Explanation and Comparison Table of Changes - Guidelines for Nuclear Transfers and Annexes A, B and C of the Guidelines for Nuclear Transfers (NSG Part 1 Guidelines)

Revision 14	July 2023 Update	Reason for Amendment
Annex B, Section 2 **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 within a period of one calendar year (1 Jan – 31 Dec). **2.2. Nuclear grade graphite** Graphite having a purity level better than 5 ppm (parts per million) boron equivalent and with a density greater than 1.50 g/cm^3 for use in a nuclear reactor as defined in paragraph 1.1. above, in quantities exceeding 1 kg.	*Annex B, Section 2* **2. Non-nuclear material for reactors** **EXPORTS** **For the purposes of export control, the Government will determine whether or not the exports of non-nuclear materials meeting the specifications identified in paragraphs 2.1. and 2.2. are for nuclear reactor use. Non-nuclear materials having the specifications in paragraphs 2.1. and 2.2. not for use in a nuclear reactor as defined in Annex B, Section 1.1. are not covered by this section.** **2.1. Deuterium and heavy water** Deuterium, heavy water (deuterium oxide) and any other deuterium compound in which the ratio of deuterium to hydrogen atoms exceeds 1:5000 for use in a nuclear reactor as defined in paragraph 1.1. above in quantities exceeding 200 kg of deuterium atoms for any one recipient country within	This amendment to add an Export Note to Section 2 clarifies that exports of Deuterium and Heavy Water are only controlled if they are for nuclear reactor use.

EXPLANATORY NOTE For the purpose of export control, the Government will determine whether or not the exports of graphite meeting the above specifications are for nuclear reactor use. Graphite having a purity level better than 5 ppm (parts per million) boron equivalent and with a density greater than 1.50 g/cm3 not for use in a nuclear reactor as defined in paragraph 1.1. above is not covered by this paragraph Boron Equivalent (BE) may be determined experimentally or is calculated as the sum of BE_Z for impurities (excluding BE_{carbon} since carbon is not considered an impurity) including boron, where: BE_Z ppm = CF x concentration of element Z (in ppm); CF is the conversion factor: (σ_Z x A_B) divided by (σ_B x A_Z); σ_B and σ_Z are the thermal neutron capture cross sections (in barns) for naturally occurring boron and element Z respectively; and A_B and A_Z are the atomic masses of naturally occurring boron and element Z respectively.	a period of one calendar year (1 Jan – 31 Dec). **2.2. Nuclear grade graphite** Graphite having a purity level better than 5 ppm (parts per million) boron equivalent and with a density greater than 1.50 g/cm^3 for use in a nuclear reactor as defined in paragraph 1.1. above, in quantities exceeding 1 kg. EXPLANATORY NOTE ~~For the purpose of export control, the Government will determine whether or not the exports of graphite meeting the above specifications are for nuclear reactor use. Graphite having a purity level better than 5 ppm (parts per million) boron equivalent and with a density greater than 1.50 g/cm3 not for use in a nuclear reactor as defined in paragraph 1.1. above is not covered by this paragraph.~~ Boron Equivalent (BE) may be determined experimentally or is calculated as the sum of BE_Z for impurities (excluding BE_{carbon} since carbon is not considered an impurity) including boron, where:	

	BE_Z ppm = CF x concentration of element Z (in ppm); CF is the conversion factor: (σ_Z x A_B) divided by (σ_B x A_Z); σ_B and σ_Z are the thermal neutron capture cross sections (in barns) for naturally occurring boron and element Z respectively; and A_B and A_Z are the atomic masses of naturally occurring boron and element Z respectively.	
Annex B, Section 6 **6. Plants for the production or concentration of heavy water, deuterium and deuterium compounds and equipment especially designed or prepared therefor** INTRODUCTORY NOTE Heavy water can be produced by a variety of processes. However, the two processes that have proven to be commercially viable are the water-hydrogen sulphide exchange process (GS process) and the ammonia-hydrogen exchange process. The GS process is based upon the exchange of hydrogen and deuterium	*Annex B, Section 6* **6. Plants for the production or concentration of heavy water, deuterium and deuterium compounds and equipment especially designed or prepared therefor** INTRODUCTORY NOTE Heavy water can be produced by a variety of processes. ~~However, the two~~ **Five processes are demonstrated here. Older** processes that have proven to be commercially viable are the water-hydrogen sulphide exchange process, **the Girdler-Sulphide** (GS) process~~)~~ and the ammonia-hydrogen exchange process. **Three newer processes first demonstrated in the early 2000s, are**	This amendment to Section 6 (Heavy Water production plants) adds three new processes used for the production of heavy water or for heavy water upgraders systems. The previous text identified (and explained) the Water-Hydrogen Sulphide Exchange Process (or Girdler-Sulphide (GS) process) and the Ammonia-Hydrogen Exchange Process. The amended section also includes Combined Electrolysis and Catalytic Exchange (CECE), Combined Industrial Reforming and Catalytic Exchange (CIRCE) and Bithermal Hydrogen-Water exchange (BHW). In addition, entry (6.6) on infrared absorption analyzers has been deleted since the infrared absorption analyzers used in heavy water production

between water and hydrogen sulphide within a series of towers which are operated with the top section cold and the bottom section hot. Water flows down the towers while the hydrogen sulphide gas circulates from the bottom to the top of the towers. A series of perforated trays are used to promote mixing between the gas and the water. Deuterium migrates to the water at low temperatures and to the hydrogen sulphide at high temperatures. Gas or water, enriched in deuterium, is removed from the first stage towers at the junction of the hot and cold sections and the process is repeated in subsequent stage towers. The product of the last stage, water enriched up to 30% by weight in deuterium, is sent to a distillation unit to produce reactor grade heavy water; i.e., 99.75% by weight deuterium oxide (D_2O). The ammonia-hydrogen exchange process can extract deuterium from synthesis gas through contact with liquid ammonia (NH_3) in the presence of a catalyst. The synthesis gas is fed into exchange towers and to an ammonia converter. Inside the towers the gas flows from the bottom to the top while the liquid NH_3 flows from the top to the	**based on catalysed hydrogen-water exchange and have been shown to have the potential for production or upgrading of heavy water on an industrial scale with favourable economics. These processes are: Combined Electrolysis and Catalytic Exchange (CECE), Combined Industrial Reforming and Catalytic Exchange (CIRCE) and Bithermal Hydrogen-Water exchange (BHW).** The GS process is based upon the exchange of hydrogen and deuterium between water and hydrogen sulphide within a series of towers which are operated with the top section cold and the bottom section hot. Water flows down the towers while the hydrogen sulphide gas circulates from the bottom to the top of the towers. A series of perforated trays are used to promote mixing between the gas and the water. Deuterium migrates to the water at low temperatures and to the hydrogen sulphide at high temperatures. Gas or water, enriched in deuterium, is removed from the first stage towers at the junction of the hot and cold sections and the process is repeated in subsequent stage towers. The product of the last stage, water enriched up to 30% by weight in deuterium, is sent to a distillation unit to produce reactor grade heavy water;	plants are not especially designed or prepared for heavy water production. A new entry (6.10) has been added for columns or towers packed with hydrogen isotope exchange catalyst to account for the addition of the 3 new processes. Finally, some small updates to process data were made within Section 6.

bottom. The deuterium is stripped from the hydrogen in the synthesis gas and concentrated in the NH_3. The NH_3 then flows into an ammonia cracker at the bottom of the tower while the gas flows into an ammonia converter at the top. Further enrichment takes place in subsequent stages and reactor grade heavy water is produced through final distillation. The synthesis gas feed can be provided by an ammonia plant that, in turn, can be constructed in association with a heavy water ammonia-hydrogen exchange plant. The ammonia-hydrogen exchange process can also use ordinary water as a feed source of deuterium. Many of the key equipment items for heavy water production plants using GS or the ammonia-hydrogen exchange processes are common to several segments of the chemical and petroleum industries. This is particularly so for small plants using the GS process. However, few of the items are available 'off-the-shelf'. The GS and ammonia-hydrogen processes require the handling of large quantities of flammable, corrosive and toxic fluids at elevated pressures. Accordingly, in establishing the design and operating standards for plants and equipment using these	i.e., 99.75% by weight deuterium oxide (D_2O). The ammonia-hydrogen exchange process can extract deuterium from synthesis gas through contact with liquid ammonia (NH_3) in the presence of a catalyst. The synthesis gas is fed into exchange towers and to an ammonia converter. Inside the towers the gas flows from the bottom to the top while the liquid NH_3 flows from the top to the bottom. The deuterium is stripped from the hydrogen in the synthesis gas and concentrated in the NH_3. The NH_3 then flows into an ammonia cracker at the bottom of the tower while the gas flows into an ammonia converter at the top. Further enrichment takes place in subsequent stages and reactor grade heavy water is produced through final distillation. The synthesis gas feed can be provided by an ammonia plant that, in turn, can be constructed in association with a heavy water ammonia-hydrogen exchange plant. The ammonia-hydrogen exchange process can also use ordinary water as a feed source of deuterium. Many of the key equipment items for heavy water production plants using GS or the ammonia-hydrogen exchange processes are common to several segments of the	

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

	grade in either process are examples of such systems. **Of the three main heavy water production processes employing hydrogen-water exchange, two (CECE and CIRCE) are only practical when integrated into large hydrogen production processes where hydrogen is being made for other commercial uses. The third process Bithermal Hydrogen-Water exchange (BHW) could potentially be used in a stand-alone plant. All these processes require large quantities of specialised wet-proofed platinised catalysts installed in long columns to provide good contact with the water flowing down. The CECE process requires such wet-proofed platinised catalyst exchange columns to be provided with hydrogen from a water electrolyser that receives its water feed from the exchange columns. In this way, the heavier isotope (deuterium) will build up a concentration in the electrolyser that receives its water feed from the exchange columns. The electrolyser system may potentially build up its deuterium concentration to almost pure heavy water. In practice the process will be staged and the large first stage typically raises the deuterium concentration by a**	

	factor between 5 and 20. The CIRCE process is similar, but uses a steam-hydrocarbon reformer as the source of hydrogen, providing the reformer with its source of water for steam. In all these plants, the CECE process is typically used as the final stage to produce reactor-grade heavy water. It should be noted that the largest hydrogen production plants in the world produce enough hydrogen to extract about 20-60 Mg per year of heavy water using a CECE or CIRCE process. A BHW process is conceptually the same as the GS, but using hydrogen instead of hydrogen sulphide with a catalyst to promote the deuterium transfer. In an arrangement analogous to the GS process, the BHW process exploits the effect of temperature on the equilibrium ratio of deuterium between water and hydrogen. The equilibrium falls with rising temperature. As water flows down through upper cold and lower hot towers, deuterium is enriched between them while hydrogen is circulated up through the hot and cold towers in turn. Water taken from between cold and hot towers is sent on to higher stages for further deuterium enrichment. A BHW process could be built for any scale of production.	

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

The items of equipment which are especially designed or prepared for the production of heavy water utilising ~~either~~ **any of** the ~~water-hydrogen sulphide exchange process or the ammonia-hydrogen exchange process~~ **technologies described above** include the following:

6.2. Blowers and compressors

Single stage, low head (i.e., 0.2 MPa) centrifugal blowers or compressors for hydrogen-sulphide gas circulation (i.e., gas containing more than 70% by weight hydrogen sulphide, H_2S) especially

6.2. Blowers and compressors Single stage, low head (i.e., 0.2 MPa) centrifugal blowers or compressors for hydrogen-sulphide gas circulation (i.e., gas containing more than 70% by weight hydrogen sulphide, H_2S) especially designed or prepared for heavy water production utilising the water-hydrogen sulphide exchange process. These blowers or compressors have a throughput capacity greater than or equal to 56 m^3/s while operating at pressures greater than or equal to 1.8 MPa suction and have seals designed for wet H_2S service. **6.3. Ammonia-hydrogen exchange towers** Ammonia-hydrogen exchange towers greater than or equal to 35 m in height with diameters of 1.5 m to 2.5 m capable of operating at pressures greater than 15 MPa especially designed or prepared for heavy water production utilising the ammonia-hydrogen exchange process. These towers also have at least one flanged, axial opening of the same diameter as the cylindrical part through which the tower internals can be inserted or withdrawn.	designed or prepared for heavy water production utilising the water-hydrogen sulphide exchange process. These blowers or compressors have a throughput capacity greater than or equal to ~~56~~ **5** m^3/s while operating at pressures greater than or equal to 1.8 MPa suction and have seals designed for wet H_2S service. **6.3. Ammonia-hydrogen exchange towers** Ammonia-hydrogen exchange towers greater than or equal to 35 m in height with diameters of 1.5 m ~~to 2.5 m~~ **or greater** capable of operating at pressures greater than 15 MPa especially designed or prepared for heavy water production utilising the ammonia-hydrogen exchange process. These towers also have at least one flanged, axial opening of the same diameter as the cylindrical part through which the tower internals can be inserted or withdrawn. **6.6.** *[No longer used – since 14 July 2023]* ~~**Infrared absorption analysers**~~ ~~Infrared absorption analysers capable of on-line hydrogen/deuterium ratio analysis where deuterium concentrations are equal to or greater than 90% by weight.~~	

6.6. Infrared absorption analysers Infrared absorption analysers capable of on-line hydrogen/deuterium ratio analysis where deuterium concentrations are equal to or greater than 90% by weight. **6.8. Complete heavy water upgrade systems or columns therefor** Complete heavy water upgrade systems, or columns therefor, especially designed or prepared for the upgrade of heavy water to reactor-grade deuterium concentration. EXPLANATORY NOTE These systems, which usually employ water distillation to separate heavy water from light water, are especially designed or prepared to produce reactor grade heavy (i.e., typically 99.75% by weight D2O from heavy water feedstock of lesser concentration.	**6.8. Complete heavy water finishing units, upgrade systems or columns therefor** Complete heavy water upgrade systems, or columns ~~therefor~~ **with diameters of 0.1 m or greater**, especially designed or prepared for the upgrade of heavy water to reactor-grade deuterium concentration. EXPLANATORY NOTE ~~These~~ **Heavy water upgrade** systems **typically support the operation of a heavy water moderated nuclear reactor or are part of a GS heavy water production plant (in which case they are commonly termed 'finishing units').** ~~, which usually employ water distillation to~~ **Upgraders** separate heavy water from light water~~,~~**.** ~~are especially designed or prepared to produce reactor-grade heavy water (i.e., typically 99.75% by weight D_2O) from heavy water feedstock of lesser~~ **Such systems usually employ water distillation, but may also be based on the CECE process. In heavy water moderated nuclear reactors, upgraders maintain the heavy water** concentration **in the reactor core**.	

	6.10. Columns or towers packed with hydrogen isotope exchange catalyst **Complete columns or towers especially designed or prepared for hydrogen isotope exchange having all of the following:** **1. Packed with random or structured wet-proofed platinised catalysts;** **2. Constructed of carbon steel or stainless steel;** **3. Capable of operating with pressure in the range of 0.1 to 4 MPa; and** **4. Capable of operating at temperatures in the range of 293 K (20°C) to 473 K (200°C).** **EXPLANATORY NOTE** **In heavy water production processes, primary stage catalyst columns have typical diameters greater than 0.5 m and typical heights greater than 10 m. In heavy water upgraders, a typical minimum practical diameter is 0.1 m.**	