GUIDELINES FOR NUCLEAR TRANSFERS

1. The following fundamental principles for safeguards and export controls should apply to nuclear transfers for peaceful purposes to any non-nuclear-weapon State and, in the case of controls on retransfer, to transfers to any State. In this connection, suppliers have defined an export trigger list.

Prohibition on nuclear explosives

2. Suppliers should authorise transfer of items or related technology identified in the trigger list only upon formal governmental assurances from recipients explicitly excluding uses which would result in any nuclear explosive device.

Physical protection

3. (a) All nuclear materials and facilities identified by the agreed trigger list should be placed under effective physical protection levels to prevent unauthorised use and handling, consistent with the relevant International Atomic Energy Agency (IAEA) recommendations, in particular those set out in Information Circular (INFCIRC)/225.

   (b) The implementation of measures of physical protection in the recipient country is the responsibility of the Government of that country. However, in order to implement the terms agreed upon amongst suppliers, the levels of physical protection on which these measures have to be based should be the subject of an agreement between supplier and recipient.

   (c) In each case, special arrangements should be made for a clear definition of responsibilities for the transport of trigger list items.

Safeguards

4. (a) Suppliers should transfer trigger list items or related technology to a non-nuclear weapon State only when the receiving State has brought into force an agreement with the IAEA requiring the application of safeguards on all source and special fissionable material in its current and future peaceful activities. Suppliers should authorise such transfers only upon formal governmental assurances from the recipient that:

   – if the above-mentioned agreement should be terminated the recipient will bring into force an agreement with the IAEA based on existing IAEA model safeguards agreements requiring the application of safeguards on all trigger list items or related technology transferred by the supplier or processed, or produced or used in connection with such transfers; and

   – if the IAEA decides that the application of IAEA safeguards is no longer possible, the supplier and recipient should elaborate appropriate verification measures. If the recipient does not accept these measures, it should allow at the request of the supplier the restitution of transferred and derived trigger list items.

(b) Transfers covered by paragraph 4(a) to a non-nuclear-weapon State without such a safeguards agreement should be authorised only in exceptional cases when they are deemed essential for the safe operation of existing facilities and if safeguards are applied to those facilities. Suppliers should inform and, if appropriate, consult in the event that they intend to authorise or to deny such transfers.

(c) The policy referred to in paragraph 4(a) and 4(b) does not apply to agreements or contracts drawn up on or prior to April 3, 1992. In case of countries that have adhered or will adhere to INFCIRC/254/Rev. 1/Part 1 later than April 3, 1992, the policy only applies to agreements (to be) drawn up after their date of adherence.

(d) Under agreements to which the policy referred to in paragraph 4(a) does not apply (see paragraphs 4(b) and (c)) suppliers should transfer trigger list items or related technology only when covered by IAEA safeguards with duration and coverage provisions in conformity with IAEA document GOV/1621. However, suppliers undertake to strive for the earliest possible implementation of the policy referred to in paragraph 4(a) under such agreements.

(e) Suppliers reserve the right to apply additional conditions of supply as a matter of national policy.

5. Suppliers will jointly reconsider their common safeguards requirements, whenever appropriate.

Special controls on sensitive exports

6. Suppliers should exercise a policy of restraint in the transfer of sensitive facilities, equipment, technology and material usable for nuclear weapons or other nuclear explosive devices, especially in cases when a State has on its territory entities that are the object of active Nuclear Suppliers Group (NSG) Guidelines Part 2 denial notifications from more than one NSG Participating Government.

(a) In the context of this policy, suppliers should not authorise the transfer of enrichment and reprocessing facilities, and equipment and technology therefor if the recipient does not meet, at least, all of the following criteria:

(i) Is a Party to the Treaty on the Non-Proliferation of Nuclear Weapons and is in full compliance with its obligations under the Treaty;

(ii) Has not been identified in a report by the IAEA Secretariat which is under consideration by the IAEA Board of Governors, as being in breach of its obligations to comply with its safeguards agreement, nor continues to be the subject of Board of Governors decisions calling upon it to take additional steps to comply with its safeguards obligations or to build confidence in the peaceful nature of its nuclear programme, nor has been reported by the IAEA Secretariat as a state where the IAEA is currently unable to implement its safeguards agreement. This criterion would not apply in cases where the IAEA Board of Governors or the United Nations Security Council subsequently decides that adequate assurances exist as to the peaceful purposes of the recipient's nuclear programme and its compliance with its safeguards obligations. For the purposes of this paragraph, "breach" refers only to serious breaches of proliferation concern;

(iii) Is adhering to the NSG Guidelines and has reported to the Security Council of the United Nations that it is implementing effective export controls as identified by United Nations Security Council Resolution (UNSCR) 1540;

(iv) Has concluded an inter-governmental agreement with the supplier including assurances regarding non-explosive use, effective safeguards in perpetuity, and retransfer;

(v) Has made a commitment to the supplier to apply mutually agreed standards of physical protection based on current international guidelines; and

(vi) Has committed to IAEA safety standards and adheres to accepted international safety conventions.

(b) In considering whether to authorise such transfers, suppliers, while taking into account paragraphs 4(e), 6(a), and 10, should consult with potential recipients to ensure that enrichment and reprocessing facilities, equipment and technology are intended for peaceful purposes only; also taking into account at their national discretion, any relevant factors as may be applicable.

(c) Suppliers will make special efforts in support of effective implementation of IAEA safeguards for enrichment or reprocessing facilities, equipment or technology and should, consistent with paragraphs 4 and 14 of the Guidelines, ensure their peaceful nature. In this regard suppliers should authorise transfers, pursuant to this paragraph, only when the recipient has brought into force a Comprehensive Safeguards Agreement, and an Additional Protocol based on the Model Additional Protocol or, pending this, is implementing appropriate safeguards agreements in cooperation with the IAEA, including a regional accounting and control arrangement for nuclear materials, as approved by the IAEA Board of Governors.

(d) In accordance with paragraph 17(b) of the Guidelines, prior to beginning transfers of enrichment or reprocessing facilities, equipment, or technology, suppliers should consult with Participating Governments regarding the non-proliferation-related terms and conditions applicable to the transfer.

(e) If enrichment or reprocessing facilities, equipment, or technology are to be transferred, suppliers should encourage recipients to accept, as an alternative to national plants, supplier involvement and/or other appropriate multinational participation in resulting facilities. Suppliers should also promote international (including IAEA) activities concerned with multinational regional fuel cycle centres.

Special arrangements for export of enrichment facilities, equipment and technology

7. All States that meet the criteria in paragraph 6 above are eligible for transfers of enrichment facilities, equipment and technology. Suppliers recognise that the application of the Special Arrangements below must be consistent with principles of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), in particular Article IV. Any application by the

suppliers of the following Special Arrangements may not abrogate the rights of States meeting the criteria in paragraph 6.

(a) For a transfer of an enrichment facility, or equipment or technology therefor, suppliers should seek a legally-binding undertaking from the recipient state that neither the transferred facility, nor any facility incorporating such equipment or based on such technology, will be modified or operated for the production of greater than 20% enriched uranium. Suppliers should seek to design and construct such an enrichment facility or equipment therefor so as to preclude, to the greatest extent practicable, the possibility of production of greater than 20% enriched uranium.

(b) For a transfer of an enrichment facility or equipment based on a particular enrichment technology which has been demonstrated to produce enriched uranium on a significant scale as of 31 December 2008, suppliers should:

   (1) Avoid, as far as practicable, the transfer of enabling design and manufacturing technology associated with such items; and
   (2) Seek from recipients an appropriate agreement to accept sensitive enrichment equipment, and enabling technologies, or an operable enrichment facility under conditions that do not permit or enable replication of the facilities.

   Information required for regulatory purposes or to ensure safe installation and operation of a facility should be shared to the extent necessary without divulging enabling technology.

(c) Cooperative enrichment enterprises based on a particular enrichment technology which has not been demonstrated to produce enriched uranium on a significant scale as of 31 December 2008, may be developed by participants individually or jointly; and any transfer of the resulting facilities and equipment will become subject to paragraph 7(b) no later than prior to the deployment of a prototype. For the purposes of paragraph 7(c) of the Guidelines, a prototype is a system or facility which is operated to generate technical information to confirm the technical potential or viability of the separation process for large-scale separation of uranium isotopes.

   Suppliers may propose alternative arrangements relating to control of transfers of new enrichment technology to facilitate cooperation on enrichment technology. Such arrangements should be equivalent to those in paragraph 7(b), and the NSG should be consulted on these arrangements. Participating Governments will review the arrangements for export of enrichment facilities, equipment and technology every five years beginning in 2013 for the purpose of addressing changes in enrichment technology and commercial practices.

(d) Suppliers recognise that when implementing the arrangements envisaged by paragraph 7 in relation to existing and new cooperative enrichment enterprises, enabling technology may be held by, shared among, and transferred between partners of such enterprises, if partners agree to do so on the basis of their established decision making processes. Suppliers recognise that uranium enrichment may involve supply chains for the production and transfer of equipment for enrichment facilities and such transfers can be made, subject to the relevant provisions of these Guidelines.

(e) Suppliers should make special efforts to ensure effective implementation of IAEA safeguards at supplied enrichment facilities, consistent with paragraphs 14 and 15 of the Guidelines. For a transfer of an enrichment facility, the supplier and recipient state should work together to ensure that the design and construction of the transferred facility is implemented in such a way so as to facilitate IAEA safeguards. The supplier and recipient state should consult with the IAEA about such design and construction features at the earliest possible time during the facility design phase, and in any event before construction of the enrichment facility is started. The supplier and recipient state should also work together to assist the recipient state in developing effective nuclear material and facilities protection measures, consistent with paragraphs 13 and 15 of the Guidelines.

(f) Suppliers should satisfy themselves that recipients have security arrangements in place that are equivalent or superior to their own to protect the facilities and technology from use or transfer inconsistent with the national laws of the receiving state.

Definitions Section:

For the purpose of implementing paragraph 7 of the Guidelines “Cooperative Enrichment Enterprise” means a multi-country or multi-company (where at least two of the companies are incorporated in different countries) joint development or production effort. It could be a consortium of states or companies or a multinational corporation.

Controls on supplied or derived material usable for nuclear weapons or other nuclear explosive devices

8. Suppliers should, in order to advance the objectives of these guidelines and to provide opportunities further to reduce the risks of proliferation, include, whenever appropriate and practicable, in agreements on supply of nuclear materials or of facilities which produce material usable for nuclear weapons or other nuclear explosive devices, provisions calling for mutual agreement between the supplier and the recipient on arrangements for reprocessing, storage, alteration, use, transfer or retransfer of any material usable for nuclear weapons or other nuclear explosive devices involved.

Controls on retransfer

9. (a) Suppliers should transfer trigger list items or related technology only upon the recipient’s assurance that in the case of:

(1) retransfer of such items or related technology,

or

(2) transfer of trigger list items derived from facilities originally transferred by the supplier, or with the help of equipment or technology originally transferred by the supplier;

the recipient of the retransfer or transfer will have provided the same assurances as those required by the supplier for the original transfer.

(b) In addition the supplier's consent should be required for:

(1) any retransfer of trigger list items or related technology and any transfer referred to under paragraph 9(a) (2) from any State which does not require full scope safeguards, in accordance with paragraph 4(a) of these Guidelines, as a condition of supply;

(2) any retransfer of enrichment, reprocessing or heavy water production facilities, equipment or related technology, and for any transfer of facilities or equipment of the same type derived from items originally transferred by the supplier;

(3) any retransfer of heavy water or material usable for nuclear weapons or other nuclear explosive devices.

(c) To ensure the consent right as defined under paragraph 9(b), government to government assurances will be required for any relevant original transfer.

(d) Suppliers should consider restraint in the transfer of items and related technology identified in the trigger list if there is a risk of retransfers contrary to the assurances given under paragraph 9(a) and (c) as a result of a failure by the recipient to develop and maintain appropriate, effective national export and transshipment controls, as identified by UNSCR1540.

Non-proliferation Principle

10. Notwithstanding other provisions of these Guidelines, suppliers should authorise transfer of items or related technology identified in the trigger list only when they are satisfied that the transfers would not contribute to the proliferation of nuclear weapons or other nuclear explosive devices or be diverted to acts of nuclear terrorism.

Implementation

11. Suppliers should have in place legal measures to ensure the effective implementation of the Guidelines, including export licensing regulations, enforcement measures, and penalties for violations.

SUPPORTING ACTIVITIES

Support for access to nuclear material for peaceful uses

12. Suppliers should, in accordance with the objective of these guidelines, facilitate access to nuclear material for the peaceful uses of nuclear energy, and encourage, within the scope of Article IV of the NPT, recipients to take the fullest possible advantage of the international commercial market and other available international mechanisms for nuclear fuel services while not undermining the global fuel market.

Physical security

13. Suppliers should promote international co-operation in the areas of physical security through the exchange of physical security information, protection of nuclear materials in transit, and recovery of stolen nuclear materials and equipment. Suppliers should promote broadest adherence to the respective international instruments, inter alia, to the Convention on the Physical Protection of Nuclear Material, as well as implementation of INFCIRC/225, as amended from time to time. Suppliers recognise the importance of these activities and other relevant IAEA activities in preventing the proliferation of nuclear weapons and countering the threat of nuclear terrorism.

Support for effective IAEA safeguards

14. Suppliers should make special efforts in support of effective implementation of IAEA safeguards. Suppliers should also support the IAEA's efforts to assist Member States in the improvement of their national systems of accounting and control of nuclear material and to increase the technical effectiveness of safeguards.

    Similarly, they should make every effort to support the IAEA in increasing further the adequacy of safeguards in the light of technical developments and the rapidly growing number of nuclear facilities, and to support appropriate initiatives aimed at improving the effectiveness of IAEA safeguards.

Trigger list plant design features

15. Suppliers should encourage the designers and makers of trigger list facilities to construct them in such a way as to facilitate the application of safeguards and to enhance physical protection, taking also into consideration the risk of terrorist attacks. Suppliers should promote protection of information on the design of trigger list installations, and stress to recipients the necessity of doing so. Suppliers also recognise the importance of including safety and non-proliferation features in design and construction of trigger list facilities.

Export Controls

16. Suppliers should, where appropriate, stress to recipients the need to subject transferred trigger list items and related technology and trigger list items derived from facilities originally transferred by the supplier or with the help of equipment or technology originally transferred by the supplier to export controls as outlined in UNSCR1540. Suppliers are encouraged to offer assistance to recipients to fulfil their respective obligations under UNSCR1540 where appropriate and feasible.

Consultations

17. (a) Suppliers should maintain contact and consult through regular channels on matters connected with the implementation of these Guidelines.

    (b) Suppliers should consult, as each deems appropriate, with other governments concerned on specific sensitive cases, to ensure that any transfer does not contribute to risks of conflict or instability.

(c) Without prejudice to sub-paragraphs (d) to (f) below:

- In the event that one or more suppliers believe that there has been a violation of supplier/recipient understanding resulting from these Guidelines, particularly in the case of an explosion of a nuclear device, or illegal termination or violation of IAEA safeguards by a recipient, suppliers should consult promptly through diplomatic channels in order to determine and assess the reality and extent of the alleged violation. Suppliers are also encouraged to consult where nuclear material or nuclear fuel cycles activity undeclared to the IAEA or a nuclear explosive activity is revealed.

- Pending the early outcome of such consultations, suppliers will not act in a manner that could prejudice any measure that may be adopted by other suppliers concerning their current contacts with that recipient. Each supplier should also consider suspending transfers of Trigger List items while consultations under 17(c) are ongoing, pending supplier agreement on an appropriate response.

- Upon the findings of such consultations, the suppliers, bearing in mind Article XII of the IAEA Statute, should agree on an appropriate response and possible action, which could include the termination of nuclear transfers to that recipient.

(d) If a recipient is reported by the IAEA to be in breach of its obligation to comply with its safeguards agreement, suppliers should consider the suspension of the transfer of Trigger List items to that State whilst it is under investigation by the IAEA. For the purposes of this paragraph, "breach" refers only to serious breaches of proliferation concern.

(e) Suppliers support the suspension of transfers of Trigger List items to States that violate their nuclear non-proliferation and safeguards obligations, recognising that the responsibility and authority for such decisions rests with national governments or the United Nations Security Council. In particular, this is applicable in situations where the IAEA Board of Governors takes any of the following actions:

- Finds, under Article XII.C of the Statute, that there has been non-compliance in the recipient, or requires a recipient to take specific actions to bring itself into compliance with its safeguards obligations;

- Decides that the IAEA is not able to verify that there has been no diversion of nuclear material required to be safeguarded, including situations where actions taken by a recipient have made the IAEA unable to carry out its safeguards mission in that State.

An extraordinary Plenary meeting will take place within one month of the Board of Governors' action, at which suppliers will review the situation, compare national policies and decide on an appropriate response.

(f) The provisions of subparagraph (e) above do not apply to transfers under paragraph 4(b) of the Guidelines.

18. Unanimous consent is required for any changes in these Guidelines, including any which might result from the reconsideration mentioned in paragraph 5.

ANNEX A
TRIGGER LIST REFERRED TO IN GUIDELINES

GENERAL NOTES

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

2. With reference to paragraph 9(b)(2) of the Guidelines, *same type* should be understood as when the design, construction or operating processes are based on the same or similar physical or chemical processes as those identified in the Trigger List.

3. Suppliers recognise the close relationship for certain isotope separation processes between plants, equipment and technology for uranium enrichment and that for isotope separation of "other elements" for research, medical and other non-nuclear industrial purposes. In that regard, suppliers should carefully review their legal measures, including export licensing regulations and information/technology classification and security practices, for isotope separation activities involving "other elements" to ensure the implementation of appropriate protection measures as warranted. Suppliers recognise that, in particular cases, appropriate protection measures for isotope separation activities involving "other elements" will be essentially the same as those for uranium enrichment. (See Introductory Note in Section 5 of the Trigger List.) In accordance with paragraph 17(a) of the Guidelines, suppliers shall consult with other suppliers as appropriate, in order to promote uniform policies and procedures in the transfer and protection of plants, equipment and technology involving isotope separation of "other elements". Suppliers should also exercise appropriate caution in cases involving the application of equipment and technology, derived from uranium enrichment processes, for other non-nuclear uses such as in the chemical industry.

TECHNOLOGY CONTROLS

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

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

In addition to controls on "technology" transfer for nuclear non-proliferation reasons, suppliers should promote protection of this technology for the design, construction, and operation of trigger list facilities in consideration of the risk of terrorist attacks, and should stress to recipients the necessity of doing so.

SOFTWARE CONTROLS

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

For the purposes of implementation of the Guidelines for "software" transfers, suppliers should apply the same principles as for "technology" transfers.

DEFINITIONS

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

"development" is related to all phases before "production" such as:

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

"in the public domain" 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).

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

"other elements" - All elements other than hydrogen, uranium and plutonium.

"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” means a collection of one or more “programs” or “microprograms” fixed in any tangible medium of expression.

“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” 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”.

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

MATERIAL AND EQUIPMENT

1. Source and special fissionable material

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

1.1. "Source material"

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

1.2. "Special fissionable material"

i) The term "special fissionable material" means plutonium-239(^{239}Pu); uranium-233(^{233}U); "uranium enriched in the isotopes 235 or 233"; any material containing one or more of the foregoing; and such other fissionable material as the Board of Governors shall from time to time determine; but the term "special fissionable material" does not include source material;

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

However, for the purposes of the Guidelines, items specified in subparagraph (a) below, and exports of source or special fissionable material to a given recipient country, within a period of one calendar year (1 Jan – 31 Dec), below the limits specified in subparagraph (b) below, shall not be included:

(a) Plutonium with an isotopic concentration of plutonium-238 (^{238}Pu) exceeding 80%;

Special fissionable material when used in gram quantities or less as a sensing component in instruments; and

Source material which the Government is satisfied is to be used only in non-nuclear activities, such as the production of alloys or ceramics;

(b) Special fissionable material	50 effective grams;
Natural uranium	500 kilograms;
Depleted uranium	1000 kilograms; and
Thorium	1000 kilograms.

2. Equipment and Non-nuclear Materials

The designation of items of equipment and non-nuclear materials adopted by the Government is as follows (quantities below the levels indicated in the Annex B being regarded as insignificant for practical purposes):

2.1. Nuclear reactors and especially designed or prepared equipment and components therefor (see Annex B, section 1.);

2.2. Non-nuclear materials for reactors (see Annex B, section 2.);

2.3. Plants for the reprocessing of irradiated fuel elements, and equipment especially designed or prepared therefor (see Annex B, section 3.);

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

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

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

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

ANNEX B

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

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

A	ampere(s)	Electric current
CAS	Chemical Abstracts Service	
°C	degree(s) Celsius	Temperature
cm	centimetre(s)	Length
cm^2	square centimetre(s)	Area
cm^3	cubic centimetre(s)	Volume
°	degree(s)	Angle
g	gram(s)	Mass
g$_0$	acceleration of gravity (9.80665 m/s^2)	Acceleration
GHz	gigahertz	Frequency
GPa	gigapascal(s)	Pressure
H	henry(s)	Electrical inductance
h	hour(s)	Time
Hz	hertz	Frequency
kg	kilogram(s)	Mass
kHz	kilohertz	Frequency
kJ	kilojoule(s)	Energy, work, heat
kPa	kilopascal(s)	Pressure
kW	kilowatt(s)	Power
K	kelvin	Thermodynamic temperature
m	metre(s)	Length
m^2	square metre(s)	Area
m^3	cubic metre(s)	Volume
mA	milliampere(s)	Electric current
min	minute(s)	Time
MPa	megapascal(s)	Pressure
mm	millimetre(s)	Length
µm	micrometre(s)	Length
N	newton(s)	Force
nm	nanometre(s)	Length
Ω	ohm(s)	Electric resistance
Pa	pascal(s)	Pressure
s	second(s)	Time
"	second(s) of arc	Angle
V	volt(s)	Electrical potential
VA	volt-ampere(s)	Electric power

CLARIFICATION OF ITEMS ON THE TRIGGER LIST
(as designated in Section 2 of MATERIAL AND EQUIPMENT of Annex A)

1. Nuclear reactors and especially designed or prepared equipment and components therefor

INTRODUCTORY NOTE

Various types of nuclear reactors may be characterised by the moderator used (e.g., graphite, heavy water, light water, none), the spectrum of neutrons therein (e.g., thermal, fast), the type of coolant used (e.g., water, liquid metal, molten salt, gas), or by their function or type (e.g., power reactors, research reactors, test reactors). It is intended that all of these types of nuclear reactors are within scope of this entry and all of its sub-entries where applicable. This entry does not control fusion reactors.

1.1. 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.

EXPORTS

The export of the whole set of major items within this boundary will take place only in accordance with the procedures of the Guidelines. Those individual items within this functionally defined boundary which will be exported only in accordance with the procedures of the Guidelines are listed in paragraphs 1.2. to 1.11. The Government reserves to itself the right to apply the procedures of the Guidelines to other items within the functionally defined boundary.

1.2. Nuclear reactor vessels

Metal vessels, or major shop-fabricated parts therefor, especially designed or prepared to contain the core of a nuclear reactor as defined in paragraph 1.1. above, as well as relevant reactor internals as defined in paragraph 1.8. below.

EXPLANATORY NOTE

Item 1.2. covers nuclear reactor vessels regardless of pressure rating and includes reactor pressure vessels and calandrias. The reactor vessel head is covered by item 1.2. as a major shop-fabricated part of a reactor vessel.

1.3. Nuclear reactor fuel charging and discharging machines

Manipulative equipment especially designed or prepared for inserting or removing fuel in a nuclear reactor as defined in paragraph 1.1. above.

EXPLANATORY NOTE

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

1.4. Nuclear reactor control rods and equipment

Especially designed or prepared rods, support or suspension structures therefor, rod drive mechanisms or rod guide tubes to control the fission process in a nuclear reactor as defined in paragraph 1.1. above.

1.5. Nuclear reactor pressure tubes

Tubes which are especially designed or prepared to contain both fuel elements and the primary coolant in a reactor as defined in paragraph 1.1. above.

EXPLANATORY NOTE

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

1.6. Nuclear fuel cladding

Zirconium metal tubes or zirconium alloy tubes (or assemblies of tubes) especially designed or prepared for use as fuel cladding in a reactor as defined in paragraph 1.1. above, and in quantities exceeding 10 kg.

N.B.: For zirconium pressure tubes see 1.5. For calandria tubes see 1.8.

EXPLANATORY NOTE

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

1.7. Primary coolant pumps or circulators

Pumps or circulators especially designed or prepared for circulating the primary coolant for nuclear reactors as defined in paragraph 1.1. above.

EXPLANATORY NOTE

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

1.8. Nuclear reactor internals

Nuclear reactor internals especially designed or prepared for use in a nuclear reactor as defined in paragraph 1.1. above. This includes, for example, support columns for the core, fuel channels, calandria tubes, thermal shields, baffles, core grid plates, and diffuser plates.

EXPLANATORY NOTE

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

1.9. Heat exchangers

(a) Steam generators especially designed or prepared for the primary or intermediate coolant circuit of a nuclear reactor as defined in paragraph 1.1. above.

(b) Other heat exchangers especially designed or prepared for use in the primary coolant circuit of a nuclear reactor as defined in paragraph 1.1. above.

EXPLANATORY NOTE

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

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

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

1.10. Neutron detectors

Especially designed or prepared neutron detectors for determining neutron flux levels within the core of a reactor as defined in paragraph 1.1. above.

EXPLANATORY NOTE

The scope of this entry encompasses in-core and ex-core detectors which measure flux levels in a wide range, typically from 10^4 neutrons per cm^2 per second or more. Ex-core refers to those instruments outside the core of a reactor as defined in paragraph 1.1. above, but located within the biological shielding.

1.11. External thermal shields

External thermal shields especially designed or prepared for use in a nuclear reactor as defined in paragraph 1.1. for reduction of heat loss and also for containment vessel protection.

EXPLANATORY NOTE

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

2. Non-nuclear materials for reactors

EXPORTS

For the purposes of export control, the Government will determine whether or not the exports of non-nuclear materials meeting the specifications identified in paragraphs 2.1. and 2.2. are for nuclear reactor use. Non-nuclear materials having the specifications in paragraphs 2.1. and 2.2. not for use in a nuclear reactor as defined in Annex B, Section 1.1. are not covered by this section.

2.1. Deuterium and heavy water

Deuterium, heavy water (deuterium oxide) and any other deuterium compound in which the ratio of deuterium to hydrogen atoms exceeds 1:5000 for use in a nuclear reactor as defined in paragraph 1.1. above in quantities exceeding 200 kg of deuterium atoms for any one recipient country within a period of one calendar year (1 Jan – 31 Dec).

2.2. Nuclear grade graphite

Graphite having a purity level better than 5 ppm (parts per million) boron equivalent and with a density greater than 1.50 g/cm^3 for use in a nuclear reactor as defined in paragraph 1.1. above, in quantities exceeding 1 kg.

EXPLANATORY NOTE

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

BE_Z ppm = CF x concentration of element Z (in ppm);
CF is the conversion factor: (σ_Z x A_B) divided by (σ_B x A_Z);
σ_B and σ_Z are the thermal neutron capture cross sections (in barns) for naturally occurring boron and element Z respectively; and
A_B and A_Z are the atomic masses of naturally occurring boron and element Z respectively.

3. Plants for the reprocessing of irradiated fuel elements, and equipment especially designed or prepared therefor

INTRODUCTORY NOTE

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

Purex facilities have process functions similar to each other, including irradiated fuel element 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).

EXPORTS

The export of the whole set of major items within this boundary will take place only in accordance with the procedures of the Guidelines.

The Government reserves to itself the right to apply the procedures of the Guidelines to other items within the functionally defined boundary as listed below.

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

3.1. Irradiated fuel element decladding equipment and chopping machines

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

EXPLANATORY NOTE

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

3.2. Dissolvers

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

EXPLANATORY NOTE

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

3.3. Solvent extractors and solvent extraction equipment

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

EXPLANATORY NOTE

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

3.4. Chemical holding or storage vessels

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

1. Walls or internal structures with a boron equivalent of at least 2% ;

2. A maximum diameter of 175 mm for cylindrical vessels; or

3. A maximum width of 75 mm for either a slab or annular vessel.

EXPLANATORY NOTE

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

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

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

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

3.5. Neutron measurement systems for process control

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

EXPLANATORY NOTE

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

The scope of this entry does not include neutron detection and measurement instruments that are designed for nuclear material accountancy and safeguarding or any other application not related to integration and use with automated process control systems in a plant for the reprocessing of irradiated fuel elements.

4. Plants for the fabrication of nuclear reactor fuel elements, and equipment especially designed or prepared therefor

INTRODUCTORY NOTE

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

EXPLANATORY NOTE

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

(a) normally comes in direct contact with, or directly processes, or controls, the production flow of nuclear material;

(b) seals the nuclear material within the cladding;

(c) checks the integrity of the cladding or the seal;

(d) checks the finish treatment of the sealed fuel; or

(e) is used for assembling reactor fuel elements.

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

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

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

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

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

Item 3 typically includes equipment for:

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

(b) Helium leak detection from pressurised pins (or rods);

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

5. Plants for the separation of isotopes of natural uranium, depleted uranium or special fissionable material and equipment, other than analytical instruments, especially designed or prepared therefor

INTRODUCTORY NOTE

Plants, equipment and technology for the separation of uranium isotopes have, in many instances, a close relationship to plants, equipment and technology for isotope separation of "other elements". In particular cases, the controls under Section 5 also apply to plants and equipment that are intended for isotope separation of "other elements". These controls of plants and equipment for isotope separation of "other elements" are complementary to controls on plants and equipment especially designed or prepared for the processing, use or production of special fissionable material covered by the Trigger List. These complementary Section 5 controls for uses involving "other elements" do not apply to the electromagnetic isotope separation process, which is addressed under Part 2 of the Guidelines.

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

For some processes, the relationship to uranium isotope separation depends on the element being separated. These processes are: laser-based processes (e.g., molecular laser isotope separation and atomic vapour laser isotope separation), chemical exchange, and ion exchange. Suppliers must therefore evaluate these processes on a case-by-case basis to apply Section 5 controls for uses involving "other elements" accordingly.

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

5.1. Gas centrifuges and assemblies and components especially designed or prepared for use in gas centrifuges

INTRODUCTORY NOTE

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

5.1.1. Rotating components

(a) Complete rotor assemblies:

Thin-walled cylinders, or a number of interconnected thin-walled cylinders, manufactured from one or more of the high strength to density ratio materials described in the EXPLANATORY NOTE to this Section. If interconnected, the cylinders are joined together by flexible bellows or rings as described in section 5.1.1.(c) following. The rotor is fitted with an internal baffle (or baffles) and end caps, as described in section 5.1.1.(d) and (e) following, if in final form. However the complete assembly may be delivered only partly assembled.

(b) Rotor tubes:

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

(c) Rings or Bellows:

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

(d) Baffles:

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

(e) Top caps/Bottom caps:

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

EXPLANATORY NOTE

The materials used for centrifuge rotating components include the following:

(a) Maraging steel capable of an ultimate tensile strength of 1.95 GPa or more;

(b) Aluminium alloys capable of an ultimate tensile strength of 0.46 GPa or more;

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

5.1.2. Static components

(a) Magnetic suspension bearings:

1. Especially designed or prepared bearing assemblies consisting of an annular magnet suspended within a housing containing a damping medium. The housing will be manufactured from a UF_6-resistant material (see EXPLANATORY NOTE to Section 5.2.). The magnet couples with a pole piece or a second magnet fitted to the top cap described in Section 5.1.1.(e). The magnet may be ring-shaped with a relation between outer and inner diameter smaller or equal to 1.6:1. The magnet may be in a form having an initial permeability of 0.15 H/m or more, or a remanence of 98.5% or more, or an energy product of greater than 80 kJ/m^3. In addition to the usual material properties, it is a prerequisite that the deviation of the magnetic axes from the geometrical axes is limited to very small tolerances (lower than 0.1 mm) or that homogeneity of the material of the magnet is specially called for.

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

   EXPLANATORY NOTE

   These bearings usually have the following characteristics:

   - Designed to keep centred a rotor spinning at 600 Hz or more, and

   - Associated to a reliable electrical power supply and/or to an uninterruptible power supply (UPS) unit in order to function for more than one hour.

(b) Bearings/Dampers:

Especially designed or prepared bearings comprising a pivot/cup assembly mounted on a damper. The pivot is normally a hardened steel shaft with a hemisphere at one end with a means of attachment to the bottom cap described in section 5.1.1.(e) at the other. The shaft may however have a hydrodynamic bearing attached. The cup is pellet-shaped with a hemispherical indentation in one surface. These components are often supplied separately to the damper.

(c) Molecular pumps:

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

(d) Motor stators:

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

(e) Centrifuge housing/recipients:

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

(f) Scoops:

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

5.2. Especially designed or prepared auxiliary systems, equipment and components for gas centrifuge enrichment plants

INTRODUCTORY NOTE

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

Normally UF_6 is evaporated from the solid using heated autoclaves and is distributed in gaseous form to the centrifuges by way of cascade header pipework. The 'product' and 'tails' UF_6 gas streams flowing from the centrifuges are also passed by way of cascade header pipework to cold traps (operating at about 203 K (-70ºC)) 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.

EXPLANATORY NOTE

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

5.2.1. Feed systems/product and tails withdrawal systems

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

(a) Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process;

(b) Desublimers, cold traps or pumps used to remove UF_6 from the enrichment process for subsequent transfer upon heating;

(c) Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form;

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

5.2.2. Machine header piping systems

Especially designed or prepared piping systems and header systems for handling UF_6 within the centrifuge cascades. The piping network is normally of the 'triple' header system with each centrifuge connected to each of the headers. There is thus a substantial amount of repetition in its form. It is wholly made of or protected by UF_6-resistant materials (see EXPLANATORY NOTE to this section) and is fabricated to very high vacuum and cleanliness standards.

5.2.3 Special shut-off and control valves

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

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

EXPLANATORY NOTE

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

5.2.4. UF_6 mass spectrometers/ion sources

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

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

5.2.5. Frequency changers

Frequency changers (also known as converters or inverters) especially designed or prepared to supply motor stators as defined under 5.1.2.(d), or parts, components and sub-assemblies of such frequency changers having both of the following characteristics:

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

5.3. Especially designed or prepared assemblies and 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. Inasmuch as gaseous diffusion technology uses UF_6, all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with UF_6. A gaseous diffusion facility requires a number of these assemblies, so that quantities can provide an important indication of end use.

5.3.1. Gaseous diffusion barriers and barrier materials

(a) Especially designed or prepared thin, porous filters, with a pore size of 10 - 100 nm, a thickness of 5 mm or less, and for tubular forms, a diameter of 25 mm or less, made of metallic, polymer or ceramic materials resistant to corrosion by UF_6 (see EXPLANATORY NOTE to section 5.4.).

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

5.3.2. Diffuser housings

Especially designed or prepared hermetically sealed vessels for containing the gaseous diffusion barrier, made of or protected by UF_6-resistant materials (see EXPLANATORY NOTE to section 5.4.).

5.3.3. Compressors and gas blowers

Especially designed or prepared compressors or gas blowers with a suction volume capacity of 1 m^3 per minute or more of UF_6, with a discharge pressure of up to 500 kPa, and designed for long-term operation in the UF_6 environment, as well as separate assemblies of such compressors and gas blowers. These compressors and gas blowers have a pressure ratio of 10:1 or less and are made of, or protected by, materials resistant to UF_6 (see EXPLANATORY NOTE to section 5.4.).

5.3.4. Rotary shaft seals

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

5.3.5. Heat exchangers for cooling UF_6

Especially designed or prepared heat exchangers made of or protected by UF_6-resistant materials (see EXPLANATORY NOTE to section 5.4), and intended for a leakage pressure change rate of less than 10 Pa/h under a pressure difference of 100 kPa.

5.4. Especially designed or prepared auxiliary systems, equipment and components for use in gaseous diffusion enrichment

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 especially their shut-down, leads to serious consequences. Therefore, a strict and constant maintenance of vacuum in all technological systems, automatic protection from accidents, and precise automated regulation of the gas flow is of importance in a gaseous diffusion plant. All this leads to a need to equip the plant with a large number of special measuring, regulating and controlling systems.

Normally UF_6 is evaporated from cylinders placed within autoclaves and is distributed in gaseous form to the entry point by way of cascade header pipework. The 'product' and 'tails' UF_6 gas streams flowing from exit points are passed by way of cascade header pipework to either cold traps or to compression stations where the UF_6 gas is liquefied prior to onward transfer into suitable containers for transportation or storage. Because a gaseous diffusion enrichment plant consists of a large number of gaseous diffusion assemblies arranged in cascades, there are many 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.

EXPLANATORY NOTE

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

5.4.1. Feed systems/product and tails withdrawal systems

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

(a) Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process;

(b) Desublimers, cold traps or pumps used to remove UF_6 from the enrichment process for subsequent transfer upon heating;

(c) Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form;

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

5.4.2. Header piping systems

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

EXPLANATORY NOTE

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

5.4.3. Vacuum systems

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

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

5.4.4. Special shut-off and control valves

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

5.4.5. UF_6 mass spectrometers/ion sources

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

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

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

3. Electron bombardment ionisation sources; and

4. Having a collector system suitable for isotopic analysis.

5.5. Especially designed or prepared systems, equipment and components for use in 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 (nozzles or vortex tubes), gas compressors and heat exchangers to remove the heat of compression. An aerodynamic plant requires a number of these stages, so that quantities can provide an important indication of end use. Since aerodynamic processes use UF_6, all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of or protected by materials that remain stable in contact with UF_6.

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 which come into contact with the process gas are wholly made of or protected by UF_6-resistant materials. For the purposes of the section relating to aerodynamic enrichment items, the materials resistant to corrosion by UF_6 include copper, copper alloys, stainless steel, aluminium, aluminium oxide, aluminium alloys, nickel or alloys containing 60% by weight or more nickel and fluorinated hydrocarbon polymers.

5.5.1. Separation nozzles

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

5.5.2. Vortex tubes

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

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.

5.5.3. Compressors and gas blowers

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

5.5.4. Rotary shaft seals

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

5.5.5. Heat exchangers for gas cooling

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

5.5.6. Separation element housings

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

5.5.7. Feed systems/product and tails withdrawal systems

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

(a) Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process;

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

(c) Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form;

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

5.5.8. Header piping systems

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

5.5.9. Vacuum systems and pumps

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

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

5.5.10. Special shut-off and control valves

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

5.5.11. UF_6 mass spectrometers/Ion sources

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

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

5.5.12. UF_6/carrier gas separation systems

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

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:

(a) Cryogenic heat exchangers and cryoseparators capable of temperatures of 153 K (-120°C) or less;

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

(c) Separation nozzle or vortex tube units for the separation of UF_6 from carrier gas; or

(d) UF_6 cold traps capable of freezing out UF_6.

5.6. Especially designed or prepared systems, equipment and components for use in chemical exchange or ion exchange enrichment plants

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

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

5.6.1. Liquid-liquid exchange columns (Chemical exchange)

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

5.6.2. Liquid-liquid centrifugal contactors (Chemical exchange)

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

5.6.3. Uranium reduction systems and equipment (Chemical exchange)

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

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).

5.6.4. Feed preparation systems (Chemical exchange)

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

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, fluorinated hydrocarbon polymers, polyphenyl sulphate or polyether sulphone plastic-lined and resin-impregnated graphite.

5.6.5. Uranium oxidation systems (Chemical exchange)

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

EXPLANATORY NOTE

These systems may incorporate equipment such as:

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

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

5.6.6. Fast-reacting ion exchange resins/adsorbents (Ion exchange)

Fast-reacting ion exchange resins or adsorbents especially designed or prepared for uranium enrichment using the ion exchange process, including porous macroreticular resins, and/or pellicular structures in which the active chemical exchange groups are limited to a coating on the surface of an inactive porous support structure, and other composite structures in any suitable form including particles or 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 s) and are capable of operating at a temperature in the range of 373 K (100°C) to 473 K (200°C).

5.6.7. Ion exchange columns (Ion exchange)

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

5.6.8. Ion exchange reflux systems (Ion exchange)

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

(b) Especially designed or prepared chemical or electrochemical oxidation systems for regeneration of the chemical oxidising agent (agents) 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 cation in which case the reduction system would regenerate Ti^{+3} by reducing Ti^{+4}.

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

5.7. Especially designed or prepared 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 a uranium compound, sometimes mixed with another gas or gases. Common nomenclature for such processes include:

- first category - atomic vapour laser isotope separation;
- second category - molecular laser isotope separation, including chemical reaction by isotope selective laser activation.

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

(a) Devices to feed uranium-metal vapour (for selective photo-ionisation) or devices to feed the vapour of a uranium compound (for selective photo-dissociation or selective excitation/activation);

(b) Devices to collect enriched and depleted uranium metal as ‘product’ and ‘tails’ in the first category, and devices to collect enriched and depleted uranium compounds as ‘product’ and ‘tails’ in the second category;

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

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

EXPLANATORY NOTE

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

5.7.1. Uranium vaporisation systems (atomic vapour based methods)

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

EXPLANATORY NOTE

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

5.7.2. Liquid or vapour uranium metal handling systems and components (atomic vapour based methods)

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

EXPLANATORY NOTE

The liquid uranium metal handling systems may consist of crucibles and cooling equipment for the crucibles. The crucibles and other parts of this system that come into contact with molten uranium, molten uranium alloys or uranium metal vapour are made of or protected by materials of suitable corrosion and heat resistance. Suitable materials may include tantalum, yttria-coated graphite, graphite coated with other rare earth oxides (see INFCIRC/254/Part 2 as amended) or mixtures thereof.

5.7.3. Uranium metal ‘product’ and ‘tails’ collector assemblies (atomic vapour based methods)

Especially designed or prepared ‘product’ and ‘tails’ collector assemblies for collecting 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 vapour or liquid (such as yttria-coated graphite or tantalum) and may include pipes, valves, fittings, gutters, feed-throughs, heat exchangers and collector plates for magnetic, electrostatic or other separation methods.

5.7.4. Separator module housings (atomic vapour based methods)

Especially designed or prepared cylindrical or rectangular vessels for containing the uranium metal vapour 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 closing to allow refurbishment of internal components.

5.7.5. Supersonic expansion nozzles (molecular based methods)

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

5.7.6. ‘Product’ or ‘tails’ collectors (molecular based methods)

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

EXPLANATORY NOTE

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

5.7.7. UF_6/carrier gas compressors (molecular based methods)

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

5.7.8. Rotary shaft seals (molecular based methods)

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

5.7.9. Fluorination systems (molecular based methods)

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

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

5.7.10. UF_6 mass spectrometers/ion sources (molecular based methods)

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

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

5.7.11. Feed systems/product and tails withdrawal systems (molecular based methods)

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

(a) Feed autoclaves, ovens, or systems used for passing UF_6 to the enrichment process;

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

(c) Solidification or liquefaction stations used to remove UF_6 from the enrichment process by compressing and converting UF_6 to a liquid or solid form;

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

5.7.12. UF_6/carrier gas separation systems (molecular based methods)

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

EXPLANATORY NOTE

These systems may incorporate equipment such as:

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

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

(c) UF_6 cold traps capable of freezing out UF_6.

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

5.7.13. Laser systems

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

EXPLANATORY NOTE

The lasers and laser components of importance in laser-based enrichment processes include those identified in INFCIRC/254/Part 2 as amended. The laser system typically contains both optical and electronic components for the management of the laser beam (or beams) and the transmission to the isotope separation chamber. The laser system for atomic vapour based methods usually consists of tunable dye lasers pumped by another type of laser (e.g., copper vapour lasers or certain solid-state lasers). The laser system for molecular based methods may consist of carbon dioxide lasers or excimer lasers and a multi-pass optical cell. Lasers or laser systems for both methods require spectrum frequency stabilisation for operation over extended periods of time.

5.8. Especially designed or prepared 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 ionising uranium vapour, 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 (see INFCIRC/254/Part 2 as amended), and metal removal systems for the collection of ‘product’ and ‘tails’.

5.8.1. Microwave power sources and antennae

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

5.8.2. Ion excitation coils

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

5.8.3. Uranium plasma generation systems

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

5.8.4. *[No longer used – since 14 June 2013]*

5.8.5. 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 vapour, such as yttria-coated graphite or tantalum.

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

5.9. Especially designed or prepared systems, equipment and components for use in electromagnetic enrichment plants

INTRODUCTORY NOTE

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

5.9.1. Electromagnetic isotope separators

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

(a) Ion sources

Especially designed or prepared single or multiple uranium ion sources consisting of a vapour source, ioniser, 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 specially designed to contain the ion sources, collector plates and water-cooled liners and have provision for diffusion pump connections and opening and closing for removal and reinstallation of these components.

(d) Magnet pole pieces

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

5.9.2. High voltage power supplies

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

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

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

5.9.3. Magnet power supplies

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

1. Capable of continuously producing a current output of 500 A or greater at a voltage of 100 V or greater; and

2. Current or voltage regulation better than 0.01% over a period of 8 h.

6. Plants for the production or concentration of heavy water, deuterium and deuterium compounds and equipment especially designed or prepared therefor

INTRODUCTORY NOTE

Heavy water can be produced by a variety of processes. Five processes are demonstrated here. Older processes that have proven to be commercially viable are the water-hydrogen sulphide exchange process, the Girdler-Sulphide (GS) process and the ammonia-hydrogen exchange process. Three newer processes first demonstrated in the early 2000s, are based on catalysed hydrogen-water exchange and have been shown to have the potential for production or upgrading of heavy water on an industrial scale with favourable economics. These processes are: Combined Electrolysis and Catalytic Exchange (CECE), Combined Industrial Reforming and Catalytic Exchange (CIRCE) and Bithermal Hydrogen-Water exchange (BHW).

The GS process is based upon the exchange of hydrogen and deuterium between water and hydrogen sulphide 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 sulphide 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 sulphide at high temperatures. Gas or water, enriched in deuterium, is removed from the first stage towers at the junction of the hot and cold sections and the process is repeated in subsequent stage towers. The product of the last stage, water enriched up to 30% by weight in deuterium, is sent to a distillation unit to produce reactor grade heavy water; i.e., 99.75% by weight deuterium oxide (D_2O).

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

Many of the key equipment items for heavy water production plants using GS or the ammonia-hydrogen exchange processes are common to several segments of the chemical and petroleum industries. This is particularly so for small plants using the GS process. However, few of the items are available ‘off-the-shelf’. The GS and ammonia-hydrogen processes require the handling of large quantities of flammable, corrosive and toxic fluids at elevated pressures. Accordingly, in establishing the design and operating standards for plants and equipment using these processes, careful attention to the materials selection and specifications is required to ensure long service life with high safety and reliability factors. The choice of scale is primarily a function of economics and need. 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 processes, items of equipment which individually are not especially designed or prepared for heavy water production can be assembled into systems which are especially designed or prepared for producing heavy water. The catalyst production system used in the ammonia-hydrogen exchange process and water distillation systems used for the final concentration of heavy water to reactor-grade in either process are examples of such systems.

Of the three main heavy water production processes employing hydrogen-water exchange, two (CECE and CIRCE) are only practical when integrated into large hydrogen production processes where hydrogen is being made for other commercial uses. The third process Bithermal Hydrogen-Water exchange (BHW) could potentially be used in a stand-alone plant. All these processes require large quantities of specialised wet-proofed platinised catalysts installed in long columns to provide good contact with the water flowing down. The CECE process requires such wet-proofed platinised catalyst exchange columns to be provided with hydrogen from a water electrolyser that receives its water feed from the exchange columns. In this way, the heavier isotope (deuterium) will build up a concentration in the electrolyser that receives its water feed from the exchange columns. The electrolyser system may potentially build up its deuterium concentration to almost pure heavy water. In practice the process will be staged and the large first stage typically raises the deuterium concentration by a factor between 5 and 20. The CIRCE process is similar, but uses a steam-hydrocarbon reformer as the source of hydrogen, providing the reformer with its source of water for steam. In all these plants, the CECE process is typically used as the final stage to produce reactor-grade heavy water. It should be noted that the largest hydrogen production plants in the world produce enough hydrogen to extract about 20-60 Mg per year of heavy water using a CECE or CIRCE process. A BHW process is conceptually the same as the GS, but using hydrogen instead of hydrogen sulphide with a catalyst to promote the deuterium transfer. In an arrangement analogous to the GS process, the BHW process exploits the effect of temperature on the equilibrium ratio of deuterium between water and hydrogen. The equilibrium falls with rising temperature. As water flows down through upper cold and lower hot towers, deuterium is enriched between them while hydrogen is circulated up through the hot and cold towers in turn. Water taken from between cold and hot towers is sent on to higher stages for further deuterium enrichment. A BHW process could be built for any scale of production.

The key component in these processes is clearly the specialised wet-proofed platinised catalyst that has proven to be relatively difficult to manufacture on a large scale at reasonable cost. Operating conditions are benign, with non-toxic fluids and catalysts, pressure between atmospheric and about 4 MPa and temperatures in the range 293 K (20°C) to 473 K (200°C). None of the equipment is significantly different from that used in various part of the chemical process industry other than the wet-proofed platinised catalyst.

The items of equipment which are especially designed or prepared for the production of heavy water utilising any of the technologies described above include the following:

6.1. Water-hydrogen sulphide exchange towers

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

6.2. Blowers and compressors

Single stage, low head (i.e., 0.2 MPa) centrifugal blowers or compressors for hydrogen-sulphide gas circulation (i.e., gas containing more than 70% by weight hydrogen sulphide, H_2S) especially designed or prepared for heavy water production utilising the water-hydrogen sulphide exchange process. These blowers or compressors have a throughput capacity greater than or equal to 5 m^3/s while operating at pressures greater than or equal to 1.8 MPa suction and have seals designed for wet H_2S service.

6.3. Ammonia-hydrogen exchange towers

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

6.4. Tower internals and stage sumps

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

6.5. NH_3 crackers

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

6.6. *[No longer used – since 14 July 2023]*

6.7. Catalytic burners

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

6.8. Complete heavy water finishing units, upgrade systems or columns therefor

Complete heavy water upgrade systems, or columns with diameters of 0.1 m or greater, especially designed or prepared for the upgrade of heavy water to reactor-grade deuterium concentration.

EXPLANATORY NOTE

Heavy water upgrade systems typically support the operation of a heavy water moderated nuclear reactor or are part of a GS heavy water production plant (in which case they are commonly termed 'finishing units'). Upgraders separate heavy water from light water. Such systems usually employ water distillation, but may also be based on the CECE process. In heavy water moderated nuclear reactors, upgraders maintain the heavy water concentration in the reactor core.

6.9. NH_3 synthesis converters or synthesis units

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

EXPLANATORY NOTE

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

6.10. Columns or towers packed with hydrogen isotope exchange catalyst

Complete columns or towers especially designed or prepared for hydrogen isotope exchange having all of the following:

1. Packed with random or structured wet-proofed platinised catalysts;

2. Constructed of carbon steel or stainless steel;

3. Capable of operating with pressure in the range of 0.1 to 4 MPa; and

4. Capable of operating at temperatures in the range of 293 K (20°C) to 473 K (200°C).

EXPLANATORY NOTE

In heavy water production processes, primary stage catalyst columns have typical diameters greater than 0.5 m and typical heights greater than 10 m. In heavy water upgraders, a typical minimum practical diameter is 0.1 m.

7. Plants for the conversion of uranium and plutonium for use in the fabrication of fuel elements and the separation of uranium isotopes as defined in sections 4 and 5 respectively, and equipment especially designed or prepared therefor

EXPORTS

The export of the whole set of major items within this boundary will take place only in accordance with the procedures of the Guidelines**.** All of the plants, systems, and especially designed or prepared equipment within this boundary can be used for the processing, production, or use of special fissionable material.

7.1. Plants for the conversion of uranium and equipment especially designed or prepared therefor

INTRODUCTORY NOTE

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

7.1.1. Especially designed or prepared systems for the conversion of uranium ore concentrates to UO_3

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 ($UO_2(NO_3)_2$)using a solvent such as tributyl phosphate (TBP). Next, the uranyl nitrate is converted to UO_3 either by concentration and denitration or by neutralisation with gaseous NH_3 to produce ammonium diuranate with subsequent filtering, drying, and calcining.

7.1.2. Especially designed or prepared systems for the conversion of UO_3 to UF_6

EXPLANATORY NOTE

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

7.1.3. Especially designed or prepared systems for the conversion of UO_3 to UO_2

EXPLANATORY NOTE

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

7.1.4. Especially designed or prepared systems for the conversion of UO_2 to UF_4

EXPLANATORY NOTE

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

7.1.5. Especially designed or prepared systems for the conversion of UF_4 to UF_6

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 263 K (-10°C). The process requires a source of gaseous F_2.

7.1.6. Especially designed or prepared systems for the conversion of UF_4 to uranium metal

EXPLANATORY NOTE

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

7.1.7. Especially designed or prepared systems for the conversion of UF_6 to UO_2

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 hydrolysed to UO_2 using hydrogen and steam. In the second, UF_6 is hydrolysed by solution in water, NH_3 is added to precipitate ammonium diuranate, and the diuranate is reduced to UO_2 with hydrogen at 1093 K (820°C). In the third process, gaseous UF_6, CO_2, and NH_3 are combined in water, precipitating ammonium uranyl carbonate. The ammonium uranyl carbonate is combined with steam and hydrogen at 773-873 K (500-600°C) to yield UO_2 .

UF_6 to UO_2 conversion is often performed as the first stage of a fuel fabrication plant.

7.1.8. Especially designed or prepared systems for the conversion of UF_6 to UF_4

EXPLANATORY NOTE

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

7.1.9. Especially designed or prepared systems for the conversion of UO_2 to UCl_4

EXPLANATORY NOTE

Conversion of UO_2 to UCl_4 can be performed by one of two processes. In the first, UO_2 is reacted with carbon tetrachloride (CCl_4) at approximately 673 K (400°C). In the second, UO_2 is reacted at approximately 973 K (700°C) in the presence of carbon black (CAS 1333-86-4), carbon monoxide, and chlorine to yield UCl_4.

7.2. Plants for the conversion of plutonium and equipment especially designed or prepared therefor

INTRODUCTORY NOTE

Plutonium conversion plants and systems perform one or more transformations from one plutonium chemical species to another, including: conversion of plutonium nitrate (PuN) to plutonium dioxide (PuO_2), conversion of PuO_2 to plutonium tetrafluoride (PuF_4), and conversion of PuF_4 to plutonium metal. Plutonium conversion plants are usually associated with reprocessing facilities, but may also be associated with plutonium fuel fabrication facilities. Many of the key equipment items for plutonium conversion plants are common to several segments of the chemical process industry. For example, the types of equipment employed in these processes may include: furnaces, rotary kilns, fluidised 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.

7.2.1. Especially designed or prepared systems for the conversion of plutonium nitrate to oxide

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 minimise toxicity hazards. In most reprocessing facilities, this process involves the conversion of PuN to PuO_2. Other processes can involve the precipitation of plutonium oxalate or plutonium peroxide.

7.2.2. Especially designed or prepared systems for plutonium metal production

EXPLANATORY NOTE

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

ANNEX C

CRITERIA FOR LEVELS OF PHYSICAL PROTECTION

1. The purpose of physical protection of nuclear materials is to prevent unauthorised use and handling of these materials. Paragraph 3(a) of the Guidelines document calls for effective physical protection levels consistent with the relevant IAEA recommendations, in particular those set out in INFCIRC/225.

2. Paragraph 3(b) of the Guidelines document states that implementation of measures of physical protection in the recipient country is the responsibility of the Government of that country. However, the levels of physical protection on which these measures have to be based should be the subject of an agreement between supplier and recipient. In this context these requirements should apply to all States.

3. The IAEA document entitled “The Physical Protection of Nuclear Material” (INFCIRC/225) and similar documents which from time to time are prepared by international groups of experts and updated as appropriate to account for changes in the state of the art and state of knowledge with regard to physical protection of nuclear material are a useful basis for guiding recipient States in designing a system of physical protection measures and procedures.

4. The categorisation of nuclear material presented in the attached table or as it may be updated from time to time by mutual agreement of suppliers shall serve as the agreed basis for designating specific levels of physical protection in relation to the type of materials, and equipment and facilities containing these materials, pursuant to paragraph 3(a) and 3(b) of the Guidelines document.

5. The agreed levels of physical protection to be ensured by the competent national authorities in the use, storage and transportation of the materials listed in the attached table shall as a minimum include protection characteristics as follows:

CATEGORY III

Use and Storage within an area to which access in controlled.

Transportation under special precautions including prior arrangements among sender, recipient and carrier, and prior agreement between entities subject to the jurisdiction and regulation of supplier and recipient States, respectively, in case of international transport, specifying time, place and procedures for transferring transport responsibility.

CATEGORY II

Use and Storage within a protected area to which access is controlled, i.e., an area under constant surveillance by guards or electronic devices, surrounded by a physical barrier with a limited number of points of entry under appropriate control, or any area with an equivalent level of physical protection.

Transportation under special precautions including prior arrangements among sender, recipient, and carrier, and prior agreement between entities subject to the jurisdiction and regulation of supplier and recipient States, respectively, in case of international transport, specifying time, place and procedures for transferring transport responsibility.

CATEGORY I

Materials in this category shall be protected with highly reliable systems against unauthorised use as follows:

Use and storage within a highly protected area (i.e., a protected area as defined for Category II above), to which, in addition, access is restricted to persons whose trustworthiness has been determined, and which is under surveillance by guards who are in close communication with appropriate response forces. Specific measures taken in this context should have as their objective the detection and prevention of any assault, unauthorised access or unauthorised removal of material.

Transportation under special precautions as identified above for transportation of Category II and III materials and, in addition, under constant surveillance by escorts and under conditions which assure close communication with appropriate response forces.

6. Suppliers should request identification by recipients of those agencies or authorities having responsibility for ensuring that levels of protection are adequately met and having responsibility for internally co-ordinating response/recovery operations in the event of unauthorised use or handling of protected materials. Suppliers and recipients should also designate points of contact within their national authorities to co-operate on matters of out-of-country transportation and other matters of mutual concern.

TABLE: CATEGORISATION OF NUCLEAR MATERIAL

Material	Form	Category I	Category II	Category III
1. Plutonium***[a]**	Unirradiated***[b]**	2 kg or more	Less than 2 kg but more than 500 g	500 g or less***[c]**
2. Uranium-235	Unirradiated***[b]**			
	- uranium enriched to 20% ^{235}U or more	5 kg or more	Less than 5 kg but more than 1 kg	1 kg or less***[c]**
	- uranium enriched to 10% ^{235}U but less than 20%	-	10 kg or more	Less than 10 kg***[c]**
	- uranium enriched above natural, but less than 10% ^{235}U***[d]**	-	-	10 kg or more
3. Uranium-233	Unirradiated***[b]**	2 kg or more	Less than 2 kg but more than 500 g	500 g or less***[c]**
4. Irradiated fuel			Depleted or natural uranium, thorium or low-enriched fuel (less than 10% fissile content)***[e][f]**	

[a] As identified in the Trigger List.

[b] Material not irradiated in a reactor or material irradiated in a reactor but with a radiation level equal to or less than 1 gray/hour at one metre unshielded.

[c] Less than a radiologically significant quantity should be exempted.

[d] Natural uranium, depleted uranium, and thorium and quantities of uranium enriched to less than 10% not falling in Category III should be protected in accordance with prudent management practice.

[e] Although this level of protection is recommended, it would be open to States, upon evaluation of the specific circumstances, to assign a different category of physical protection.

[f] Other fuel which by virtue of its original fissile material content is classified as Category I or II before irradiation may be reduced one category levels while the radiation level from the fuel exceed 1 gray/hour at one metre unshielded.