

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

NOTE: The auxiliary systems, equipment and components for a gas centrifuge enrichment plant are the systems of the plant needed to feed UF₆ 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 of UF₆ from the centrifuges, together with the equipment required to drive the centrifuges or to control the plant.

Normally UF₆ 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" of UF₆ gaseous streams flowing from the centrifuges are also passed by way of cascade header pipework to cold traps (operating at about -70 °C) where they are condensed prior to onward transfer into suitable containers for transportation or storage. Because an enrichment plant consists of many thousands of centrifuges arranged in cascades, there are many kilometers of cascade header pipework incorporating thousands of welds with a substantial amount of repetition of layout. The equipment, component and piping systems are fabricated to very high vacuum and cleanliness standards.

The following items either come into direct contact with UF₆ process gas or directly control the centrifuge and the passage of the gas from centrifuge to centrifuge and cascade to cascade.

(a) Feed Systems/Product and Tails Withdrawal Systems:

Especially designed or prepared process systems including:

1. Feed autoclaves (or stations), used for passing UF₆ to the centrifuge cascades at up to 100 kN/m² (15 psi) and at a rate of 1 kg/h or more.
2. Desublimers (or cold traps) used to remove UF₆ from the cascades at up to 3 kN/m² (0.5 lb/in²) pressure. The desublimers are capable of being chilled to -70 °C and heated to 70 °C.
3. Product and tails stations used for trapping UF₆ into containers.

This plant equipment and pipework are wholly made of or lined with UF₆ resistant materials (see Footnote to this Section) and are fabricated to very high vacuum and cleanliness standards.

(b) Machine Header Piping Systems:

Especially designed or prepared piping systems and header systems for handling UF₆ within the centrifuge cascades.

This 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 UF₆ resistant

materials (see Note to this Section) and is fabricated to very high vacuum and cleanliness standards.

(c) UF₆ Mass Spectrometers/Ion Sources: Especially designed or prepared magnetic or quadrupole mass spectrometers capable of taking "on-line" sample of feed, product or tails from UF₆ 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, monel or nickel-plate.
3. Electron bombardment ionization sources.
4. Having a collector system suitable for isotope analysis.

(d) Frequency Changers: Frequency changers (also known as converters or invertors) especially designed or prepared to supply motor stators as defined under Section 1.2(d), or parts, components and subassemblies of such frequency changers having all of the following characteristics:

1. A multiphase output of 600 Hz to 2000Hz.
2. High stability (with frequency control better than 0.1%).
3. Low harmonic distortion (less than 2%).
4. An efficiency of greater than 80%.

FOOTNOTE

Materials resistant to corrosion by UF₆ include stainless steel, aluminum, aluminum alloys, nickel or alloys containing 60% or more nickel.

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APPENDIX C TO PART 110—ILLUSTRATIVE LIST OF GASEOUS DIFFUSION ENRICHMENT PLANT ASSEMBLIES AND COMPONENTS UNDER NRC EXPORT LICENSING AUTHORITY

NOTE—In the gaseous diffusion method of uranium isotope separation, the main technological assembly is a special porous gaseous diffusion barrier, heat exchanger for cooling the gas (which is heated by the process of compression), seal valves and control valves, and pipelines. Inasmuch as gaseous diffusion technology uses uranium hexafluoride (UF₆), all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with UF₆. A gaseous diffusion facility requires a number of these assemblies, so that quantities can provide an important indication of end use.

The auxiliary systems, equipment and components for gaseous diffusion enrichment plants are the systems of plant needed to feed UF₆ 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" UF₆ 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 for 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 UF₆ 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" UF₆ gaseous streams flowing from exit points are passed by way of cascade header pipework to either cold traps or to compression stations where the UF₆ gas is liquified prior to onward transfer into suitable containers for transportation or storage. Because a gaseous diffusion enrichment plant consists of a large number of gaseous diffusion assemblies arranged in cascades, there are many kilometers of cascade header pipework, incorporating thousands of welds with substantial amounts of repetition of layout. The equipment, components and piping systems are fabricated to very high vacuum and cleanliness standards.

The items listed below either come into direct contact with the UF₆ 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, UF₆-resistant materials. For the purposes of this appendix the materials resistant to corrosion by UF₆ include stainless steel, aluminum, aluminum alloys, aluminum oxide, nickel or alloys containing 60 percent or more nickel, and UF₆-resistant fully fluorinated hydrocarbon polymers.

1. Assemblies and components especially designed or prepared for use in gaseous diffusion enrichment.

1.1 Gaseous Diffusion Barriers

Especially designed or prepared thin, porous filters, with a pore size of 100-1000 Å (angstroms), a thickness of 5 mm or less, and for tubular forms, a diameter of 25 mm or less, made of metallic, polymer or ceramic materials resistant to corrosion by UF₆, and especially prepared compounds or powders for the manufacture of such filters. Such compounds and powders include nickel or alloys containing 60 percent or more nickel, aluminum oxide, or UF₆-resistant fully fluorinated hydrocarbon polymers having a purity of 99.9 percent 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.

1.2 Diffuser Housings

Especially designed or prepared hermetically sealed cylindrical vessels greater than 30 cm in diameter and greater than 90 cm in length, or rectangular vessels of comparable dimensions, which have an inlet connection and two outlet connections all of which are greater than 5 cm in diameter, for containing the gaseous diffusion barrier, made of or lined with UF₆-resistant materials and designed for horizontal or vertical installation.

1.3 Compressors and Gas Blowers

Especially designed or prepared axial, centrifugal, or positive displacement compressors, or gas blowers with a suction volume capacity of 1 m³/min or more of UF₆, and with a discharge pressure of up to several hundred kN/m² (100 PSI), designed for long-term operation in the UF₆ 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 UF₆.

1.4 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 UF₆. Such seals are normally designed for a buffer gas in-leakage rate of less than 1000 cm³/min.

1.5 Heat Exchangers for Cooling UF₆

Especially designed or prepared heat exchangers made of or lined with UF₆ 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 N/m² (0.0015 PSI) per hour under a pressure difference of 100 kN/m² (15 PSI).

2. Auxiliary systems, equipment and components especially designed or prepared for use in gaseous diffusion enrichment.

2.1 Feed Systems/Product and Tails Withdrawal Systems

Especially designed or prepared process systems, capable of operating at pressures of 300 kN/m² (45 PSI) or less, including:

1. Feed autoclaves (or systems), used for passing UF₆ to the gaseous diffusion cascades;
2. Desublimers (or cold traps) used to remove UF₆ from diffusion cascades;

3. Liquefaction stations where UF₆ gas from the cascade is compressed and cooled to form liquid UF₆;

4. "Product" or "tails" stations used for transferring UF₆ into containers.

2.2 Header Piping Systems

Especially designed or prepared piping systems and header systems for handling UF₆ within the gaseous diffusion cascades. This piping network is normally of the "double" header system with each cell connected to each of the headers.

2.3 Vacuum Systems

(a) Especially designed or prepared large vacuum manifolds, vacuum headers and vacuum pumps having a suction capacity of 5 m³/min or more.

(b) Vacuum pumps especially designed for service in UF₆-bearing atmospheres made of, or lined with, aluminum, nickel, or alloys bearing more than 60 percent nickel. These pumps may be either rotary or positive displacement, may have fluorocarbon seals, and may have special working fluids present.

2.4 Special Shut-Off and Control Valves

Especially designed or prepared manual or automated shut-off and control bellows valves made of UF₆ resistant materials with a diameter of 4 cm to 1.5 m for installation in main and auxiliary systems of gaseous diffusion enrichment plants.

2.5 UF₆ 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 UF₆ gas streams and having all of the following characteristics:

(a) unit resolution for mass greater than 320;

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

(c) electron bombardment ionization sources;

(d) having a collector system suitable for isotopic analysis.

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APPENDIX D TO PART 110—ILLUSTRATIVE LIST OF AERODYNAMIC ENRICHMENT PLANT EQUIPMENT AND COMPONENTS UNDER NRC EXPORT LICENSING AUTHORITY

NOTE—In aerodynamic enrichment processes, a mixture of gaseous UF₆ 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 included 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. Because aerodynamic processes use UF₆, all equipment, pipeline and instrumentation surfaces (that come in contact with the gas) must be made of materials that remain stable in contact with UF₆. All surfaces which come into contact with the process gas are made of or protected by UF₆-resistant materials; including copper, stainless steel, aluminum, aluminum alloys, nickel or alloys containing 60% or more nickel and UF₆-resistant fully fluorinated hydrocarbon polymers.

The following items either come into direct contact with the UF₆ process gas or directly control the flow within the cascade:

(1) Separation nozzles and assemblies.

Especially designed or prepared nozzles that consist of slit-shaped, curved channels having a radius of curvature less than 1 mm (typically 0.1 to 0.05 mm). The nozzles are resistant to UF₆ corrosion and have a knife-edge within the nozzle that separates the gas flowing through the nozzle into two fractions.

(2) Vortex tubes and assemblies.

Especially designed or prepared vortex tubes that are cylindrical or tapered, made of or protected by materials resistant to UF₆ corrosion, have 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.

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.

(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 UF₆ corrosion and with a suction volume capacity of 2 m³/min or more of UF₆/carrier gas (hydrogen or helium) mixture. These compressors and gas blowers typically have a pressure ratio between 1.2:1 and 6:1.

(4) Rotary shaft seals.

Especially designed or prepared 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 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 UF₆/carrier gas mixture.

(5) Heat exchangers for gas cooling.