to corrosion by UF_6 include copper, stainless steel, aluminium, aluminium alloys, nickel or alloys containing 60% or more nickel and UF_6-resistant fully fluorinated hydrocarbon polymers.

28.1. *Uranium vaporization systems (AVLIS)

Especially designed or prepared uranium vaporization systems which contain high-power strip or scanning electron beam guns with a delivered power on the target of more than 2.5 kW/cm.

28.2. *Liquid uranium metal handling systems (AVLIS)

Especially designed or prepared liquid metal handling systems for molten uranium or uranium alloys, consisting of crucibles and cooling equipment for the crucibles.

EXPLANATORY NOTE
The crucibles and other parts of this system that come into contact with molten uranium or uranium alloys are made of, or protected by, material of suitable corrosion and heat resistance. Suitable materials include tantalum, yttria-coated graphite, graphite coated with other rare earth oxides or mixtures thereof.

28.3. *Uranium metal 'product' and 'tails' collector assemblies (AVLIS)

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

EXPLANATORY 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.

28.4. *Separator module housings (AVLIS)

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.

EXPLANATORY 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 closure to allow refurbishment of internal components.

28.5. *Supersonic expansion nozzles (MLIS)

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

28.6. *Uranium pentafluoride product collectors (MLIS)

Especially designed or prepared uranium pentafluoride (UF_5) solid product collectors consisting of filter, impact or cyclone-type collectors, or combinations thereof and which are corrosion resistant to the UF_5/UF_6 environment.

28.7. *UF_6/carrier gas compressors (MLIS)

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.

28.8. *Rotary shaft seals (MLIS)

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.

28.9. *Fluorination systems (MLIS)

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

EXPLANATORY 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 to MLIS units for additional enrichment. In one approach the fluorination reaction may be accomplished within the isotopic 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.

28.10. *UF_6 mass spectrometers/ion sources (MLIS)

Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking 'on-line' samples of feed, 'product' or 'tails', from UF_6 gas streams and having all the following characteristics:

(a) Unit resolution for mass greater than 320;

(b) Ion sources constructed of or lined with nichrome or monel or nickel plated;

(c) Electron bombardment ionization sources; and;

(d) Collector system suitable for isotopic analysis.

28.11. *Feed systems/'product' and 'tails' withdrawal systems (MLIS)

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; and

(d) 'Product' or 'tails' stations used for transferring UF_6 into containers.

28.12. *UF_6/carrier gas separation systems (MLIS)

Especially designed or prepared process systems for separating UF_6 from carrier gas. The carrier gas may be nitrogen, argon, or other gas.

EXPLANATORY NOTE

These systems may incorporate equipment such as:

i) Cryogenic heat exchangers or cryoseparators capable of temperatures of -120°C or less, or

ii) Cryogenic refrigeration units capable of temperatures of -120°C or less, or

iii) UF_6 cold traps capable of temperatures of -20°C or less.

28.13. *Laser systems (AVLIS, MLIS and CRISLA):

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

EXPLANATORY NOTE

The laser system for the AVLIS process usually consists of two lasers: a copper vapor laser and a dye laser. The laser system for MLIS usually consists of a CO_2 or excimer laser and a multi-pass optical cell with revolving mirrors at both ends. Lasers or laser systems for both processes require a spectrum frequency stabilizer for operation over extended periods of time.

28.14. Lasers, laser amplifiers and oscillators as follows:

(a) Copper vapor lasers having both of the following characteristics:

(i) Operating at wavelengths between 500 and 600 nm; and

(ii) An average output power equal to or greater than 40 W;

(b) Argon ion lasers having both of the following characteristics:

(i) Operating at wavelengths between 400 and 515 nm; and

(ii) 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:

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

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

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

(ii) 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:

(i) Operating at wavelengths between 300 and 800 nm;

(ii) An average output power greater than 1 W;

(iii) A repetition rate greater than 1 kHz; and

(iv) Pulse width less than 100 ns;

(e) Tunable pulsed dye laser amplifiers and oscillators having all of the following characteristics:

(i) Operating at wavelengths between 300 and 800 nm;

(ii) An average output power greater than 30 W;

(iii) A repetition rate greater than 1 kHz; and

(iv) Pulse width less than 100 ns;

NOTE
Item 28.14(e) above does not include single mode oscillators.

(f) Alexandrite lasers having all of the following characteristics:

(i) Operating at wavelengths between 720 and 800 nm;

(ii) A bandwidth of 0.005 nm or less;

(iii) A repetition rate greater than 125 Hz; and

(iv) An average output power greater than 30 W;

(g) Pulsed carbon dioxide lasers having all of the following characteristics:

(i) Operating at wavelengths between 9000 and 11000 nm;

(ii) A repetition rate greater than 250 Hz;

(iii) An average output power greater than 500 W; and

(iv) Pulse width of less than 200 ns;

NOTE
Item 28.14(g) above does not include 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:

(i) Operating at wavelengths between 240 and 360 nm;

(ii) Repetition rate greater than 250 Hz; and

(iii) 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) Integrated pulse dye lasers having both of the following characteristics:

(i) A wavelength of 589 nm; and

(ii) An average power greater than 10 W average power;

28.15. AVLIS systems for stable isotopes

Atomic vapor laser isotope separation (AVLIS) systems for enriching stable isotopes of biological, medical, or industrial interest.

29. *Systems, equipment, and components for use in plasma separation enrichment plants

INTRODUCTORY 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 and metal removal systems for the collection of 'product' and 'tails'.

29.1. *Microwave power sources and antennae

Especially designed or prepared microwave power sources and antennae for producing or accelerating ions and having both of the following characteristics:

(a) Greater than 30 GHz frequency; and

(b) Greater than 50 kW mean power output for ion production.

29.2. *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.

29.3. *Uranium plasma generation systems

Especially designed or prepared systems for the generation of uranium plasma, which may contain high-power strip or scanning electron beam guns with a delivered power on the target of more than 2.5 kW/cm.

29.4. *Liquid uranium metal handling systems

Especially designed or prepared liquid metal handling systems for molten uranium or uranium alloys, consisting of crucibles and cooling equipment for the crucibles.

EXPLANATORY NOTE

The crucibles and other parts of this system that come into contact with molten uranium or uranium alloys are made of, or protected by, materials of suitable corrosion and heat resistance. Suitable materials include tantalum, yttria-coated graphite, graphite coated with other rare earth oxides or mixtures thereof.

29.5. *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.

29.6. *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.

EXPLANATORY 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 closure to allow for refurbishment of internal components and are constructed of a suitable non-magnetic material such as stainless steel.

29.7. *Superconducting solenoidal electromagnets

Superconducting solenoidal electromagnets having all of the following characteristics:

(a) Capable of creating magnetic fields of more than 2 T;

(b) A ratio of length to inner diameter greater than 2;

(c) An inner diameter greater than 300 mm; and

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

NOTE 1
This item does not prohibit magnets especially designed for and used 'as part of' medical nuclear magnetic resonance (NMR) imaging systems. However, such items shall be reported.

NOTE 2
'As part of' does not necessarily mean physical part in the same shipment. Separate shipments from different sources are allowed, provided the related export documents clearly specify the 'as part of' relationship.

30. *Electromagnetic enrichment plants, systems, equipment and components

INTRODUCTORY NOTE
In the electromagnetic process uranium metal ions produced by ionization of a salt feed material (typically UCl_4) are accelerated and pass 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.

30.1. *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, 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;

EXPLANATORY NOTE
The housings are especially designed to contain the ion sources, collector plates and water-cooled liners and have provision for diffusion pump connections and openings and closures for removal and reinstallation of these components.

(d) Magnet pole pieces:

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

30.2. *High voltage power supplies

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

(a) Capable of continuous operation;

(b) Output voltage of 20,000 V or greater;

(c) Output current of 1 A or greater; and

(d) Voltage regulation of better than 0.1% over a time period of 8 hours.

30.3. *Magnet power supplies

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

(a) Capable of continuously producing a current of 500 A or greater;

(b) At a voltage of 100 V or greater; and

(c) With a current or voltage regulation better than 0.1% over a time period of 8 hours.

30.4. *High-power, direct current power supplies, other than those specified in 30.3, having both of the following characteristics:

(a) Capable of continuously producing over a time period of 8 hours, 100 V or greater with current output of 500 A or greater; and

(b) Current or voltage stability better than 0.1% over a time period of 8 hours.

30.5. *High-voltage, direct current power supplies, other than those specified in 30.2, having both of the following characteristics:

(a) Capable of continuously producing, over a time period of 8 hours, 100 V or greater with current output of 500 A or greater; and

(b) Current or voltage stability better than 0.1% over a time period of 8 hours.

30.6. Vacuum pumps having all of the following characteristics:

(a) Input throat size equal to or greater than 380 mm;

(b) Pumping speed equal to or greater than 15 m^3/s; and

(c) Capable of producing an ultimate vacuum better than 13.3 mPa.

TECHNICAL NOTE
The pumping speed is determined at the measurement point with nitrogen gas or air.

The ultimate vacuum is determined at the input of the pump with the input of the pump blocked off.

30.7. *Electromagnetic isotope separators other than those specified in 30.1 designed for or equipped with single or multiple ion sources capable of providing a total ion beam current of 50 mA or greater.

TECHNICAL NOTE
A single 50 mA ion source cannot produce more than 3 g of separated highly enriched uranium (HEU) per year from natural abundance feed.

NOTE 1
Item 30.7 includes separators capable of enriching stable isotopes as well as those for uranium.

NOTE 2
Item 30.7 includes separators with ion sources and collectors both in the magnetic field and those configurations in which they are external to the related export documents clearly specify the 'as part of' relationship.

ANALYTICAL INSTRUMENTS AND PROCESS CONTROL SYSTEMS USED IN URANIUM ENRICHMENT

31. *Mass spectrometers

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

31.1. Inductively coupled plasma mass spectrometers (ICP/MS);

31.2. Glow discharge mass spectrometers (GDMS);

31.3. Thermal ionization mass spectrometers (TIMS);

31.4. *Electron bombardment mass spectrometers which have a source chamber constructed from or lined with or plated with materials resistant to UF_6;

31.5. Molecular beam mass spectrometers having both of the following characteristics:

(a) A source chamber constructed from or lined with or plated with stainless steel or molybdenum, and

(b) equipped with a cold trap capable of cooling to 193 K (-80°C) or less;.

31.6. *Molecular beam mass spectrometers having a source chamber constructed from or lined with or plated with materials resistant to UF_6.

31.7. *Mass spectrometers equipped with a microfluorination ion source designed for use with actinides or actinide fluorides.

32. Enrichment plant instrumentation and process control systems

Instrumentation for monitoring temperature, pressure, pH, fluid level or flow rate especially designed to be corrosion resistant to UF_6 by being made of, or protected by, any of the following materials:

(a) Stainless steel;

(b) Aluminium;

(c) Aluminium alloys;

(d) Nickel; and

(e) Alloys containing 60% or more nickel.

33. *Software for the control of uranium enrichment plants or facilities

OTHER ISOTOPE SEPARATION PLANTS

34. Heavy water, deuterium and deuterium compound production plants and equipment

INTRODUCTORY 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% in deuterium, is sent to a distillation unit to produce reactor grade heavy water i. e., 99.75% deuterium oxide.

The ammonia-hydrogen exchange process can extract deuterium from synthesis gas through contact with liquid ammonia in the presence of a catalyst. The synthesis gas is fed into exchange towers and then to an ammonia converter. Inside the towers the gas flows from the bottom to the top while the liquid ammonia flows from the top to the bottom. The deuterium is stripped from the hydrogen in the synthesis gas and concentrated in the ammonia. The ammonia 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 the 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. However, few of the items are available 'off-the-shelf'. The GS and the 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 standard 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. Thus, most of the equipment items would be prepared according to the requirements of the customer.

Finally, it should be noted that, in both the GS and the ammonia-hydrogen exchange process, 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:

34.1. Water-hydrogen sulfide exchange towers

Exchange towers especially designed or prepared for the production of heavy water utilizing the water-hydrogen sulfide exchange process having all of the following characteristics:

(a) Constructed of fine carbon steel (such as ASTM A516);

(b) Diameters of 6 m to 9 m;

(c) Capable of operating at pressures greater than or equal to 2 MPa; and

(d) With a corrosion allowance of 6 mm or greater.

34.2. 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% 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/second while operating at pressures greater than or equal to 1.8 MPa suction and have seals designed for wet H_2S service.

34.3. 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.

34.4. 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 ammonia within a contacting stage internal to the stage towers.

34.5. Ammonia crackers

Ammonia 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.

34.6. Infrared absorption analyzers

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

34.7. 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.

34.8. Heavy water upgrade systems

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

EXPLANATORY 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% deuterium oxide) from heavy water feedstock of lesser concentration.

34.9. Platinized catalysts

Platinized catalysts especially 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.

34.10. Specialized packing

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

(a) Made of phosphor bronze mesh chemically treated to improve wettability; and

(b) Designed to be used in vacuum distillation towers.

34.11. Circulating pumps

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

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

(b) A capacity greater than 8.5 m^3/h; and

(c) Either of the following characteristics:

(i) For concentrated potassium amide solutions (1% or greater), operating pressure of 1.5-60 MPa; or

(ii) For dilute potassium amide solutions (less than 1%), operating pressure of 20-60 MPa.

34.12. Turboexpanders

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

(a) Designed for operation with an outlet temperature of 35 K (- 238 ^{o}C) or less; and

(b) Designed for a throughput of hydrogen gas of 1000 kg/h or greater.

34.13. Water-hydrogen sulfide exchange tray columns and internal contactors

(a) Water-hydrogen sulfide exchange tray columns, having all of the following characteristics:

(i) Can operate at pressures of 2 MPa or greater;

(ii) Constructed of carbon steel having an austentitic ASTM (or equivalent standard) grain size number of 5 or greater; and

(iii) With a diameter of 1.8 m or greater.

(b) Internal contactors for the water-hydrogen sulfide exchange tray columns specified in item 34.13(a).

TECHNICAL NOTE

Internal contactors of the columns are segmented trays which have an effective assembled diameter of 1.8 m or greater; are designed to facilitate countercurrent contacting and are constructed of stainless steels with a carbon content of 0.03% or less. These may be sieve trays, valve trays, bubble cap trays, or turbogrid trays.

34.14. Hydrogen cryogenic distillation columns having all of the following characteristics:

(a) Designed to operate with internal temperatures of -238^{o}C (35 K) or less;

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

(c) Constructed of either:

(i) Stainless steel of the 300 series with low sulfur content and with an austenitic ASTM (or equivalent standard) grain size number of 5 or greater; or

(ii) Equivalent materials which are both cryogenic and H_2-compatible; and

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

34.15. Ammonia synthesis converters

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

35. *Plants for the separation of lithium 6 and specially designed equipment therefor

Lithium isotope separation facilities or plants, and equipment therefor, as follows:

35.1. *Facilities or plants for the separation of lithium isotopes;

35.2. *Equipment for the separation of lithium isotopes, as follows:

(a) Packed liquid-liquid exchange columns especially designed for lithium amalgams;

(b) Mercury or lithium amalgam pumps;

(c) Lithium amalgam electrolysis cells;

(d) Evaporators for concentrated lithium hydroxide solution.

36. * Tritium facilities or plants, and equipment therefor

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

36.2. *Equipment for tritium facilities or plants, as follows:

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

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

NOTE

See also item 18.

URANIUM AND PLUTONIUM CONVERSION PLANTS AND EQUIPMENT

INTRODUCTORY NOTE 1

Uranium conversion plants and systems may perform one or more transformations from one uranium chemical species to another, including:

i) Conversion of uranium ore concentrates to UO_3;

ii) Conversion of UO_3 to UO_2;

iii) Conversion of uranium oxides to UF_4 or UF_6;

iv) Conversion of UF_6 to UF_4;

v) Conversion of UF_4 to UF_6;

vi) Conversion of UF_4 to uranium metal;

vii) Conversion of uranium fluorides to UO_2;

viii) Conversion of uranium oxides to UCl_4.

The above listing is not exhaustive. It covers only the major conversion methods. All systems that convert uranium to and from various chemical species are covered by this section, whether or not they are specifically listed.

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. However, few of the items are available 'off-the-shelf'; most would be prepared according to the requirements and specifications of the customer. Particular care in designing for the criticality hazards associated with highly enriched uranium is essential. In some instances, special design and construction considerations are required to address the corrosive properties of some of the chemicals handled (HF, F_2, ClF_3, and uranium fluorides). ***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.***

INTRODUCTORY NOTE 2

Plutonium conversion plants and systems perform one or more transformations from one plutonium chemical species to another including:

i) Conversion of plutonium nitrate to PuO_2;

ii) Conversion of PuO_2 to PuF_4;

iii) Conversion of PuF_4 to plutonium metal.

Plutonium conversion plants are normally 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. However, few of the items are available 'off-the-shelf'; 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). ***Finally, it should be noted that, for all plutonium conversion processes, items of equipment which individually are not especially designed or prepared for plutonium conversion can be assembled into systems which are especially designed or prepared for use in plutonium conversion.***

37. Specially designed or prepared systems for the conversion of uranium ore concentrates to UO_3 conversion systems

EXPLANATORY 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 using a solvent such as tributyl phosphate. Next, the uranyl nitrate is converted to UO_3 either by concentration and denitration, or by neutralization with gaseous ammonia to produce ammonium diuranate with subsequent filtering, drying, and calcining.

38. *Specially designed or prepared systems for the conversion of UO_3 to UF_6

EXPLANATORY NOTE

Conversion of UO_3 to UF_6 can be performed directly by fluorination. The process requires a source of fluorine gas or chlorine trifluoride.

39. Specially designed or prepared systems for the conversion of UO_3 to UO_2

EXPLANATORY NOTE

Conversion of UO_3 to UO_2 can be performed through reduction of UO_3 with cracked ammonia gas or hydrogen.

40. *Specially designed or prepared systems for the conversion of UO_2 to UF_4

EXPLANATORY NOTE

Conversion of UO_2 to UF_4, can be performed by reacting UO_2 with hydrogen fluoride gas (HF) or freon gas at 300-500 °C.

41. *Specially designed or prepared systems for the conversion of UF_4 to UF_6

EXPLANATORY 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 -10°C (263 K). The process requires a source of fluorine gas.

42. *Specially designed or prepared systems for the conversion of UF_4 to U metal

EXPLANATORY NOTE

Conversion of UF_4 to U 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 (1130°C).

43. *Specially designed or prepared systems for the conversion of UF_6 to UO_2

EXPLANATORY 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, ammonia is added to precipitate ammonium diuranate, and the diuranate is reduced to UO_2 with hydrogen at 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 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.

44. *Specially designed or prepared systems for the conversion of UF_6 to UF_4

EXPLANATORY NOTE

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

45. *Specially designed or prepared systems for the conversion of UO_2 to UCl_4

EXPLANATORY NOTE

Conversion of UO_2 to UCl_4 can be performed by reacting UO_2 with CCl_4 at high temperature. In the first, UO_2 is reacted with carbon tetrachloride (CCl_4) at approximately 400°C. In the second, UO_2 is reacted at approximately 700°C in the presence of carbon black (CAS 1333-86-4), carbon monoxide, and chlorine to yield UCl_4.

46. *Fluorine production electrolytic cells

Electrolytic cells for fluorine production with an output capacity greater than 10 g of fluorine per hour and especially designed parts and accessories therefor.

47. *Plutonium nitrate to oxide conversion systems

EXPLANATORY 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 plutonium nitrate to plutonium dioxide. Other processes can involve the precipitation of plutonium oxalate or plutonium peroxide.

48. *Plutonium metal production systems

EXPLANATORY NOTE

This process usually involves the fluorination of plutonium dioxide, normally with highly corrosive hydrogen fluoride, to produce plutonium fluoride which is subsequently reduced using high purity calcium metal to produce metallic plutonium and 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 reduction to metal.

NUCLEAR REACTORS AND EQUIPMENT

49. Nuclear reactors and equipment

49.1. Complete nuclear reactors

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

EXPLANATORY 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.

49.2. Nuclear reactor vessels

Metal vessels, or major shop-fabricated parts therefor, especially designed or prepared to contain the core of a nuclear reactor as well as relevant reactor internals.

EXPLANATORY NOTE

The reactor vessel head is covered by item 49.2 as a major shop-fabricated part of a reactor vessel.

49.3. Nuclear reactor fuel charging and discharging machines

Manipulative equipment especially designed or prepared for inserting or removing fuel in a nuclear reactor.

EXPLANATORY NOTE

The items noted in 49.3 are capable of on-load operation or employing technically sophisticated positioning or alignment features to allow complex off-load fueling operations such as those in which direct viewing or access to the fuel is not normally available.

49.4. Nuclear reactor control rods and equipment

Especially designed or prepared rods, support or suspension structures therefore, rod drive mechanisms or rod guide tubes to control the fission process rate in a nuclear reactor.

49.5. Nuclear reactor pressure tubes

Tubes which are especially designed or prepared to contain fuel elements and the primary coolant in a reactor at an operating pressure in excess of 50 atmospheres.

49.6. Zirconium tubes

Zirconium metal and alloys in the form of tubes or assemblies of tubes, especially designed or prepared for use in a reactor and in which the relation of hafnium to zirconium is less than 1:500 parts by weight.

49.7. Primary coolant pumps

Pumps especially designed or prepared for circulating the primary coolant for nuclear reactors.

EXPLANATORY NOTE
Especially designed or prepared pumps may include elaborate sealed or multi-sealed system to prevent leakage of primary coolant, canned-driven pumps and pumps with inertial mass systems. This definition encompasses pumps certified to NC-1 (or equivalent) standards.

49.8. Nuclear reactor internals

Nuclear reactor internals especially designed or prepared for use in a nuclear reactor, including support columns for the core, fuel channels, thermal shields, baffles, core grid plates, and diffuser plates.

EXPLANATORY NOTE 1
'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.

EXPLANATORY NOTE 2
Nuclear reactor internals are normally supplied by the reactor supplier. In some cases, certain internal support components are included in the fabrication of the reactor vessel. These items are sufficiently critical to the safety and reliability of the operation of the reactor (and, therefore, to the guarantees and the liability of the reactor supplier), so that their supply, outside the basic supply arrangement for the reactor itself, would not be common practice. Therefore, although the separate supply of these unique, especially designed and prepared, critical, large and expensive items would not necessarily be considered as falling outside the area of concern, such a mode of supply is considered unlikely.

49.9. Heat exchangers

Heat exchangers (steam generators) especially designed or prepared for use in the primary coolant circuit of a nuclear reactor.

EXPLANATORY NOTE
Steam generators are especially designed or prepared to transfer the heat generated in the reactor (primary side) to the feed water (secondary side) for steam generation. In the case of liquid metal fast breeder reactor for which an intermediate liquid metal coolant loop is also present, the heat exchangers transferring the heat from the primary side to the intermediate coolant circuit are understood to be within the scope of control in addition to the steam generator .

49.10. Neutron detection and measuring instruments

Especially designed or prepared neutron detection and measuring instruments for determining neutron flux levels within the core of a nuclear reactor.

<u>*EXPLANATORY NOTE*</u>

The scope of this entry encompasses in-core and ex-core instrumentation which measures flux levels in a large range, typically from 10^4 neutrons per cm^2 per second to 10^{10} neutrons per cm^2 per second or more. Ex-core refers to those instruments outside the core of a nuclear reactor as defined in paragraph 49, but located within the biological shielding.

49.11. 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.

49.12. Nuclear grade graphite

Graphite having a purity level better than 5 parts per million boron equivalent and with a density greater than 1.50 g/cm^3.

<u>*EXPLANATORY NOTE*</u>

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:

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

ii) CF is the conversion factor : (σ_z x A_B) divided by (σ_B x A_z) ;

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

49.13. Nuclear reactor simulators

Electronic simulators especially designed or prepared to provide full mock-up simulation of the operation and control of a nuclear reactor.

NUCLEAR FUEL FABRICATION PLANTS

50. Fuel element fabrication plants and equipment

INTRODUCTORY NOTE

Nuclear fuel elements are manufactured from one or more source or special fissionable materials. 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 design 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.

EXPLANATORY NOTE

Items of equipment that are considered to fall within the meaning of the phrase 'equipment for the fabrication of fuel elements' include the equipment which:

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

i) Seals the nuclear material within the cladding;

ii) Checks the integrity of the cladding or the seal; or

iii) Provides for the finishing surface treatment of the sealed fuel.

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

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

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

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

Typically item iii includes equipment for:

a) X-ray examination of pin or rod end cap welds;

b) Helium leak detection from pressurized pins or rods; and

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

REPROCESSING TECHNOLOGY AND EQUIPMENT

51. *Irradiated Fuel element reprocessing plants and equipment

INTRODUCTORY NOTE

Reprocessing irradiated 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 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).

51.1. *Irradiated fuel element chopping machines

INTRODUCTORY NOTE

This equipment breaches the cladding of the fuel to expose the irradiated nuclear material to dissolution. Especially designed metal cutting shears are the most commonly employed, although advanced equipment, such as lasers, may be used.

Remotely operated equipment especially designed or prepared for use in a reprocessing plant as identified above and intended to cut, chop, or shear irradiated nuclear fuel assemblies, bundles, or rods.

51.2. *Dissolvers

INTRODUCTORY NOTE

Dissolvers normally receive the chopped-up spent fuel. In these criticality safe vessels, the irradiated nuclear material is dissolved in nitric acid and the remaining hulls are removed from the process stream.

Criticality safe tanks (e.g. small diameter, annular, or slab tanks) 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 and maintained.

51.3. *Solvent extractors and solvent extraction equipment

INTRODUCTORY NOTE

Solvent extractors both receive the solution of irradiated fuel from the dissolvers and the organic solution that 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.

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.

51.4. *Chemical holding or storage vessels

INTRODUCTORY 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:

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 reused in the nuclear fuel cycle.

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.

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.

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. They are normally fabricated of materials such as low carbon stainless steels, titanium, or zirconium, or other high quality materials. Holding and storage vessels may be designed for the remote operation and maintenance and may have the following features for control of nuclear criticality:

(a) Walls or internal structures with a boron equivalent of at least 2%; or

(b) A maximum diameter of 175 mm for cylindrical vessels; or

(c) A maximum width of 75 mm for either a slab or annular vessel.

51.5. Hot cells related equipment especially designed or prepared for the handling or processing of radioisotopes or radiation sources in medical and industrial applications as follows:

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

(i) A `cold area´ greater than 0.09 m^2;

(ii) A density greater than 3 g/cm^3; <u>and</u>

(iii) A thickness of 100 mm or greater.

<u>TECHNICAL NOTE</u>
In item 51.5(a)(i) above the term `cold area' means the viewing area of the window exposed to the lowest level of radiation in the design application.

(b) Radiation-hardened TV cameras, or lenses therefor, especially designed or rated as radiation hardened to withstand a total radiation dose greater than 5 x 10^4 Gy (silicon) without operational degradation.

<u>TECHNICAL NOTE</u>
The term Gy (silicon) refers to the energy in Joules per kilogram absorbed by an unshielded silicon sample when exposed to ionising radiation.

(c) 'Robots' or 'end-effectors', having either of the following characteristics:

(i) Especially designed to comply with national safety standards applicable to handling high explosives (for example, meeting electrical code ratings for high explosives); <u>or</u>

(ii) Especially designed or rated as radiation hardened to withstand a total radiation dose greater than 5 x 10^4 Gy (silicon) without operational degradation;

<u>TECHNICAL NOTE</u>
The term Gy (silicon) refers to the energy in Joules per kilogram absorbed by an unshielded silicon sample when exposed to ionizing radiation.

(d) Control units especially designed for any of the 'robots' or 'end-effectors' specified in item 51.5(c).

<u>NOTE</u>
Item 51.5(d) above does not include 'robots' especially designed for non-nuclear industrial applications such as automobile paint-spraying booths.

TECHNICAL NOTE 1

In item 51.5(d) above '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:

i) is multifunctional

ii) is capable of positioning or orienting material, parts, tools, or special devices through variable movements in three-dimensional space;

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

TECHNICAL NOTE 2

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.

TECHNICAL NOTE 3

In the above definition ´user-accessible programmability´ means the facility allowing a user to insert, modify or replace "programs" by means other than:

i) physical change in wiring or interconnections

ii) the setting of function controls including entry of parameters.

TECHNICAL NOTE 4

The above definition does not include the following devices:

Manipulation mechanisms which are only manually/teleoperator controllable;

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;

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;

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;

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 51.5(d)'end-effectors' are grippers, ´active tooling units´, and any other tooling that is attached to the baseplate on the end of a 'robot' manipulator arm.

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

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

(i) A capability of penetrating 0.6 m or more of hot cell wall (through-the-wall operation); <u>or</u>

(ii) 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).

<u>*TECHNICAL NOTE*</u>
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.

51.6. *Hot cells and related equipment especially designed or prepared for the handling and processing of irradiated nuclear material

<u>*EXPLANATORY NOTE*</u>
Small-scale chemical separation of plutonium or uranium or both from irradiated nuclear material requires radiation protection from fission products' gamma activity and from plutonium toxicity. This separation is normally conducted in especially designed or prepared lead- or concrete- shielded cells provided with viewing ports made of high-density glass and remote manipulators. Protection from plutonium toxicity is obtained with an airtight internal lining of the hot cell normally made of low-carbon steel. Hot cells are provided with an air extraction system capable of maintaining a slightly negative pressure and equipped with high efficiency particulate air filters, which prevent the release of aerosols from the hot cell into the environment.

INDUSTRIAL EQUIPMENT AND MACHINE TOOLS

52. *Machine tools and machine tool control units

NOTE
Items 52-64 list specific types of machine tools and industrial equipment.

52.1. *Turning, milling and grinding machines having one or more of the following characteristics:

(a) Vacuum chucks suitable for holding hemispherical parts; or

(b) Machines installed within glove boxes or equivalent containment facilities; or

(c) Explosion-proofing features.

52.2. Machine tools 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, as follows:

(a) Machine tools for turning, grinding, milling or any combination thereof with both of the following characteristics:

(i) Two or more axes that can be coordinated simultaneously for contouring control; and

(ii) One or more of the following characteristics:

(A) Two or more contouring rotary axes; or

(B) One or more contouring tilting spindles; or

(C) Camming (axial displacement) in one revolution of the spindle less (better) than 0.0008 mm total indicator reading (TIR); or

(D) Run out (out-of-true running) in one revolution of the spindle less (better) than 0.0006 mm TIR for grinding or milling machines, 0.0008 mm TIR for turning machines; or

(E) Positioning accuracies, with all compensations available, less (better) than either of the following:

(I) 0.001^{o} on any rotary axis; or

(II) The applicable specification from the following:

✧ 0.004 mm along any linear axis (overall positioning) for grinding machines; or

✧ 0.006 mm along any linear axis (overall positioning) for milling machines; or

✧ 0.010 mm along any linear axis (overall positioning) for turning machines; or

(F) Capable of turning or boring of diameters equal to or greater than 2 meters.

(b) Electrical discharge machines (EDM) as follows:

(i) Wire feed EDMs that have five or more axes that can be coordinated simultaneously for contouring control;

(ii) Non-wire feed EDMs that have two or more contouring rotary axes and that can be coordinated simultaneously for contouring control.

(c) Other machine tools for removing metals, ceramics or composites with both of the following characteristics:

(i) Remove material by means of any of the following methods:

(A) Water or other liquid jets, including those employing abrasive additives; or

(B) Electron beam; or

(C) Laser beam; and

(ii) Have two or more rotary axes having both of the following characteristics:

(A) Capable of being coordinated simultaneously for contouring control; and

(B) Capable of a positioning accuracy of less (better) than 0.003°.

52.3. Numerical control units for machine tools having either of the following characteristics:

(a) Having more than four interpolating axes that can be coordinated simultaneously for contouring control; or

(b) Having two, three, or four interpolating axes that can be coordinated simultaneously for contouring control with one or more of the following characteristics:

(i) Capable of real-time processing of data to modify the tool path during the machining operation by automatic calculation and modification of part program data for machining in two or more axes by means of measuring cycles and access to source data; or

(ii) Capable of receiving directly (on-line) and processing computer-aided design (CAD) data for internal preparation of machine instructions; or

(iii) Capable, without modification, according to the manufacturer's technical specifications, of accepting additional boards that would permit increasing the number of interpolating axes that can be coordinated simultaneously for contouring control, above the control levels, even if they do not contain these additional boards.

52.4. Motion control boards for machine tools specially designed for machine tools having one or more of the following characteristics:

(a) Providing interpolation in more than four axes; or

(b) Capable of real time processing of data to modify the tool path during the machining operation by automatic calculation and modification of part program data for machining in two or more axes by means of measuring cycles and access to source data ; or

(c) Capable of receiving directly (on-line) and processing CAD data for internal preparation of machine instructions.

52.5. Software

(a) Software specially designed or modified for the development, production, or use of equipment listed in 52.2,52.3 or 52.4;

(b) Specific software as follows:

(i) Software to provide adaptive control and having both of the following characteristics:

(A) For flexible manufacturing units (FMUs) that consist at least of equipment described in articles 52 and 54; and

(B) Capable of generating or modifying in real time processing, part program data by using the signals obtained simultaneously by means of at least two detection techniques, such as:

(I) Machine vision (optical ranging);

(II) Infrared imaging;

(III) Acoustical imaging (acoustical ranging);

(IV) Tactile measurement;

(V) Inertial positioning;

(VI) Force measurement;

(VII) Torque measurement;

(ii) Software for electronic devices other than those listed in 52.3 or 52.4 above that provides numerical control capability equivalent to that specified in 52.3.

52.6. Components and parts for machine tools

Components and parts for machine tools included in 52.2 as follows:

(a) Spindle assemblies, consisting of spindles and bearings as a minimal assembly, with radial (run out) or axial (camming) axis motion in one revolution of the spindle less (better) than 0.0008 mm TIR;

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

NOTE
Item 52.6(b) does not cover 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.

(c) Rotary position feedback units (e.g. inductive-type devices, graduated scales, laser, or infrared systems) having, with compensation, an accuracy less (better) than 0.00025° of arc;

NOTE 1
Item 52.6(c)does not cover 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.

NOTE 2
Item 52.6(c) does not cover dimensional inspection machines. Item 54 covers dimensional inspection machines.

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

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

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

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

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

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

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

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

52.7. Components and sub-assemblies

(a) Specially designed components or sub-assemblies or printed circuit boards with mounted components and software capable of upgrading, according to the manufacturer's specifications, numerical control units, motion control boards, machine tools, or feedback devices to the specifications described in 52.2, 52.3,52.4, 52.6(b) and 52.6(c);

(b) Compound rotary tables.

52.8. Technology

(a) Technology for the production of equipment listed in 52.2, 52.3, 52.4, 52.6, and 52.7.

(b) Other technology for either of the following uses:

(i) Development of interactive graphics as an integrated part in numerical control units for preparation or modification of part programs; or

(ii) Development of integration software for incorporation of expert systems for advanced decision support of shop floor operations into numerical control units.

TECHNICAL NOTE

'Accuracy'

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

'Adaptive control'

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

'Camming' (axial displacement)

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

'Compound rotary table'

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

'Contouring control'

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

'Digital computer'

Equipment, which can, in the form of one or more discrete variables:

- *i) Accept data;*
- *ii) Store data or instructions in fixed or alterable (writable) storage devices;*
- *iii) Process data by means of a stored sequence of instructions which is modifiable; and*
- *iv) Provide output of data*

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

'flexible manufacturing unit' (FMU)

An entity which includes a combination of at least:

- *i) A digital computer including its own main storage and its own related equipment; and*
- *ii) Two or more of the machines described in items 52, 53, 54 and 55.*

N.B. 'flexible manufacturing unit' (FMU) is sometimes also referred to as 'flexible manufacturing system' (FMS) or 'flexible manufacturing cell' (FMC).

'Laser'

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

'Main storage'

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

'Microprogram'

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

'Motion control board'

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

'Numerical control'

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

'Part program'

An ordered set of instructions in a language and in a format required to cause operations to be effected under automatic control, which is either written in the form of a machine program on an input medium or prepared as input data for processing in a computer to obtain a machine program (Ref.ISO 2806-1980).

'Positioning accuracy'

Of numerically controlled machine tools is to be determined and presented in conjunction with the requirements below:

i) Test conditions (ISO/230/2 paragraph 3):

a) For 12 hours before and during measurements, the machine tool and accuracy measuring equipment will be kept at the same ambient temperature. During the pre-measurement time, the slides of the machine will be continuously cycled identically to the way they will be cycled during the accuracy measurements;

b) The machine shall be equipped with any mechanical, electronic, or software compensation to be exported with the machine;

c) Accuracy of measuring equipment for the measurements shall be at least four times more accurate than the expected machine tool accuracy;

d) Power supply for slide drives shall be as follows:

(A) Line voltage variation shall not be greater than ± 10% of nominal rated voltage;

(B) Frequency variation shall not be greater than ± 2 Hz of normal frequency;

(C) Lineouts of interrupted service are not permitted.

ii) Test Program (ISO/230/2 paragraph 4):

a) Feed rate (velocity of slides) during measurement shall be the rapid traverse rate:

N.B.: In the case of machine tools which generate optical quality surfaces, the feed rate shall be equal to or less than 50mm per minute;

b) The limit of the axis travel to the other without returning to the starting position for each move to the target position;

c) Axes not being measured shall be retained at mid-travel during test of an axis.

iii) Presentation of test results (ISO/230/2 paragraph 2); The results of the measurements must include:

a) Positioning accuracy and

b) The mean reversal error.

'Program'

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

'Real-time processing'

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

'Robot'

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

i) Is multifunctional;

ii) Is capable of positioning or orienting material, parts, tools or special devices through variable movements in three-dimensional space;

iii) Incorporates three or more closed or open loop servo-devices which may include stepping motors; and

iv) Has user-accessible programmability by means of teach/playback method or by means of an electronic computer, which may be a programmable logic controller, i.e. without mechanical intervention.

N.B. The above definition does not include the following devices:

a) Manipulation mechanisms which are only manually/teleoperator controllable;

b) Fixed sequence manipulation mechanisms which are automated moving devices, operating according to mechanically fixed programmed motions. The program is mechanically limited by fixed stops, such as pins or cams. The sequence of motions and the selection of paths or angles are not variable or changeable by mechanical, electronic or electrical means;

c) Mechanically controlled variable sequence manipulation mechanisms which are automated moving devices, operating according to mechanically fixed programmed motions. The program is mechanically limited by fixed, but adjustable, stops, such as pins or cams. The sequence of motions and the selection of paths or angles are variable within the fixed program pattern. Variations or modifications of the program pattern (e.g. changes of pins 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.

f) Robots specially designed for non-nuclear industrial applications such as automobile paint-spraying booths.

'End effector'

End effectors include grippers, active tooling units, and any other tooling that is attached to the base plate on the end of a robot manipulator arm.

'Run out' (out-of-true-running)

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

'Sensors'

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

'Software'

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

'Tilting spindle'

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

'User-accessible programmability'

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

i) A physical change in wiring or interconnections; or

ii) The setting of function controls including entry of parameters.

53. Spin-forming and flow-forming machines

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

53.1. Machines which have both of the following characteristics:

(a) Three or more rollers (active or guiding); <u>and</u>

(b) Which, according to the manufacturer's technical specification, can be equipped with numerical control units or a computer control.

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

NOTE
Item 53.1 above 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.

54. Dimensional inspection machines

Dimensional inspection machines, devices or systems, as follows, and especially designed software therefor.

54.1. Computer controlled or numerically controlled dimensional inspection machines having both of the following characteristics:

(a) Two or more axes; and

(b) A one-dimensional length 'measurement uncertainty' equal to or better (less) than (6+ L/1000) µm (L is the measured length in millimetres) (Ref: VDI/VDE 2617 parts 1 and 2);

54.2. Linear and angular displacement measuring devices, as follows:

(a) Linear measuring instruments having any of the following characteristics:

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

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

(A) Linearity equal to or less (better) than 0.1% within a measuring range up to 5 mm; and

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

(iii) Measuring systems that have both of the following characteristics:

(A) Contain a laser; and

(B) Maintain for at least 12 hours, over a temperature range of ± 1 K around a standard temperature and a standard pressure:

(I) A resolution over their full scale of 0.1 µm or better; and

(II) A 'measurement uncertainty' equal to or less (better) than (0.2 ±L/2000) µm (L is the measured length in mm)

<u>NOTE</u>
Item 54.2(a)(iii) does 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.

(b) Angular measuring instruments having an 'angular position deviation' equal to or less (better) than 0.00025°;

<u>NOTE</u>
Item 54.2(b) does not include optical instruments, such as autocollimators, using collimated light to detect angular displacement of a mirror.

(c) Systems for simultaneous linear-angular inspection of hemishells, having both of the following characteristics:

(i) 'Measurement uncertainty' along any linear axis equal to or less (better) than 3.5 µm per 5 mm; <u>and</u>

(ii) 'Angular position deviation' equal to or less than 0.02°.

<u>NOTE</u>
Especially designed software for the systems described in paragraph 54.2(c) includes software for simultaneous measurement of wall thickness and contour.

<u>TECHNICAL NOTE 1</u>
Item 54 includes machine tools that can be used as measuring machines if they meet or exceed the criteria specified for the measuring machine function.

<u>TECHNICAL NOTE 2</u>
Machines described in item 54 are required to be reported if they exceed the threshold specified anywhere within their operating range.

<u>TECHNICAL NOTE 3</u>
The probe used in determining the 'measurement uncertainty' of a dimensional inspection system shall be as described in VDI/VDE 2617 parts 2, 3 and 4.

<u>TECHNICAL NOTE 4</u>
All parameters of measurement values in this item represent plus/minus, i.e. not total band.

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

'Resolution'

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

'Linearity'

(Usually measured in terms of 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.

'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. (Reference: VD1/VDE 2617. Draft: 'Rotary table on coordinate measuring machines').

55. Isostatic presses (cold and hot)

'Isostatic presses', and related equipment, as follows:

55.1. 'Isostatic presses' having both of the following characteristics:

(a) Capable of achieving a maximum working pressure of 69 MPa or greater; and

(b) A chamber cavity with an inside diameter in excess of 152 mm;

55.2. Dies, moulds, and controls especially designed for the ´isostatic presses´ specified in item 55.1.

TECHNICAL NOTE 1
In item 55,´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.

TECHNICAL NOTE 2
In item 55, 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.

56. *Rotor fabrication and assembly equipment

56.1. *Rotor assembly equipment for assembly of rotor tube sections, baffles, and end caps;

NOTE
Item 56.1 includes precision mandrels, clamps and shrink fit machines.

56.2. *Rotor straightening equipment for alignment of rotor tube sections to a common axis;

NOTE
Normally such equipment will consist of precision measuring probes linked to a computer that subsequently controls the action of, for example, pneumatic rams used for aligning the rotor tube sections.

56.3. *Bellows-forming mandrels and dies for producing single-convolution bellows.

TECHNICAL NOTE

The bellows referred to in item 56.3 have all of the following characteristics:

i) Inside diameter between 75 and 400 mm;

ii) Length equal to or greater than 12.7 mm;

iii) Single convolution depth greater than 2 mm; and

iv) Made of high-strength aluminium alloys, maraging steel, or high strength 'fibrous or filamentary materials'.

57. *Centrifugal balancing machines

Centrifugal multi-plane balancing machines, fixed or portable, horizontal or vertical, as follows; and especially designed software therefor:

57.1. *Centrifugal balancing machines designed for balancing flexible rotors having a length of 400 mm or more and having all the following characteristics:

(a) A swing or journal diameter of 75 mm or more;

(b) Mass capability of from 0.9 to 23 kg; and

(c) Capable of balancing speed of revolution more that 5000 rpm.

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

(a) A journal diameter of 75 mm or more;

(b) Mass capability of from 0.9 to 23 kg;

(c) Capable of balancing to a residual imbalance of 0.010 kg mm/kg per plane or better; and

(d) Belt drive type.

58. *Fibrous and Filamentary material winding machines and related equipment

58.1. *Filament winding machines having all of the following characteristics:

(a) Having motions for positioning, wrapping, and winding fibrous and filamentary material winding coordinated and programmed in two or more axes;

(b) Capable of fabricating composite structures or laminates from 'fibrous or filamentary materials'; and

(c) Capable of winding cylindrical rotors of diameter between 75 and 400 mm and lengths of 400 mm or greater;

58.2. *Coordinating and programming controls for the machines specified in item 58.1.

58.3. *Mandrels for the machines specified in item 58.1.

59. Electron beam welding machines

Electron beam welding machines with a chamber of 0.5 m^3 or more.

60. Plasma spray systems

Plasma spray systems, atmospheric or vacuum.

61. Oxidation furnaces

Vacuum oxidation furnaces with all of the following characteristics:

(a) Having a steam supply capable of introducing slightly superheated steam into the bottom of the furnace at a controlled rate;

(b) Capable of containing a retort of working diameter of 600 mm or more and a workable height of 1200 mm or more; and

(c) Having a radiant heater to uniformly heat the retort to a temperature of 673 K (400°C) or more.

TECHNICAL NOTE

Oxidation furnaces are used to deposit a controlled oxide layer on the surface of the centrifuge components made from maraging steel.

62. *High temperature furnaces

62.1. *Controlled atmosphere (vacuum or inert gas) induction furnaces, and power supplies therefor, as follows:

(a) Furnaces having all of the following characteristics:

(i) Capable of operation at temperatures above 1123 K (850 °C);

(ii) Induction coils 600 mm or less in diameter; and

(iii) Designed for power inputs of 5 kW or more;

TECHNICAL NOTE
Item 62.1(a) does not prohibit furnaces designed for the processing of semiconductor wafers. Such furnaces must, however, be reported to the IAEA.

(b) Power supplies, with a specified output power of 5 kW or more, especially designed for furnaces specified in item 63.1(a).

62.2. *Vacuum or other controlled environment metallurgical melting and casting furnaces and related equipment as follows:

(a) Arc remelt and casting furnaces having both of the following characteristics:

(i) Consumable electrode capacities between 1000 and 20000 cm^3; and

(ii) Capable of operating with melting temperatures above 1973K (1700°C);

(b) Electron beam melting furnaces and plasma atomization and melting furnaces, having both of the following characteristics:

(i) A power of 50 kW or greater; and

(ii) Capable of operating with melting temperatures above 1473K (1200°C);

(c) Computer control and monitoring systems specially configured for any of the furnaces specified in item 62.2(a) or 62.2(b).

63. Vibration test equipment

Vibration test systems, equipment, components and software therefor, as follows:

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

(a) Employing feedback or closed loop control techniques and incorporating a digital control unit;

(b) Capable of vibrating at 10 g RMS or more between 20 and 2000 Hz; and

(c) Capable of imparting forces of 50 kN or greater measured ´bare table´;

63.2. Digital control units, combined with 'especially designed software' for vibration testing, with a real-time bandwidth greater than 5 kHz and being designed for use with the systems listed in 63.1;

63.3. Vibration thrusters (shaker units), with or without associated amplifiers, capable of imparting a force of 50 kN, measured 'bare table', or greater, which are usable for the systems listed in 63.1;

63.4. 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, measured 'bare table', or greater, which are usable for the systems listed in 63.1;

EXPLANATORY NOTE

The term 'bare table' refers to a flat table or surface with no fixtures or fittings.

63.5. 'Especially designed software' for use with the systems listed in 63.1 or for the electronic units listed in 63.4.

IMPLOSION SYSTEMS DEVELOPMENT EQUIPMENT

64. *Hydrodynamic experiment equipment

64.1. *Velocity interferometers for measuring velocities in excess of 1 km per second during time intervals less than 10µs;

NOTE
Item 64.1 includes velocity interferometers such as VISARs (Velocity interferometer systems for any reflector) and DLIs (Doppler laser interferometers).

64.2. *Manganin gauges for pressures greater than 10 GPa;

64.3. *Quartz pressure transducers for pressures greater than 10 GPa;

64.4. *Pindomes;

64.5. *Schliering systems for measuring the density variations in an explosion;

64.6. *Pressure transducers capable of measuring absolute pressures at any point in the range 0 to 13 kPa and having both of the following characteristics:

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

(b) Having either of the following characteristics:

(i) A full scale of less than 13 kPa and an 'accuracy' of better than ± 1% of full scale; or

(ii) A full scale of 13 kPa or greater and an 'accuracy' of better than ± 130 Pa.

TECHNICAL NOTES
In item 64.6 pressure transducers are devices that convert pressure measurements into an electrical signal.

In item 64.6 'accuracy' includes non-linearity, hysteresis, and repeatability at ambient temperature.

65. Flash x-ray equipment

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

(a) Set 1 Characteristics

(i) An accelerator peak electron energy of 500 keV or greater but less than 25 MeV; and

(ii) With a figure of merit (K) of 0.25 or greater; or

(b) Set 2 characteristics

(i) An accelerator peak electron energy of 25 MeV or greater; and

(ii) A peak power greater than 50 MW.

TECHNICAL NOTES:

The figure of merit K is defined as:

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

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

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

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.

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

66. *Gun systems

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

67. *Mechanical rotating mirror cameras

Mechanical rotating mirror cameras, as follows, and especially designed components therefor:

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

67.2. *Streak cameras with writing speeds greater than 0.5 mm/µs.

NOTE
In item 67 components of such cameras include their synchronizing electronics units and rotor assemblies consisting of turbines, mirrors, and bearings.

68. *Electronic streak and framing cameras and components

68.1. *Electronic streak cameras capable of 50 ns or less time resolution;

68.2. *Streak tubes for cameras specified in item 68.1 above;

68.3. *Electronic (or electronically shuttered) framing cameras capable of 50 ns or less frame exposure time including single frame cameras;

68.4. *Framing tubes and solid-state imaging devices for use with cameras listed in 68.3 above, as follows:

(a) Proximity focused image intensifier tubes having the photocathode deposited on a transparent conductive coating to decrease photocathode sheet resistance;

(b) Gate silicon intensifier target (SIT) vidicon tubes, where a fast system allows gating the photoelectons from the photocathode before they impinge on the SIT plate;

(c) Kerr or Pockels cell electro-optical shuttering; or

(d) Other framing tubes and solid-state imaging devices having a fast-image gating time of less than 50 ns especially designed for cameras listed in 68.3.

68.5. *Electronic modules or assemblies (e.g. plug-ins) designed for use with instrumentation cameras and that enable the performance specifications of 68.1 and 68.3 to be achieved.

68.6. *Solid-state imaging devices having an area of 40 cm^2 or greater and a quantum efficiency of greater than 50%.

69. Electronic Digital Computers

Electronic digital computers and microprocessors with a composite theoretical performance (CTP) of greater than 28,000 million theoretical operations per second (MTOPS).

NOTE 1
This item includes parallel clusters, including those assembled from commercial-off-the-shelf (COTS) networking technology, capable of an aggregate performance level exceeding 28,000 MTOPS.

NOTE 2
This item does not include computers essential for medical applications and incorporated in equipment or systems designed or modified for identifiable and dedicated medical applications. Equipment containing computers meeting or exceeding the specifications above must, however, be reported to the IAEA.

70. *Computer codes for nuclear explosives

Hydrodynamics codes, neutronic codes, photon transport codes and/or equation-of-state and related nuclear data and opacity files usable for calculating implosion or gun type weapons.

NOTE
These items include software, equations or data in any form usable for calculations for implosion or gun type weapons.

71. Detonators and multi-point initiator systems

71.1. Electrically driven explosive detonators as follows:

(a) Exploding bridge (EB);

(b) Exploding bridge wire (EBW);

(c) Slapper; and

(d) Exploding foil initiators (EFI).

NOTE
Item 71.1 does not include detonators using only primary explosives, such as lead azide.

TECHNICAL NOTE
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 non-slapper types, the exploding conductor starts a chemical detonation in a contacting high-explosive material such as PETN (pentaerythritoltetranitrate). In slapper detonators, the explosive vaporization of the electrical conductor drives a 'flyer' or 'slapper' across a gap, and the impact of the slapper on the 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'.

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

71.3. Optically driven prompt explosive detonators

TECHNICAL NOTE
These detonators are sometimes referred to as laser slappers. The detonators operate by means of laser light evaporating the surface of a flyer or slapper, generating a plasma that drives the flyer across a gap.

72. *Explosive lenses

Explosive lenses designed to uniformly initiate the detonation of the surface of a high explosive charge.

73. *Firing sets and high-current pulse generators

73.1. *Explosive detonator firing sets designed to drive multiple controlled detonators covered under item 71 above;

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

(a) Designed for portable, mobile or ruggedized use;

(b) Enclosed in a dust-tight enclosure;

(c) Capable of delivering their energy in less than 15 µs;

(d) Having an output greater than 100 A;

(e) Having a rise time of less than 10 µs into loads of less than 40 ohms.

NOTE 1
Rise time is defined as the time interval from 10% to 90% current amplitude when driving a resistive load.

NOTE 2
Item 73.2(e) includes xenon flashlamp drivers.

(f) No dimension greater than 25.4 cm;

(g) Weight less than 25 kg; and

(h) Specified for use over an extended temperature range 223 to 373 K (-50°C to 100°C) or specified as suitable for aerospace applications.

74. Switching devices

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

(a) Containing three or more electrodes;

(b) Anode peak voltage rating of 2500 V or more;

(c) Anode peak current rating of 100 A or more; and

(d) Anode delay time of 10 µs or less;

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

(a) Anode delay time of 15 µs or less; and

(b) Rated for a peak current of 500 A or more;

74.3. Modules or assemblies with a fast switching function having all of the following characteristics:

(a) Anode peak voltage rating greater than 2000 V;

(b) Anode peak current rating of 500 A or more; and

(c) Turn-on time of 1 µs or less.

75. Pulse discharge capacitors

Pulse discharge capacitors with either of the following sets of characteristics:

75.1. Set 1 Characteristics

(a) Voltage rating greater than 1.4 kV,

(b) Energy storage greater than 10 J,

(c) Capacitance greater than 0.5 µF, and

(d) Series inductance less than 50 nH; or

75.2. Set 2 Characteristics

(a) Voltage rating greater than 750 V,

(b) Capacitance greater than 0.25 µF, and

(c) Series inductance less than 10 nH.

76. High explosives

High explosive substances or mixtures, in any form, containing any of the following:

76.1. Cyclotetramethylenetetranitramine (HMX);

76.2. Cyclotrimethylenetrinitramine (RDX);

76.3. Triaminotrinitrobenzene (TATB);

76.4. Hexanitrostilbene (HNS), except when contained in pharmaceuticals;

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

76.6. Pentaerythritoltetranitrate (PETN), except when contained in pharmaceuticals.

OTHER EQUIPMENT

77. *Crucibles

77.1. *Crucibles made of, or coated with, any of the following materials:

(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); <u>or</u>

(i) Zirconium oxide (zirconia) (ZrO_2);

77.2. *Crucibles made of or lined with tantalum, having a purity of 99.9% or greater by weight;

77.3. *Crucibles having both of the following characteristics:

(a) Made of or lined with tantalum having a purity of 98% or greater by weight; <u>and</u>

(b) Coated with tantalum carbide, nitride, boride or any combination of thereof.

78. Neutron generator systems

78.1. *Neutron generator systems, including tubes, having both of the following characteristics:

(a) Designed for operation without an external vacuum system; <u>and</u>

(b) Utilizing electrostatic acceleration to induce a deuterium-deuterium or tritium-deuterium nuclear reaction.

78.2. Neutron generator systems that utilize dense plasma focus for deuterium-deuterium or tritium-deuterium reaction.

79. Time delay generation or time interval measurement equipment

79.1. Digital time delay generators with a resolution of 50 ns or less over time intervals of 1 µs or greater;

79.2. Multi-channel (three or more) or modular time interval meter and chronometry equipment with time resolution less than 50 ns over time ranges greater than 1 µs.

80. Oscilloscopes

Oscilloscopes, transient recorders and especially designed components therefor as follows:

80.1. Non-modular analogue oscilloscopes having a bandwidth of 1 GHz or greater;

80.2. Modular analogue oscilloscope systems having either of the following characteristics;

(a) A mainframe with a bandwidth of 1 GHz or greater; or

(b) Plug-in modules with an individual bandwidth of 4 GHz or greater.

80.3. Analogue sampling oscilloscopes for the analysis of recurring phenomena with an effective bandwidth greater than 4 GHz;

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

NOTE 1

Especially designed components for analogue oscilloscopes, are:

i) Plug-in units;

ii) External amplifiers;

iii) Pre-amplifiers;

iv) Sampling devices; and

v) Cathode ray tubes.

NOTE 2

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

81. High-speed pulse generators

High-speed pulse generators having both of the following characteristics:

(a) Output voltage greater than 6 V into a resistive load of less than 55-ohms; and

(b) 'Pulse transition time' less than 500 ps.

TECHNICAL NOTE
In item 81(b) 'pulse transition time' is defined as the time interval between 10% and 90% voltage amplitude.

82. Pulse amplifiers

Pulse amplifiers having all of the following characteristics:

(a) Gain greater than 6 dBs;

(b) Baseband bandwidth greater than 500 MHz (having the low frequency half-power point at less than 1 MHz and the high frequency half-powered point greater than 500 MHz); and

(c) Output voltage greater than 2 volts into 55 ohms or less. (This corresponds to an output greater than 16 dBm in a 50 ohm system.)

83. Photomultiplier tubes

Photomultiplier tubes having both of the following characteristics:

(a) Photocathode area of greater than 20 cm^2; and

(b) Anode pulse rise time of less than 1 ns.

84. Frequency changers

Frequency changers or generators (also known as converters or inverters), other than those specified in item 23.4, having all of the following characteristics:

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

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

(c) Total harmonic distortion better (less) than 10%; and

(d) Frequency control better (less) than 0.1%.

85. Bellows-sealed valves

Valves having all of the following characteristics:

(a) Nominal size of 5 mm or greater;

(b) Having a bellows seal or a diaphragm; and

(c) Wholly made of or lined with aluminium, aluminium alloy, nickel, or nickel alloy containing more than 60% nickel.

TECHNICAL NOTE
For valves with different inlet and outlet diameter, the nominal size parameter in item 85(a) refers to the smallest diameter.

86. Scroll compressors and vacuum pumps

Bellows-sealed scroll compressors and bellows-sealed scroll-type vacuum pumps in which all surfaces that come in contact with the process gas are made from any of the following materials: aluminium, aluminium alloy, aluminium oxide, stainless steel, nickel, nickel alloy, phosphor bronze, and fluoropolymers.

87. Ion accelerators

Ion accelerators having both of the following characteristics:

(a) Capable of accelerating ions to energies between 120 MeV and 20 GeV; and

(b) Having a figure of merit (K) of 82.0 or greater.

TECHNICAL NOTE
The figure of merit K is defined as K=I(E-120), where I is the average accelerator beam current in mA and E is the final energy in MeV.

APPENDIX 1: GENERAL PRINCIPLES

The description of an item in the Annex includes any such item, whether in new or used condition.

Where the description of any item in Annex 3 contains no qualifications or specifications, it is regarded as including all varieties of that item. Category captions are only for convenience of reference and do not affect the interpretation of item definitions.

The objective of these controls should not be defeated by the transfer of component parts.

The objectives of these controls should not be defeated by the transfer to Iraq 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 be removed or used for other purposes. In judging whether the controlled component or components are to be considered principal elements, licensing authorities should weigh the factors of quantities, value and technological know-how involved and other special circumstances which might establish the controlled component or components as the principal element of the item being procured.

APPENDIX 2: TECHNOLOGY AND SOFTWARE CONTROLS

The transfer of "technology" or "software" directly associated with any item in Annex 3 will be subject to as great a degree of scrutiny and control as the item itself. The transfer of "technology" or "software" for prohibited items is also prohibited.

The licensing for transfer to Iraq of any item in Annex 3 which is not proscribed to Iraq may entail the transfer to the same end user of the minimum "technology" or "software" required for the installation, operation, maintenance and repair of the item.

Controls on transfers of "software" do not apply to:

(a) Software generally available to the public being:

- **(i)** sold from stock at retail selling points without restrictions; and
- **(ii)** designed for installation by the user without further substantial support by the supplier; or

(b) Software "in the public domain".

APPENDIX 3: LIST OF NUCLEAR ACTIVITIES PERMITTED UNDER SECURITY COUNCIL RESOLUTION 707

ANNEX 4 of the OMV Plan is reproduced for convenience.

ANNEX 4
LIST OF NUCLEAR ACTIVITIES PERMITTED UNDER SECURITY COUNCIL RESOLUTION 707

The following peaceful applications of isotopes imported from other States after prior approval by the IAEA are permitted:

1. AGRICULTURAL APPLICATIONS

1.1. Soil fertility, irrigation and crop production

1.2. Plant breeding and genetics

1.3. Animal production and health

1.4. Insect and pest control

1.5. Food preservation

1.6. Other uses as approved by the IAEA

2. INDUSTRIAL APPLICATIONS

2.1. Radiography and other non-destructive testing methods

2.2. Industrial process control and quality control

2.3. Radiotracer applications in oil, chemical and metallurgical processes

2.4. Development of water and mineral resources

2.5. Industrial radiation processing

2.6. Other uses as approved by the IAEA

3. MEDICAL APPLICATIONS

3.1. Diagnostic and therapeutic medicine including dosimetry

3.2. Radiotherapy by teletherapy and brachytherapy

3.3. Nutrition and health-related environmental studies

3.4. Other uses as approved by the IAEA

APPENDIX 4 : 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.

'Basic scientific research'

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

'Depleted Uranium'

Uranium in which the abundance ratio of the isotope uranium-235 is less than that occurring in natural uranium, e.g. uranium in spent fuel from natural uranium fuelled reactors and tails from uranium enrichment processes.

'Development'

is related to all phases before 'production' such as:

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

'Direct-Use Material'

Nuclear material that can be used for the manufacture of nuclear explosives components without transmutation or further enrichment, such as plutonium containing less than 80% plutonium-238, HEU and uranium-233. Chemical compounds, mixtures of direct-use materials (e.g. MOX) and plutonium contained in spent fuel also fall into this category. Unirradiated direct-use material would require less processing time and effort than irradiated direct-use material (contained in spent fuel).

'Enriched Uranium'

Uranium having a higher abundance ratio of the isotope uranium-235 than natural uranium. Enriched uranium is considered as special fissionable material.

'High Enriched Uranium (HEU)'

Uranium enriched to 20% uranium-235 or more. HEU is considered as special fissionable material and as direct-use material.

'In the public domain'

'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.

'Low Enriched Uranium (LEU)'

Uranium enriched to less than 20% uranium-235.

'Microprogram'

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

'Mixed Oxide (MOX)'

A reactor fuel consisting of a mixture of the oxides of uranium and plutonium. MOX is used for recycling reprocessed spent fuel (after separation of waste) into thermal nuclear reactors (thermal recycling) and as a fuel for fast breeder reactors. MOX is considered special fissionable material and as direct-use material.

'Natural Uranium'

Uranium as it normally occurs in nature, having an atomic weight of approximately 238 and containing minute quantities of uranium-234, 0.7% uranium-235 and 99.3% uranium-238.

'Plutonium'

A radioactive element which occurs only in trace amounts in nature, with atomic number 94 and symbol Pu. As produced by irradiating uranium fuels, plutonium contains varying percentages of the isotopes 238, 239, 240, 241, and 242. Plutonium is considered as special fissionable material and direct-use material.

'Production'

means all production phases such as:

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

'Program'

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

'Software'

A collection of one or more 'programs' or 'microprograms' fixed in any tangible medium of expression.

'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.
- The term "source material" is interpreted as not applying to ore or ore residue, in particular to yellowcake, a concentrate consisting essentially of U_30_8.

'Specially Designed Software'

Refers to the minimum operating systems, diagnostic systems, maintenance systems, and application software necessary to be executed on particular equipment to perform the function for which it was designed. To make other incompatible equipment perform the same function requires:

- modification of this software or
- addition of programs

'Special Fissionable Material'

- The term "Special Fissionable Material" means plutonium-239; uranium-233; uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing. The term special fissionable material does not include source material.

- The term “Uranium Enriched in the Isotopes 235 or 233” means uranium containing 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.

'Technical assistance'

'Technical assistance' may take forms such as: instruction, skills, training, working knowledge, consulting services.

NOTE

'Technical assistance' may involve transfer of 'technical data'.

'Technical Data'

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

'Technology'

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

'Uranium-233'

An isotope of uranium which is produced by transmutation of thorium-232 and which is considered as special fissionable material and as direct-use material.

'Use'

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

APPENDIX 5: INTERNATIONAL SYSTEM OF UNITS AND ABBREVIATIONS

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.

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

A---------------------------ampere(s)

Bq --------------------- becquerel(s)

ºC ---------------degree(s) Celsius

CA---- chemical abstracts service

Ci -- ------------------------- curie(s)

cm --------------------centimetre(s)

dB ----------------------- decibel(s)

dBm decibel referred to 1 milliwatt

g ----------------------------- gram(s)

g acceleration of gravity (9.81 m/s^2)

GBq ------------- gigabecquerel(s)

GH ------------------------ gigahertz

GPa ------------------ gigapascal(s)

Gy ------------------------------ gray

h ------------------------------ hour(s)

Hz -------------------------------hertz

J------------------------------ joule(s)

K------------------------------- kelvin

keV ----thousand electron volt(s)

kg -----------------------kilogram(s)

kHz------------------------- kilohertz

kN ------------------ kilonewton(s)

kPa ------------------- kilopascal(s)

kV ---------------------- kilovolt(s)

kW -----------------------kilowatt(s)

m --------------------------- metre(s)

mA ----------------- milliampere(s)

MeV ----- million electron volt(s)

MHz -------------------- megahertz

ml ---------------------- millilitre(s)

mm ------------------- millimetre(s)

MPa ---------------- megapascal(s)

mPa------------------ millipascal(s)

MW ------------------- megawatt(s)

µF --------------------microfarad(s)

µm ------------------ micrometre(s)

µs -------------------microsecond(s)

N ------------------------- newton(s)

nm -------------------- nanometre(s)

ns------------------- nanosecond(s)

nH------------------ nanohenry(ies)

ps -------------------- picosecond(s)

RMS ------------ root mean square

rpm ------- revolutions per minute

s -------------------------- second(s)

T ---------------------------- tesla(s)

TIR -------- total indicator reading

V ----------------------------- volt(s)

W ----------------------------watt(s)