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**Law No. (10) of 2011 ratifying the Protocol Additional to the Agreement between the Kingdom of Bahrain and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons**

We, Hamad bin Isa Al Khalifa King of the Kingdom of Bahrain

Having reviewed the Constitution,

Decree No. (10) of 1988 approving the accession of the State of Bahrain to the Treaty on the Non-Proliferation of Nuclear Weapons signed on 1 July 1968;

Law No. (13) of 2009 ratifying the Agreement between the Kingdom of Bahrain and the International Atomic Energy Agency for the Application of Aafeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons and the Protocol annexed thereto,

And the the Protocol Additional to the Agreement between the Kingdom of Bahrain and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, signed in Vienna on 21 September 2010,

The Shura Council and the Council of Representatives have approved the following law, which we have ratified and enacted:

**Article one**

The Protocol Additional to the Agreement between the Kingdom of Bahrain and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, signed in Vienna on 21 September 2010,attached to this Law has been ratified.

**Article two**

The Prime Minister and the Ministers - each within his jurisdiction - shall implement this law, and it shall come into effect from the day following the date of its publication in the Official gazette.

**King of the Kingdom of Bahrain**

**Hamad bin Isa Al Khalifa,**

Issued at Riffa Palace:

On: 10 Rajab 1433 A.H.

corresponding to: 12 June 2011

**Protocol Additional To The Agreement Between Kingdom of Bahrain And The International Atomic Energy Agency For The Application Of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons.**

Whereas the Kingdom of Bahrain (hereinafter referred to as "Bahrain") and the International Atomic Energy Agency (hereinafter referred to as the "Agency") are parties to an Agreement for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (hereinafter referred to as the "Safeguards Agreement"), which entered into force on 10 May 2009,

**Aware Of** the desire of the international community to further enhance nuclear non-proliferation by strengthening the effectiveness and improving the efficiency of the Agency's safeguards system,

Recalling that the Agency must take into account in the implementation of safeguards the need to: avoid hampering the economic and technological development of Bahrain or international cooperation in the field of peaceful nuclear activities; respect health, safety, physical protection and other security provisions in force and the rights of individuals; and take every precaution to protect commercial, technological and industrial secrets as well as other confidential information coming to its knowledge

Whereas the frequency and intensity of activities described in this Protocol shall be kept to the minimum consistent with the objective of strengthening the effectiveness and improving the efficiency of Agency safeguards

Now Therefore Bahrain and the Agency have agreed as follows:

**Relationship Between The Protocol And The Safeguards Agreement**

**Article 1**

The provisions of the Safeguards Agreement shall apply to this Protocol to the extent that they are relevant to and compatible with the provisions of this Protocol. In case of conflict between the provisions of the Safeguards Agreement and those of this Protocol, the provisions of this Protocol shall apply.

**PROVISION OF INFORMATION**

**Article 2**

a- Bahrain shall provide the Agency with a declaration containing:

1. A general description of and information specifying the location of nuclear fuel cycle-related research and development activities not involving nuclear material carried out anywhere that are funded, specifically authorized or controlled by, or carried out on behalf of Bahrain.

2. Information identified by the Agency on the basis of expected gains in effectiveness or efficiency, and agreed to by Bahrain, on operational activities of safeguards relevance at facilities and at locations outside facilities where nuclear material is customarily used.

3. A general description of each building on each site, including its use and, if not apparent from that description, its contents. The description shall include a map of the site.

4. A description of the scale of operations for each location engaged in the activities specified in Annex I to this Protocol.

5. Information specifying the location, operational status and the estimated annual production capacity of uranium mines and concentration plants and thorium concentration plants, and the current annual production of such mines and concentration plants for Bahrain as a whole. Bahrain shall provide, upon request by the Agency, the current annual production of an individual mine or concentration plant. The provision of this information does not require detailed nuclear material accountancy.

6. Information regarding source material which has not reached the composition and purity suitable for fuel fabrication or for being isotopically enriched, as follows:

(a) The quantities, the chemical composition, the use or intended use of such material, whether in nuclear or non-nuclear use, for each location in Bahrain at which the material is present in quantities exceeding ten metric tons of uranium and/or twenty metric tons of thorium, and for other locations with quantities of more than one metric ton, the aggregate for Bahrain as a whole if the aggregate exceeds ten metric tons of uranium or twenty metric tons of thorium. The provision of this information does not require detailed nuclear material accountancy

(b) The quantities, the chemical composition and the destination of each export out of Bahrain, of such material for specifically non-nuclear purposes in quantities exceeding:

1. Ten metric tons of uranium, or for successive exports of uranium from Bahrain to the same State, each of less than ten metric tons, but exceeding a total of ten metric tons for the year;

2. Twenty metric tons of thorium, or for successive exports of thorium from Bahrain to the same State, each of less than twenty metric tons, but exceeding a total of twenty metric tons for the year;

(c) The quantities, the chemical composition, current location and the destination of each import into Bahrain, of such material for specifically non-nuclear purposes in quantities exceeding:

1. Ten metric tons of uranium, or for successive imports of uranium into Bahrain each of less than ten metric tons, but exceeding a total of ten metric tons for the year,

2. Twenty metric tons of thorium, or for successive imports of thorium into Bahrain each of less than twenty metric tons, but exceeding a total of twenty metric tons for the year;

it being understood that there is no requirement to provide information on such material intended for a non-nuclear use once it is in its non-nuclear end-use form.

a) Information regarding the quantities, uses and locations of nuclear material exempted from safeguards pursuant to Article 36 of the Safeguards Agreement;

b) Information regarding the quantities (which may be in the form of estimates) and uses at each location, of nuclear material exempted from safeguards pursuant to Article 35(b) of the Safeguards Agreement but not yet in a non-nuclear end-use form, in quantities exceeding those set out in Article 36 of the Safeguards Agreement. The provision of this information does not require detailed nuclear material accountancy.

7. Information regarding the location or further processing of intermediate or high-level waste containing plutonium, high enriched uranium or uranium-233 on which safeguards have been terminated pursuant to Article 11 of the Safeguards Agreement. For the purpose of this paragraph, "further processing" does not include repackaging of the waste or its further conditioning not involving the separation of elements, for storage or disposal.

8. The following information regarding specified equipment and non-nuclear material listed in Annex II:

a) For each export out of Bahrain of such equipment and material: the identity, quantity, location of intended use in the receiving State and date or, as appropriate, expected date, of export;

b) Upon specific request by the Agency, confirmation by Bahrain, as importing State, of information provided to the Agency by another State concerning the export of such equipment and material to Bahrain.

9. General plans for the succeeding ten-year period relevant to the development of the nuclear fuel cycle (including planned nuclear fuel cycle-related research and development activities) when approved by the appropriate authorities in Bahrain.

b. Bahrain shall make every reasonable effort to provide the Agency with the following information:

(1) A general description of and information specifying the location of nuclear fuel cycle-related research and development activities not involving nuclear material which are specifically related to enrichment, reprocessing of nuclear fuel or the processing of intermediate or high-level waste containing plutonium, high enriched uranium or uranium-233 that are carried out anywhere in Bahrain but which are not funded, specifically authorized or controlled by, or carried out on behalf of, Bahrain. For the purpose of this paragraph, "processing" of intermediate or high-level waste does not include repackaging of the waste or its conditioning not involving the separation of elements, for storage or disposal

(2) A general description of activities and the identity of the person or entity carrying out such activities, at locations identified by the Agency outside a site which the Agency considers might be functionally related to the activities of that site. The provision of this information is subject to a specific request by the Agency. It shall be provided in consultation with the Agency and in a timely fashion.

(c) Upon request by the Agency, Bahrain shall provide amplifications or clarifications of any information it has provided under this Article, in so far as relevant for the purpose of safeguards.

**Article 3**

**A.** Shall provide to the Agency the information identified in Article “2”.a.”1”, “3”, “4”, “5”, “6” , “7” and “10” and Article 2.b.”1” within 180 days of the entry into force of this Protocol.

B. shall provide to the Agency, by 15 May of each year, updates of the information referred to in paragraph a. above for the period covering the previous calendar year. If there has been no change to the information previously provided, Bahrain shall so indicate.

C. shall provide to the Agency, by 15 May of each year, the information identified in Article 2.a.”6” (b) and (c) for the period covering the previous calendar year.

D. D. Bahrain Shall provide to the Agency on a quarterly basis the information identified in Article 2.a.”9” This information shall be provided within sixty days of the end of each quarter.

E. Bahrain shall provide to the Agency the information identified in Article 2.a.”8” 180 days before further processing is carried out and, by 15 May of each year, information on changes in location for the period covering the previous calendar year.

F. Bahrain and the Agency shall agree on the timing and frequency of the provision of the information identified in Article 2.a.”2”

G. Bahrain shall provide to the Agency the information in Article 2.a.”9” (b) within sixty days of the Agency's request.

**Complementary Access**

**Article 4**

The following shall apply in connection with the implementation of complementary access under Article 5 of this Protocol

a- The Agency shall not mechanistically or systematically seek to verify the information referred to in Article 2; however, the Agency shall have access to:

1. Any location referred to in Article 5.a.”1” or “2” on a selective basis in order to assure the absence of undeclared nuclear material and activities

2. Any location referred to in Article 5. b. or c. to resolve a question relating to the correctness and completeness of the information provided pursuant to Article 2 or to resolve an inconsistency relating to that information.

3. Any location referred to in Article 5.a. “2” to the extent necessary for the Agency to confirm, for safeguards purposes, Bahrain's declaration of the decommissioned status of a facility or of a location outside facilities where nuclear material was customarily used.

b- 1- Except as provided in paragraph “2” below, the Agency shall give advance notice of access of at least 24 hours;

2- For access to any place on a site that is sought in conjunction with design information verification visits or ad hoc or routine inspections on that site, the period of advance notice shall, if the Agency so requests, be at least two hours but, in exceptional circumstances, it may be less than two hours.

c- Advance notice shall be in writing and shall specify the reasons for access and the activities to be carried out during such access.

D. In the case of a question or inconsistency, the Agency shall provide Bahrain with an opportunity to clarify and facilitate the resolution of the question or inconsistency. Such an opportunity will be provided before a request for access, unless the Agency considers that delay in access would prejudice the purpose for which the access is sought. In any event, the Agency shall not draw any conclusions about the question or inconsistency until Bahrain has been provided with such an opportunity

E. Unless otherwise agreed to by Bahrain, access shall only take place during regular working hours.

F. Bahrain shall have the right to have Agency inspectors accompanied during their access by representatives of Bahrain, provided that the inspectors shall not thereby be delayed or otherwise impeded in the exercise of their functions.

**Article 5**

Bahrain shall provide the Agency with access to:

**A-**

1. Any place on a site

2. Any location identified by Bahrain under Article 2.a.”5” to “8”

3. Any decommissioned facility or decommissioned location outside facilities where nuclear material was customarily used

b- Any location identified by Bahrain under Article 2.a.”1”, Article 2.a.”4”,Article 2.a.”9” (b) or Article 2.b, other than those referred to in paragraph a.”1” above, provided that if Bahrain is unable to provide such access, Bahrain shall make every reasonable effort to satisfy Agency requirements, without delay, through other means

c. Any location specified by the Agency, other than locations referred to in paragraphs a. and b. above, to carry out location-specific environmental sampling, provided that if Bahrain is unable to provide such access, Bahrain shall make every reasonable effort to satisfy Agency requirements, without delay, at adjacent locations or through other means.

**Article 6**

When implementing Article 5, the Agency may carry out the following activities:

**A.** For access in accordance with Article 5.a.”1” or “3”: visual observation; collection of environmental samples; utilization of radiation detection and measurement devices; application of seals and other identifying and tamper indicating devices specified in Subsidiary Arrangements; and other objective measures which have been demonstrated to be technically feasible and the use of which has been agreed by the Board of Governors (hereinafter referred to as the "Board") and following consultations between the Agency and Bahrain.

B. For access in accordance with Article 5.a.”2”: visual observation; item counting of nuclear material; non-destructive measurements and sampling; utilization of radiation detection and measurement devices; examination of records relevant to the quantities, origin and disposition of the material; collection of environmental samples; and other objective measures which have been demonstrated to be technically feasible and the use of which has been agreed by the Board and following consultations between the Agency and Bahrain

C. For access in accordance with Article 5.b.: visual observation; collection of environmental samples; utilization of radiation detection and measurement devices; examination of safeguards relevant production and shipping records; and other objective measures which have been demonstrated to be technically feasible and the use of which has been agreed by the Board and following consultations between the Agency and Bahrain

D. For access in accordance with Article 5.c: collection of environmental samples and, in the event the results do not resolve the question or inconsistency at the location specified by the Agency pursuant to Article 5.c., utilization at that location of visual observation, radiation detection and measurement devices, and, as agreed by Bahrain and the Agency, other objective measures.

**Article 7**

**A.** **A.** Upon request by Bahrain, the Agency and Bahrain shall make arrangements for managed access under this Protocol in order to prevent the dissemination of proliferation sensitive information, to meet safety or physical protection requirements, or to protect proprietary or commercially sensitive information. Such arrangements shall not preclude the Agency from conducting activities necessary to provide credible assurance of the absence of undeclared nuclear material and activities at the location in question, including the resolution of a question relating to the correctness and completeness of the information referred to in Article 2 or of an inconsistency relating to that information.

B. Bahrain may, when providing the information referred to in Article 2, inform the Agency of the places at a site or location at which managed access may be applicable.

C. Pending the entry into force of any necessary Subsidiary Arrangements,Bahrain may have recourse to managed access consistent with the provisions of paragraph a. above.

**Article 8**

Nothing in this Protocol shall preclude Bahrain from offering the Agency access to locations in addition to those referred to in Articles 5 and 9 or from requesting the Agency to conduct verification activities at a particular location. The Agency shall, without delay, make every reasonable effort to act upon such a request.

**Article 9**

Bahrain shall provide the Agency with access to locations specified by the Agency to carry out wide-area environmental sampling, provided that if Bahrain is unable to provide such access it shall make every reasonable effort to satisfy Agency requirements at alternative locations. The Agency shall not seek such access until the use of wide-area environmental sampling and the procedural arrangements therefore have been approved by the Board and following consultations between the Agency and Bahrain

**Article 10**

The Agency shall inform Bahrain of:

a- The activities carried out under this Protocol, including those in respect of any questions or inconsistencies the Agency had brought to the attention of Bahrain, within sixty days of the activities being carried out by the Agency.

b- The results of activities in respect of any questions or inconsistencies the Agency had brought to the attention of Bahrain, as soon as possible but in any case within thirty days of the results being established by the Agency.

c- The conclusions it has drawn from its activities under this Protocol. The conclusions shall be provided annually.

**Designation Of Agency Inspectors**

**Article 11**

A (1) The Director General shall notify Bahrain of the Board's approval of any Agency official as a safeguards inspector. Unless Bahrain advises the Director General of its rejection of such an official as an inspector for Bahrain within three months of receipt of notification of the Board's approval, the inspector so notified to Bahrain shall be considered designated to Bahrain.

(2) The Director General, acting in response to a request by Bahrain or on his own initiative, shall immediately inform Bahrain of the withdrawal of the designation of any official as an inspector for Bahrain

B- A notification referred to in paragraph a. above shall be deemed to be received by Bahrain seven days after the date of the transmission by registered mail of the notification by the Agency to Bahrain.

**Visas**

**Article 12**

Bahrain shall, within one month of the receipt of a request therefor, provide the designated inspector specified in the request with appropriate multiple entry/exit and/or transit visas, where required, to enable the inspector to enter and remain on the territory of Bahrain for the purpose of carrying out his/her functions. Any visas required shall be valid for at least one year and shall be renewed, as required, to cover the duration of the inspector's designation to Bahrain.

**Subsidiary Arrangements**

**Article 13**

**A.** Where Bahrain or the Agency indicates that it is necessary to specify in Subsidiary Arrangements how measures laid down in this Protocol are to be applied, Bahrain and the Agency shall agree on such Subsidiary Arrangements within ninety days of the entry into force of this Protocol or, where the indication of the need for such Subsidiary Arrangements is made after the entry into force of this Protocol, within ninety days of the date of such indication.

B. Pending the entry into force of any necessary Subsidiary Arrangements, the Agency shall be entitled to apply the measures laid down in this Protocol.

**Communications Systems**

**Article 14**

**A.** Bahrain shall permit and protect free communications by the Agency for official purposes between Agency inspectors in Bahrain and Agency Headquarters and/or Regional Offices, including attended and unattended transmission of information generated by Agency containment and/or surveillance or measurement devices. The Agency shall have, in consultation with Bahrain, the right to make use of internationally established systems of direct communications, including satellite systems and other forms of telecommunication, not in use in Bahrain. At the request of Bahrain or the Agency, details of the implementation of this paragraph with respect to the attended or unattended transmission of information generated by Agency containment and/or surveillance or measurement devices shall be specified in the Subsidiary Arrangements.

B. Communication and transmission of information as provided for in paragraph a. above shall take due account of the need to protect proprietary or commercially sensitive information or design information which Bahrain regards as being of particular sensitivity.

**Protection Of Confidential Information**

**Article 15**

**A.** The Agency shall maintain a stringent regime to ensure effective protection against disclosure of commercial, technological and industrial secrets and other confidential information coming to its knowledge, including such information coming to the Agency's knowledge in the implementation of this Protocol.

B. The regime referred to in paragraph a. above shall include, among others, provisions relating to:

1. General principles and associated measures for the handling of confidential information;

2. Conditions of staff employment relating to the protection of confidential information.

3. Procedures in cases of breaches or alleged breaches of confidentiality.

C. The regime referred to in paragraph a. above shall be approved and periodically reviewed by the Board.

**Annexes**

**Article 16**

**A.** The Annexes to this Protocol shall be an integral part thereof. Except for the purposes of amendment of the Annexes, the term "Protocol" as used in this instrument means the Protocol and the Annexes together.

B. The list of activities specified in Annex one, and the list of equipment and material specified in Annex two , may be amended by the Board upon the advice of an open-ended working group of experts established by the Board. Any such amendment shall take effect four months after its adoption by the Board.

**Entry Into Force**

**Article 17**

**A.** This Protocol shall enter into force on the date on which the Agency receives from Bahrain written notification that Bahrain's statutory and/or constitutional requirements for entry into force have been met.

B. Bahrain may, at any date before this Protocol enters into force, declare that it will apply this Protocol provisionally.

C. The Director General shall promptly inform all Member States of the Agency of any declaration of provisional application of, and of the entry into force of, this Protocol.

**Definitions**

**Article 18**

For the purpose of this Protocol:

**A.** Nuclear fuel cycle-related research and development activities means those activities which are specifically related to any process or system development aspect of any of the following:

- conversion of nuclear material

- enrichment of nuclear material

- nuclear fuel fabrication

- reactors

- critical facilities

- reprocessing of nuclear fuel

- processing (not including repackaging or conditioning not involving the separation of elements, for storage or disposal) of intermediate or high-level waste containing plutonium, high enriched uranium or uranium-233

but do not include activities related to theoretical or basic scientific research or to research and development on industrial radioisotope applications, medical, hydrological and agricultural applications, health and environmental effects and improved maintenance.

B. Site means that area delimited by Bahrain in the relevant design information for a facility, including a closed-down facility, and in the relevant information on a location outside facilities where nuclear material is customarily used, including a closed-down location outside facilities where nuclear material was customarily used (this is limited to locations with hot cells or where activities related to conversion, enrichment, fuel fabrication or reprocessing were carried out). It shall also include all installations, co-located with the facility or location, for the provision or use of essential services, including: hot cells for processing irradiated materials not containing nuclear material; installations for the treatment, storage and disposal of waste; and buildings associated with specified activities identified by Bahrain under Article 2.a.”4” above

C. Decommissioned facility or decommissioned location outside facilities means an installation or location at which residual structures and equipment essential for its use have been removed or rendered inoperable so that it is not used to store and can no longer be used to handle, process or utilize nuclear material.

D. Closed-down facility or closed-down location outside facilities means an installation or location where operations have been stopped and the nuclear material removed but which has not been decommissioned.

E. High enriched uranium means uranium containing 20 percent or more of the isotope uranium-235.

F. Location-specific environmental sampling means the collection of environmental samples (e.g., air, water, vegetation, soil, smears) at, and in the immediate vicinity of, a location specified by the Agency for the purpose of assisting the Agency to draw conclusions about the absence of undeclared nuclear material or nuclear activities at the specified location.

G. Wide-area environmental sampling means the collection of environmental samples (e.g., air, water, vegetation, soil, smears) at a set of locations specified by the Agency for the purpose of assisting the Agency to draw conclusions about the absence of undeclared nuclear material or nuclear activities over a wide area.

H. Nuclear material means any source or any special fissionable material as defined in Article Twenty of the Statute. The term source material shall not be interpreted as applying to ore or ore residue. Any determination by the Board under Article Twenty of the Statute of the Agency after the entry into force of this Protocol which adds to the materials considered to be source material or special fissionable material shall have effect under this Protocol only upon acceptance by Bahrain.

I. Facility means:

“1” A reactor, a critical facility, a conversion plant, a fabrication plant, a reprocessing plant, an isotope separation plant or a separate storage installation.

“2” Any location where nuclear material in amounts greater than one effective kilogram is customarily used.

J. Location outside facilities means any installation or location, which is not a facility, where nuclear material is customarily used in amounts of one effective kilogram or less.

Done in Vienna on the 21st day of September 2010, in duplicate, in the Arabic and English languages, both texts being equally authentic.

**For the KINGDOM OF BAHRAIN For the INTERNATIONAL ATOMIC ENERGY AGENCY**

**Annex One**

**List of activities referred to in article 2.a. “4” of the protocol**

“1” The manufacture of centrifuge rotor tubes or the assembly of gas centrifuges.

Centrifuge rotor tubes means thin-walled cylinders as described in entry 5-1.(b) of Annex two.

Gas centrifuges means centrifuges as described in the Introductory Note to entry 5-1 of Annex two.

“2” The manufacture of diffusion barriers.

Diffusion barriers means thin, porous filters as described in entry 5-3-1(a) of Annex two.

“3” The manufacture or assembly of laser-based systems

Laser-based systems means systems incorporating those items as described in entry 5-7 of Annex two.

“4” The manufacture or assembly of electromagnetic isotope separators.

Electromagnetic isotope separators means those items referred to in entry 5-9-1 of Annex two containing ion sources as described in 5-9-1 (a) of Annex two.

“5” The manufacture or assembly of columns or extraction equipment

Columns or extraction equipment means those items as described in entries 5-6-1, 5-6-2, 5-6-3, 5-6-5, 5-6-6, 5-6-7 and 5-6-8 of Annex two.

“7” The manufacture or assembly of uranium plasma generation systems

Uranium plasma generation systems means systems for the generation of uranium plasma as described in entry 5-8-3 of Annex two.

“8” The manufacture of zirconium tubes.

Zirconium tubes means tubes as described in entry 1-6 of Annex two

“9” The manufacture or upgrading of heavy water or deuterium

Heavy water or deuterium means deuterium, heavy water (deuterium oxide) and any other deuterium compound in which the ratio of deuterium to hydrogen atoms exceeds 1:5000

“10” The manufacture of nuclear grade graphite.

Nuclear grade graphite means graphite having a purity level better than 5 parts per million boron equivalent and with a density greater than 1.50 g/cm3

“11” The manufacture of flasks for irradiated fuel

A flask for irradiated fuel means a vessel for the transportation and/or storage of irradiated fuel which provides chemical, thermal and radiological protection, and dissipates decay heat during handling, transportation and storage.

“12” The manufacture of reactor control rods

Reactor control rods means rods as described in entry 1-4 of Annex two

Criticality safe tanks and vessels means those items as described in entries 3-2 and 3-4 of Annex two.

“14” The manufacture of irradiated fuel element chopping machines

Irradiated fuel element chopping machines means equipment as described in entry 3-1 of Annex two.

“15” The construction of hot cells

Hot cells means a cell or interconnected cells totalling at least 6 m3 in volume with shielding equal to or greater than the equivalent of 0.5 m of concrete, with a density of 3.2 g/cm3 or greater, outfitted with equipment for remote operations.

**Annex Two**

**List of specified equipment and non-nuclear material for the reporting of exports and imports according to article 2.a.“9”**

**1. Reactors and equipment therefor**

**1-1 Complete nuclear reactors**

Nuclear reactors capable of operation so as to maintain a controlled self-sustaining fission chain reaction, excluding zero energy reactors, the latter being defined as reactors with a designed maximum rate of production of plutonium not exceeding 100 grams per year.

**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.

It is not intended to exclude reactors which could reasonably be capable of modification to produce significantly more than 100 grams of plutonium per year. Reactors designed for sustained operation at significant power levels, regardless of their capacity for plutonium production, are not considered as "zero energy reactors".

**1-2 Reactor pressure vessels**

Metal vessels, as complete units or as major shop-fabricated parts therefor, which are especially designed or prepared to contain the core of a nuclear reactor as defined in paragraph 1-1 above and are capable of withstanding the operating pressure of the primary coolant

**Explanatory Note**

A top plate for a reactor pressure vessel is covered by item 1-2 as a major shop-fabricated part of a pressure vessel.

Reactor internals (e.g. support columns and plates for the core and other vessel internals, control rod guide tubes, thermal shields, baffles, core grid plates, diffuser plates, etc.) are normally supplied by the reactor supplier. In some cases, certain internal support components are included in the fabrication of the pressure vessel. These items are sufficiently critical to the safety and reliability of the operation of the reactor (and, therefore, to the guarantees and liability of the reactor supplier), so that their supply, outside the basic supply arrangement for the reactor itself, would not be common practice. Therefore, although the separate supply of these unique, especially designed and prepared, critical, large and expensive items would not necessarily be considered as falling outside the area of concern, such a mode of supply is considered unlikely.

**1-3 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 capable of on-load operation or 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 Reactor control rods**

Rods especially designed or prepared for the control of the reaction rate in a nuclear reactor as defined in paragraph 1-1 above

**Explanatory Note**

This item includes, in addition to the neutron absorbing part, the support or suspension structures therefor if supplied separately.

**1-5 Reactor pressure tubes**

Tubes which are especially designed or prepared to contain fuel elements and the primary coolant in a reactor as defined in paragraph 1-1 above at an operating pressure in excess of 5.1 Mega Pascals (740 pounds square inch)

**1-6 Zirconium tubes**

Zirconium metal and alloys in the form of tubes or assemblies of tubes, and in quantities exceeding 500 kg in any period of 12 months, especially designed or prepared for use in a reactor as defined in paragraph 1-1 above, and in which the relation of hafnium to zirconium is less than 1:500 parts by weight.

**1-7 Primary coolant pumps**

Pumps 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 may include 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 NC-1 or equivalent standards.

**2- Non-nuclear materials for reactors**

**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 in any period of 12 months

**2-2 Nuclear grade graphite**

Graphite having a purity level better than 5 parts per million boron equivalent and with a density greater than 1.50 gram/sq cm for use in a nuclear reactor as defined in paragraph 1-1. above in quantities exceeding 3 x 104 kg (30 metric tons) for any one recipient country in any period of 12 months

**Note:**

For the purpose of reporting, the Government will determine whether or not the exports of graphite meeting the above specifications are for nuclear reactor use

**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)

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 chopping machines**

**Introductory Note**

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

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

**3-2 Dissolvers**

**Introductory Note**

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

Critically safe tanks (e.g. small diameter, annular or slab tanks) especially designed or prepared for use in a reprocessing plant as identified above, intended for dissolution of irradiated nuclear fuel and which are capable of withstanding hot, highly corrosive liquid, and which can be remotely loaded and maintained.

**3-3 Solvent extractors and solvent extraction equipment**

**Introductory Note**

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

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.

**3-4 Chemical holding or storage vessels**

**Introductory Note**

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

(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..

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. or a maximum diameter of 175 mm (7 inch) for cylindrical vessels

3. or a maximum width of 75 mm (3 inch) for either a slab or annular vessel

**3-5 Plutonium nitrate to oxide conversion system**

**Introductory Note**

In most reprocessing facilities, this final process involves the conversion of the plutonium nitrate solution to plutonium dioxide. 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.

Complete systems especially designed or prepared for the conversion of plutonium nitrate to plutonium oxide, in particular adapted so as to avoid criticality and radiation effects and to minimize toxicity hazards.

**3-6 Plutonium oxide to metal production system**

**Introductory Note**

This process, which could be related to a reprocessing facility, involves the fluorination of plutonium dioxide, normally with highly corrosive hydrogen fluoride, to produce plutonium fluoride which is subsequently reduced using high purity calcium metal to produce metallic plutonium and 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.

Complete systems especially designed or prepared for the production of plutonium metal, in particular adapted so as to avoid criticality and radiation effects and to minimize toxicity hazards

**4- Plants for the fabrication of fuel elements**

A "plant for the fabrication of fuel elements" includes the equipment:

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

(b) Or Which seals the nuclear material within the cladding

**5- Plants for the separation of isotopes of uranium and equipment, other than analytical instruments, especially designed or prepared therefor**

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

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

**Explanatory Note**

The gas centrifuge normally consists of a thin-walled cylinder of between 75 mm (3 inch) and 400 mm (16 inch) diameter contained in a vacuum environment and spun at high peripheral speed of the order of 300 m/s or more with its central axis vertical. In order to achieve high speed the materials of construction for the rotating components have to be of a high strength to density ratio and the rotor assembly, and hence its individual components, have to be manufactured to very close tolerances in order to minimize the unbalance. In contrast to other centrifuges, the gas centrifuge for uranium enrichment is characterized by having within the rotor chamber a rotating disc-shaped baffle and a stationary tube arrangement for feeding and extracting the Uranium hexafluoride 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 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 (0.5 inch) or less, a diameter of between 75 mm (3 inch) and 400 mm (16 inch), and manufactured from one or more of the high strength to density ratio materials described in the Explanatory Note to this Section.

(c) Rings or Bellows:

Components especially designed or prepared to give localized support to the rotor tube or to join together a number of rotor tubes. The bellows is a short cylinder of wall thickness 3 mm (0.12 inch) or less, a diameter of between 75 mm (3 inch) and 400 mm (16 inch), 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 (3 inch) and 400 mm (16 inch) 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 Uranium hexafluoride 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 (3 inch) and 400 mm (16 inch) diameter especially designed or prepared to fit to the ends of the rotor tube, and so contain the Uranium hexafluoride within the rotor tube, and in some cases to support, retain or contain as an integrated part an element of the upper bearing (top cap) or to carry the rotating elements of the motor and lower bearing (bottom cap), and manufactured from one of the high strength to density ratio materials described in the explanatory note to this Section.

Explanatory Note

The materials used for centrifuge rotating components are:

(a) Maraging steel capable of an ultimate tensile strength of 2.05 x 109 newtown/square meter (300,000 pounds per square inch) or more.

(b) Aluminium alloys capable of an ultimate tensile strength of 0.46 x 109 newtown/square meter (67,000 pounds per square inch) or more

(c) Filamentary materials suitable for use in composite structures and having a specific modulus of 12.3 x 106 m or greater and a specific ultimate tensile strength of 0.3 x 106 m or greater Specific Modulus' is the Young's Modulus in (N/m2) divided by the specific weight in (N/m3); 'Specific Ultimate Tensile Strength' is the ultimate tensile strength in (N/m2) divided by the specific weight in (N/m3)

**5-1-2 Static components**

(a) Magnetic suspension bearings

Especially designed or prepared bearing assemblies consisting of an annular magnet suspended within a housing containing a damping medium. The housing will be manufactured from a Uranium hexafluoride-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 henry/meter (120,000 In absolute metric units) or more, or a remanence of 98.5% or more, or an energy product of greater than 80 kilojoules/cubic meter (107 gauss-oersteds). In addition to the usual material properties, it is a prerequisite that the deviation of the magnetic axes from the geometrical axes is limited to very small tolerances (lower than 0.1 mm or 0.004 inch) or that homogeneity of the material of the magnet is specially called for.

(b) Bearings/Dampers:

Especially designed or prepared bearings comprising a pivot/cup assembly mounted on a damper. The pivot is normally a hardened steel shaft with a hemisphere at one end with a means of attachment to the bottom cap described in section 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 (3 inch) to 400 mm (16 inch) internal diameter, 10 mm (0.4 inch) 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 (0.08 inch) or more in depth

(d) Motor stators

Especially designed or prepared ring-shaped stators for high speed multiphase AC hysteresis (or reluctance) motors for synchronous operation within a vacuum in the frequency range of 600 - 2000 Hz and a power range of 50 - 1000 volt-ampere. The stators consist of multi-phase windings on a laminated low loss iron core comprised of thin layers typically two mm (0.08 inch) 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 (1.2 inch) with precision machined ends to locate the bearings and with one or more flanges for mounting.

 The machined ends are parallel to each other and perpendicular to the cylinder's longitudinal axis to within 0.05 degrees or less. The housing may also be a honeycomb type structure to accommodate several rotor tubes. The housings are made of or protected by materials resistant to corrosion by Uranium hexafluoride.

(f) Scoops

Especially designed or prepared tubes of up to 12 mm (0.5 inch) internal diameter for the extraction of Uranium hexafluoride gas from within the rotor tube by a Pitot tube action (that is, with an aperture facing into the circumferential gas flow within the rotor tube, for example by bending the end of a radially disposed tube) and capable of being fixed to the central gas extraction system. The tubes are made of or protected by materials resistant to corrosion by Uranium hexafluoride.

**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 Uranium hexafluoride 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 Uranium hexafluoride from the centrifuges, together with the equipment required to drive the centrifuges or to control the plant.

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

**5-2-1 feed systems/product and tails withdrawal systems**

Especially designed or prepared process systems including:

Feed autoclaves (or stations), used for passing Uranium hexafluoride to the centrifuge cascades at up to 100 kilopascals (15 pounds per square inch) and at a rate of 1 kg/h or more.

Desublimers (or cold traps) used to remove Uranium hexafluoride from the cascades at up to 3 kilopascals (0.5 pounds per square inch) pressure. The desublimers are capable of being chilled to 203 Kelvin (-70 Celsius) and heated to 343 Kelvin (70 Celsius)

'Product' and 'Tails' stations used for trapping Uranium hexafluoride into containers

This plant, equipment and pipework is wholly made of or lined with Uranium hexafluoride- resistant materials (see Explanatory Note to this section) and is fabricated to very high vacuum and cleanliness standards

**5-2-2 Machine header piping systems**

Especially designed or prepared piping systems and header systems for handling Uranium hexafluoride 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 Uranium hexafluoride-resistant materials (see Explanatory Note to this section) and is fabricated to very high vacuum and cleanliness standards.

**5-2-3 Uranium hexafluoride mass spectrometers/ion sources**

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

1. Unit resolution for atomic mass unit greater than 320

2. Ion sources constructed of or lined with nichrome or monel or nickel plated

3. Electron bombardment ionization sources

4. Having a collector system suitable for isotopic analysis

**5-2-4 Frequency changers**

Frequency changers (also known as converters or invertors) 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 all of the following characteristics:

1. A multiphase output of 600 to 2000 Hz

2. High stability (with frequency control better than 0.1%)

3. Low harmonic distortion (less than 2%)

4. An efficiency of greater than 80%

**Explanatory Note**

The items listed above either come into direct contact with the Uranium hexafluoride 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 Uranium hexafluoride include stainless steel, aluminium, aluminium alloys, nickel or alloys containing 60% or more nickel

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

**Introductory Note**

In the gaseous diffusion method of Uranium hexafluoride 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 uranium hexafluoride, all equipment, pipeline and instrumentation surfaces (that come in contact with gas) must be made of materials that remain stable in contact with Uranium hexafluoride. 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**

(a) Especially designed or prepared thin, porous filters, with a pore size of 100 - 1,000 angstroms, a thickness of 5 mm (0.2 inch) or less, and for tubular forms, a diameter of 25 mm (1 inch) or less, made of metallic, polymer or ceramic materials resistant to corrosion by Uranium hexafluoride.

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

**5-3-2 Diffuser housings**

Especially designed or prepared hermetically sealed cylindrical vessels greater than 300 mm (12 inch) in diameter and greater than 900 mm (35 inch) in length, or rectangular vessels of comparable dimensions, which have an inlet connection and two outlet connections all of which are greater than 50 mm (2 inch) in diameter, for containing the gaseous diffusion barrier, made of or lined with Uranium hexafluoride-resistant materials and designed for horizontal or vertical installation.

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

Especially designed or prepared axial, centrifugal, or positive displacement compressors, or gas blowers with a suction volume capacity of 1 cubic meter/minute or more of Uranium hexafluoride, and with a discharge pressure of up to several hundred kilopascals (100 pounds per square inch), designed for long-term operation in the Uranium hexafluoride environment with or without an electrical motor of appropriate power, as well as separate assemblies of such compressors and gas blowers.

 These compressors and gas blowers have a pressure ratio between 2:1 and 6:1 and are made of, or lined with, materials resistant to Uranium hexafluoride.

**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 Uranium hexafluoride. Such seals are normally designed for a buffer gas in-leakage rate of less than 1000 cubic centimeter/minute (60 cubic inch/minute)

**5-3-5 Heat exchangers for cooling Uranium hexafluoride**

Especially designed or prepared heat exchangers made of or lined with Uranium hexafluoride- resistant materials (except stainless steel) or with copper or any combination of those metals, and intended for a leakage pressure change rate of less than 10 Pascals(0.0015 pounds per square inch) per hour under a pressure difference of 100 kilopascals (15 pounds per square inch)

**5-4 Especially designed or prepared assemblies 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 Uranium hexafluoride 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' Uranium hexafluoride 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 Uranium hexafluoride 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' Uranium hexafluoride gaseous streams flowing from exit points are passed by way of cascade header pipework to either cold traps or to compression stations where the Uranium hexafluoride gas is liquefied prior to onward transfer into suitable containers for transportation or storage.

 Because a gaseous diffusion enrichment plant consists of a large number of gaseous diffusion assemblies arranged in cascades, there are many kilometers of cascade header pipework, incorporating thousands of welds with substantial amounts of repetition of layout. The equipment, components and piping systems are fabricated to very high vacuum and cleanliness standards.

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

Especially designed or prepared process systems, capable of operating at pressures of 300 kilopascals (45 pounds per square inch) or less, including:

Feed autoclaves (or systems), used for passing Uranium hexafluoride to the gaseous diffusion cascades

Desublimers (or cold traps) used to remove Uranium hexafluoride from diffusion cascades

Liquefaction stations where Uranium hexafluoride gas from the cascade is compressed and cooled to form liquid Uranium hexafluoride

'Product' or 'tails' stations used for transferring Uranium hexafluoride into containers

**5-4-2 Header piping systems**

Especially designed or prepared piping systems and header systems for handling Uranium hexafluoride within the gaseous diffusion cascades. 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 large vacuum manifolds, vacuum headers and vacuum pumps having a suction capacity of 5 cubic meter/minute (175 cubic feet/min) or more

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

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

Especially designed or prepared manual or automated shut-off and control bellows valves made of Uranium hexafluoride-resistant materials with a diameter of 40 to 1500 mm (1.5 to 59 inch) for installation in main and auxiliary systems of gaseous diffusion enrichment plants.

**5-4-5 Uranium hexafluoride mass spectrometers/ion sources**

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

1. Unit resolution for atomic mass unit greater than 320

2. Ion sources constructed of or lined with nichrome or monel or nickel plated

3. Electron bombardment ionization sources

4.  Collector system suitable for isotopic analysis.

**Explanatory Note**

The items listed above either come into direct contact with the Uranium hexafluoride 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 lined with, Uranium hexafluoride- resistant materials. For the purposes of the sections relating to gaseous diffusion items the materials resistant to corrosion by Uranium hexafluoride include stainless steel, aluminium, aluminium alloys, aluminium oxide, nickel or alloys containing 60% or more nickel and Uranium hexafluoride-resistant fully fluorinated hydrocarbon polymers.

**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 Uranium hexafluoride 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 Uranium hexafluoride, all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with Uranium hexafluoride.

**Explanatory Note**

The items listed in this section either come into direct contact with the Uranium hexafluoride 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 Uranium hexafluoride-resistant materials. For the purposes of the section relating to aerodynamic enrichment items, the materials resistant to corrosion by Uranium hexafluoride include copper, stainless steel, aluminium, aluminium alloys, nickel or alloys containing 60% or more nickel and Uranium hexafluoride-resistant fully 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 (typically 0.1 to 0.05 mm), resistant to corrosion by Uranium hexafluoride 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 Uranium hexafluoride, having a diameter of between 0.5 cm and 4 cm, a length to diameter ratio of 20:1 or less and with one or more tangential inlets.

 The tubes may be equipped with nozzle-type appendages at either or both ends.

Explanatory Note

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

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

Especially designed or prepared axial, centrifugal or positive displacement compressors or gas blowers made of or protected by materials resistant to corrosion by Uranium hexafluoride and with a suction volume capacity of two cubic meter/minute or more of Uranium hexafluoride/carrier gas (hydrogen or helium) mixture.

Explanatory Note

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

**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 Uranium hexafluoride/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 Uranium hexafluoride.

**5-5-6 Separation element housings**

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

Explanatory Note

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

**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 Uranium hexafluoride, including:

(a) Feed autoclaves, ovens, or systems used for passing Uranium hexafluoride to the enrichment process.

(b) Desublimers (or cold traps) used to remove Uranium hexafluoride from the enrichment process for subsequent transfer upon heating.

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

(d) 'Product' or 'tails' stations used for transferring Uranium hexafluoride 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 Uranium hexafluoride, for handling Uranium hexafluoride 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 having a suction capacity of 5 cubic meter/minute or more, consisting of vacuum manifolds, vacuum headers and vacuum pumps, and designed for service in Uranium hexafluoride-bearing atmospheres.

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

**5-5-10 pecial shut-off and control valves**

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

**5-5-11 Uranium hexafluoride mass spectrometers/ion sources**

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

1. Unit resolution for atomic mass unit greater than 320

2. Ion sources constructed of or lined with nichrome or monel or nickel plated

3. Electron bombardment ionization sources

4.  Collector system suitable for isotopic analysis.

**5-5-12 Uranium hexafluoride/carrier gas separation systems**

Especially designed or prepared process systems for separating Uranium hexafluoride from carrier gas (hydrogen or helium)

Explanatory Note

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

(a) Cryogenic heat exchangers and cryoseparators capable of temperatures of -120 Celsius or less.

(b) Cryogenic refrigeration units capable of temperatures of -120 Celsius or less.

(c) Separation nozzle or vortex tube units for the separation of Uranium hexafluoride from carrier gas.

(d) Uranium hexafluoride cold traps capable of temperatures of -20 Celsius or less.

**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 hexafluoride 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 (i.e., pulsed columns with sieve plates, reciprocating plate columns, and columns with internal turbine mixers), especially designed or prepared for Uranium enrichment using the chemical exchange process. For corrosion resistance to concentrated hydrochloric acid solutions, these columns and their internals are made of or protected by suitable plastic materials (such as fluorocarbon polymers) or glass. The stage residence time of the columns is designed to be short (30 seconds or less)

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

**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 uranium4+ 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 uranium4+ 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 sulfate, polyether sulfone, 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 Uranium6+ or Uranium4+ to Uranium3+. 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 Uranium3+ include glass, fluorocarbon polymers, polyphenyl sulfate or polyether sulfone plastic-lined and resin-impregnated graphite.

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

Especially designed or prepared systems for oxidation of Uranium3+ to Uranium4+ 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 Uranium4+ into the stripped organic stream returning from the product end of the cascade.

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

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

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

**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 100 Celsius to 200 Celsius and pressures above 0.7 MegaPascals (102 pound per square inch)

**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(s) used in ion exchange uranium enrichment cascades

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

Explanatory Note

The ion exchange enrichment process may use, for example, trivalent titanium (Titanium3+) as a reducing cation in which case the reduction system would regenerate Titanium3+ by reducing Titanium4+

The process may use, for example, trivalent iron (Fe3+) as an oxidant in which case the oxidation system would regenerate Fe3+ by oxidizing Fe2+.

**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 vapor and those in which the process medium is the vapor of a uranium compound. Common nomenclature for such processes include: first category - atomic vapor laser isotope separation (AVLIS or SILVA); second category - molecular laser isotope separation (MLIS or MOLIS) and chemical reaction by isotope selective laser activation (CRISLA). The systems, equipment and components for laser enrichment plants embrace: (a) devices to feed uranium-metal vapor (for selective photo-ionization) or devices to feed the vapor of a uranium compound (for photo-dissociation or chemical activation); (b) devices to collect enriched and depleted uranium metal as 'product' and 'tails' in the first category, and devices to collect dissociated or reacted compounds as 'product' and unaffected material as 'tails' in the second category; (c) process laser systems to selectively excite the uranium species; and (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 technologies.

Explanatory Note

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

**5-7-1 Uranium vaporization systems (AVLIS)**

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

**5-7-2 Liquid uranium metal handling systems (AVLIS)**

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

Explanatory Note

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

**5-7-3 Uranium metal 'product' and 'tails' collector assemblies (AVLIS)**

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

Explanatory Note

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

**5-7-4 Separator module housings (AVLIS)**

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

Explanatory Note

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

**5-7-5 Supersonic expansion nozzles (MLIS)**

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

**5-7-6 Uranium pentafluoride product collectors (MLIS)**

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

**5-7-7 Uranium hexafluoride/carrier gas compressors (MLIS)**

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

**5-7-8 Rotary shaft seals (MLIS)**

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

**5-7-9 Fluorination systems (MLIS)**

Especially designed or prepared systems for fluorinating Uranium pentafluoride (solid) to Uranium hexafluoride (gas).

**Explanatory Note**

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

**5-7-10 Uranium hexafluoride mass spectrometers/ion sources (MLIS)**

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

1- Unit resolution for mass greater than 320

2- Ion sources constructed of or lined with nichrome or monel or nickel plated.

3- Electron bombardment ionization sources.

4- Collector system suitable for isotopic analysis.

**5-7-11 Feed systems/product and tails withdrawal systems (MLIS)**

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

(a) Feed autoclaves, ovens, or systems used for passing Uranium hexafluoride to the enrichment process.

(b) Desublimers (or cold traps) used to remove Uranium hexafluoride from the enrichment process for subsequent transfer upon heating.

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

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

**5-7-12 Uranium hexafluoride/carrier gas separation systems (MLIS)**

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

Explanatory Note

These systems may incorporate equipment such as:

(a) Cryogenic heat exchangers or cryoseparators capable of temperatures of -120 Celsius or less.

(b) Cryogenic refrigeration units capable of temperatures of -120 Celsius or less.

(c) Uranium hexafluoride cold traps capable of temperatures of -20 Celsius or less

5-7-13 Laser systems (AVLIS, MLIS and CRISLA)

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

Explanatory Note

The laser system for the AVLIS process usually consists of two lasers: a copper vapor laser and a dye laser. The laser system for MLIS usually consists of a CO2 or excimer laser and a multi-pass optical cell with revolving mirrors at both ends. Lasers or laser systems for both processes require a spectrum frequency stabilizer for operation over extended periods of time.

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

Explanatory Note

In the plasma separation process, a plasma of uranium ions passes through an electric field tuned to the U-235 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 U-235. The plasma, which is made by ionizing uranium vapor, is contained in a vacuum chamber with a high-strength magnetic field produced by a superconducting magnet. The main technological systems of the process include the uranium plasma generation system, the separator module with superconducting magnet and metal removal systems for the collection of 'product' and 'tails'.

**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 GigaHertz frequency and greater than 50 kilowatts 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 kilohertz and capable of handling more than 40 kilowatts mean power.

**5-8-3 Uranium plasma generation systems**

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

**5-8-4 Liquid uranium metal handling systems**

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

Explanatory Note

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

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

**5-9-1 Electromagnetic isotope separators**

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

**(a) Ion sources**

Especially designed or prepared single or multiple uranium ion sources consisting of a vapor source, ionizer, and beam accelerator, constructed of suitable materials such as graphite, stainless steel, or copper, and capable of providing a total ion beam current of 50 mili Amper 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 Pascals 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 closure for removal and reinstallation of these components.

**(d) Magnet pole pieces**

Especially designed or prepared magnet pole pieces having a diameter greater than two meters 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 all of the following characteristics: capable of continuous operation, output voltage of 20,000 Volts or greater, output current of 1 Amper or greater, and voltage regulation of better than 0.01% over a time period of 8 hours.

**5-9-3 Magnet power supplies**

Especially designed or prepared high-power, direct current magnet power supplies having all of the following characteristics: capable of continuously producing a current output of 500 Ampers or greater at a voltage of 100 Volts or greater and with a current or voltage regulation better than 0.01% over a period of 8 hours.

**6- Plants for the production 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. However, the two processes that have proven to be commercially viable are the water-hydrogen sulphide exchange process (Girdler Sulfide process) and the ammonia-hydrogen exchange process.

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

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

Many of the key equipment items for heavy water production plants using Girdler sulfide 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 Girdler sulfide process however, few of the items are available "off-the-shelf". The Girdler sulfide 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 Girdler sulfide and the ammonia-hydrogen exchange processes, items of equipment which individually are not especially designed or prepared for heavy water production can be assembled into systems which are especially designed or prepared for producing heavy water. The catalyst production system used in the ammonia-hydrogen exchange process and water distillation systems used for the final concentration of heavy water to reactor-grade in either process are examples of such systems.

The items of equipment specially designed or prepared for the production of heavy water using either of the two processes - the water-hydrogen sulfide exchange process or the ammonia-hydrogen exchange process include the following:

**6-1 Water - Hydrogen Sulphide Exchange Towers**

Exchange towers fabricated from fine carbon steel with diameters of 6 meters (20 Feet) to 9 meters (30 Feet), capable of operating at pressures greater than or equal to 2 Megapascals (300 Pound-force per square inch) and with a corrosion allowance of 6 mm or greater, especially designed or prepared for heavy water production utilizing the water-hydrogen sulphide exchange process.

**6-2 Blowers and Compressors**

Single stage, low head (i.e., 0.2 Megapascals or 30 Pound-force per square inch) centrifugal blowers or compressors for hydrogen-sulphide gas circulation (i.e., gas containing more than 70% Hydrogen sulfide) especially designed or prepared for heavy water production utilizing the water-hydrogen sulphide exchange process. These blowers or compressors have a throughput capacity greater than or equal to 56 cubic meter/second (120,000 Standard cubic feet per minute) while operating at pressures greater than or equal to 1.8 Megapascals (260 Pound-force per square inch) suction and have seals designed for wet Hydrogen sulfide service.

**6-3 Ammonia-Hydrogen Exchange Towers**

Ammonia-hydrogen exchange towers greater than or equal to 35 meters (114.3 Feet) in height with diameters of 1.5 meters (4.9 Feet) to 2.5 meters (8.2 Feet) capable of operating at pressures greater than 15 Megapascals (2225 Pound per square inch) especially designed or prepared for heavy water production utilizing the ammonia-hydrogen exchange process. These towers also have at least one flanged axial opening of the same diameter as the cylindrical part through which the tower internals can be inserted or withdrawn.

**6-4 Tower Internals and Stage Pumps**

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

**6-5 Ammonia Crackers**

Ammonia crackers with operating pressures greater than or equal to 3 Megapascals (450 Pound per square inch) especially designed or prepared for heavy water production utilizing the ammonia- hydrogen exchange process.

**6-6 Infrared Absorption Analyzers**

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

**6-7 Catalytic Burners**

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

**7 - 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, conversion of Uranium trioxide to Uranium dioxide, conversion of uranium oxides to Uranium tetrafluoride or Uranium hexafluoride, conversion of Uranium tetrafluoride to Uranium hexafluoride, conversion of Uranium hexafluoride to Uranium tetrafluoride, conversion of Uranium tetrafluoride to uranium metal, and conversion of uranium fluorides to Uranium dioxide. Many of the key equipment items for uranium conversion plants are common to several segments of the chemical process industry. For example, the types of equipment employed in these processes may include: furnaces, rotary kilns, fluidized bed reactors, flame tower reactors, liquid centrifuges, distillation columns and liquid- liquid extraction columns. However, few of the items are available "off-the- shelf"; most would be prepared according to the requirements and specifications of the customer. In some instances, special design and construction considerations are required to address the corrosive properties of some of the chemicals handled (Hydrogen fluoride, Fluorine, chlorine trifluoride, and uranium fluorides). Finally, it should be noted that, in all of the uranium conversion processes, items of equipment which individually are not especially designed or prepared for uranium conversion can be assembled into systems which are especially designed or prepared for use in uranium conversion

**7-1,Especially designed or prepared systems for the conversion of uranium ore concentrates to Uranium trioxide**

Explanatory Note

Conversion of uranium ore concentrates to Uranium trioxide can be performed by first dissolving the ore in nitric acid and extracting purified uranyl nitrate using a solvent such as tributyl phosphate. Next, the uranyl nitrate is converted to Uranium trioxide either by concentration and denitration or by neutralization with gaseous ammonia to produce ammonium diuranate with subsequent filtering, drying, and calcining

**7-2 Especially designed or prepared systems for the conversion of Uranium trioxide to Uranium hexafluoride**

Explanatory Note

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

**7-3 Especially designed or prepared systems for the conversion of Uranium trioxide to Uranium dioxide**

Explanatory Note

Conversion of Uranium trioxide to Uranium dioxide can be performed through reduction of Uranium trioxide with cracked ammonia gas or hydrogen.

**7-4 Especially designed or prepared systems for the conversion of Uranium dioxide to Uranium tetrafluoride**

Explanatory Note

Conversion of Uranium dioxide to Uranium tetrafluoride can be performed by reacting Uranium dioxide with hydrogen fluoride gas at 300-500 Celsius

**7-5 Especially designed or prepared systems for the conversion of Uranium tetrafluoride to Uranium hexafluoride**

Explanatory Note

Conversion of Uranium tetrafluoride to Uranium hexafluoride is performed by exothermic reaction with fluorine in a tower reactor. Uranium hexafluoride is condensed from the hot effluent gases by passing the effluent stream through a cold trap cooled to -10 Celsius. The process requires a source of fluorine gas

**7-6 Especially designed or prepared systems for the conversion of Uranium tetrafluoride to Uranium metal**

Explanatory Note

Conversion of Uranium tetrafluoride 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 (1130 Celsius)

**7-7 Especially designed or prepared systems for the conversion of Uranium hexafluoride to Uranium dioxide**

Explanatory Note

Conversion of Uranium hexafluoride to Uranium dioxide can be performed by one of three processes. In the first, Uranium hexafluoride is reduced and hydrolyzed to Uranium dioxide using hydrogen and steam. In the second, Uranium hexafluoride is hydrolyzed by solution in water, ammonia is added to precipitate ammonium diuranate, and the diuranate is reduced to Uranium dioxide with hydrogen at 820 Celsius.

 In the third process, gaseous Uranium hexafluoride, carbon dioxide, and Ammoniac (NH3) are combined in water, precipitating ammonium uranyl carbonate. The ammonium uranyl carbonate is combined with steam and hydrogen at 500-600 Celsius to yield Uranium dioxide

Uranium hexafluoride to Uranium dioxide conversion is often performed as the first stage of a fuel fabrication plant.

**7-8 Especially designed or prepared systems for the conversion of Uranium hexafluoride to Uranium tetrafluoride**

Explanatory Note

Conversion of Uranium hexafluoride to Uranium tetrafluoride is performed by reduction with hydrogen